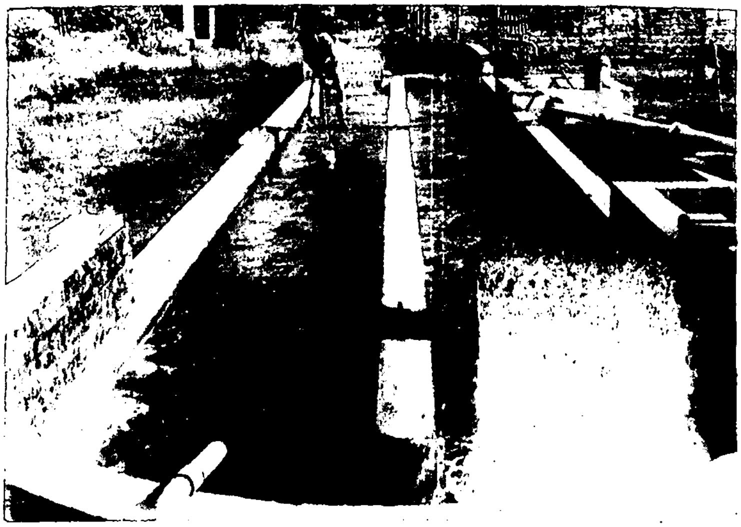

ENVIRONMENTAL POLLUTION

Convener :
DR. G. K. SETH

Editor :
R. K. SARAF

CPHERI NAGPUR

PROCEEDINGS OF SYMPOSIUM ON...

Environmental Pollution

(CPHERI, NAGPUR : JANUARY 17-19, 1973)

Organisers : IAWPC & CPHERI

Convener : Dr. G. K. SETH

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PREFACE

I have great pleasure in presenting the Proceedings of the Symposium on "Environmental Pollution" organised jointly by the Indian Association for Water Pollution Control (IAWPC) and the Central Public Health Engineering Research Institute (CPHERI) from 17th to 19th January 1973 at Nagpur.

Environmental Pollution is an inevitable outcome of human craving for betterment of living standards through unceasing efforts and activities manifesting into heavy industrialisation and consequent urbanisation. Industrial complexes are the focii of environmental pollution.

The problem of environmental pollution is not restricted to any one nation. It is a global phenomenon. The facilities and resources, however, vary from nation to nation. While developed countries like U.S.A. and U.K. could afford sophistication for pollution abatement, a developing country like ours has to resort to indigenous "know-how" suited to its economy and climatic conditions.

Since independence, the country has made remarkable progress in this direction and, through an unstinted R & D effort, has developed competent "know-how", making maximum use of indigenous materials and manpower. The "user-trials" have amply proved their competence and utility. The need of the time is to make sustained efforts, to promote their acceptability. Symposium/Seminar like the one reported herein is a positive step to accomplish this transfer of technology to the field.

This motivation tacitly blended with legislation would certainly bear fruits to arrest the environmental pollution to the bare minimum so that the environment can take care of this minimal load through dilution and self-purification.

This volume covers forty four papers accepted for presentation at the symposium alongwith valuable discussions that took place following the presentations.

I sincerely hope that this Volume will be extensively used by students, research workers and practising personnel in the field, all alike.

I wish to thank Dr. N. U. Rao, Secretary of IAWPC which, jointly with CPHERI, sponsored the symposium. I wish to record my deep appreciation to Dr. G. K. Seth, Scientist and others who conducted the symposium in an excellent manner. My thanks are also due to Dr. G. J. Mohanrao, Scientist-in-Charge of CPHERI at the time the symposium was held, for his able leadership for the entire conduct of the symposium.

Nagpur :
1st June 1973

(PROF. N. MAJUMDER)
DIRECTOR

FOREWORD

A Symposium on "Environmental Pollution" was organised jointly by the Central Public Health Engineering Research Institute (CPHERI) and the Indian Association for Water Pollution Control (IAWPC) C/o CPHERI, Nagpur at the Institute during January 17-19, 1973.

Progress of mankind in every sphere of activity, ironically enough, is closely associated with deterioration of the environment. The pollution of the environment is inevitable if technological advancement must be made for a better living. All that can be done is to provide adequate treatment and arrest it intelligently to a bare minimum and then let out to the environment so that enough dilution is available to make it innocuous so as not to cause health hazards to micro and macro life on this planet. Even if this is attained, an invaluable service shall have been rendered to ourselves and the generations to come.

There is world-wide awareness that this important subject has to be dealt with tacitly so that the earth is not doomed by pollution as is being predicted by the ecologists.

Water, air and land, the basic commodities of life are persistently getting polluted, in the wake of population growth, industrialisation, and urbanisation, on account of discharge of sewage, industrial effluents, stack emmissions, dust, smoke, solid wastes on one hand and strain on the existing resources due to population growth on the other. It is a happy augury, however, that this country, like other developed and developing countries, has taken cognisance of the situation well in time. It has embarked upon a National Water Supply and Sanitation Programme as far back as 1954. A number of research, educational institutions, government departments, industries have worked and contributed sizably to the knowledge of pollution abatement. The Indian Standards Institution, New Delhi took a step in the right direction several years ago when it came up with the first Indian Standards for discharge of effluents into water courses. Presently, comprehensive legislation is being worked upon for stringent enforcement to attain environmental pollution control.

Established in early 1959, this Institute has also contributed its mite to ameliorate the pollution hazards by developing indigenous "know-how", extension work and training of the personnel connected with Public Health Engineering.

With these varied efforts of several organisations, the country is fortunate enough to have developed adequate "know-how", and the need of the day is fortification of efforts for expeditious implementation of pollution abatement procedures in a self-sustaining and self-generating manner. It was the purpose of the Symposium to promote thinking and action in this direction.

About 200 participants took active part in the deliberations of the Symposium and made it a success.

I take this opportunity to express my gratitude to Prof. B. R. Seshachar, Indian National Science Academy, New Delhi for inaugurating the Symposium and to Dr. P. S. Mene, Vice-Chancellor, Nagpur University for presiding over the inaugural session. I am extremely grateful to Dr. B. V Bhoota, Prof. N. Majumder, Dr. T. R. Bhaskaran, Shri J. M. Dave, Shri M. Miakhan, Shri N. R. Krishnan, Prof. S. V. Patwardhan, Shri Pankaj Chatterjee, Shri Sirish Patel, Prof. A. V. S. Prabhakara Rao and Dr. N. U Rao for conducting the various technical sessions in an excellent manner.

I shall be failing in my duty if I did not thank the delegates and sponsors without whose active participation the Symposium could not have been a stimulating forum.

I express keen appreciation of the efforts of Dr. G. K. Seth and other staff members in organising the symposium and of Shri R. K. Saraf in editing the proceedings.

I also wish to thank Miss K. W. Chaudhari, Shri S. R. Algarsamy for their help in bringing out this Volume and Shri K. M. Nandgaonkar, who looked after the printing work.

I sincerely hope that this publication will be used as a reference material both by research workers and practising engineers in the public health engineering field.

Nagpur :
March, 1973.

(G. J. MOHANRAO)
SCIENTIST-INCHARGE

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CHAPTER-I

WATER POLLUTION

PROC. SYMP. ON ENVIRONMENTAL POLLUTION (1973)

Present Status of Pollution in the Hooghly Estuary With Special Reference to the Adverse Effects Observed on the Fishery Resources

V. GOPALAKRISHNAN,* P. RAY* and B. B. GHOSH*

The paper presents latest information collected by the Central Inland Fisheries Research Institute on the domestic and municipal wastes discharged into a 92 km stretch of the Hooghly Estuary and their effects on the aquatic biomass. The total volume of liquid wastes discharged is about 252 mgd, of which about 72 mgd are contributed by different industrial establishments located on both the banks. Details on the hydrobiological conditions at the regions of outfall and characters of the effluents from the more important industries are discussed in relation to the adverse effects produced on the fishery resources of the estuarine waters.

Introduction

The Bhagirathi-Hooghly river basin is a very important problem area where the population has almost crossed its saturation point in certain sectors. A large number of industrial establishments are located around Calcutta—the most populous city in India—and extend to a 92 km. stretch of the Hooghly estuary between Birlapore and Dumurdaha. The dispersal of domestic and industrial wastes in this highly industrialised belt of the estuary and its impact on aquatic life has been under study for quite some time now. The paper deals with the information obtained from a comprehensive survey of the industrial waste outfalls located on the 92 km stretch of the Hooghly estuary, total volume of waste waters discharged and the corresponding total pollutional load disposed, the pollution status around the outfall points of some of the important industries and their effects on the aquatic biomass.

Hydrological Characteristics of the Estuary

The estuarine environment is always subjected to the tidal influences and riverine drainages. It is a constantly changing ecosystem, both diurnally and seasonally, having characteristic features of its own, thoroughly different from the relatively stable conditions in the seas and rivers.

The Hooghly river is formed by three main distributaries of the Ganga river **viz.** the Bhagirathi, the Jalangi and the Churni. The tidal portion of the river is 296 km long and it drains into the Bay of Bengal south of the Sagar Island. During the monsoon period, it is connected with the Ganga but during low flow periods the supply of fresh water is mainly from the tributaries like Damodar, Rupnarain and Haldi. The flow of fresh water has been reduced considerably since the construction of the Dam on the Damodar, which diverts water for irrigational purpose.

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* Central Inland Fisheries Research Institute. Barrackpore, West Bengal.

Owing to reduction in upland discharges brought about by the shift of the main course of the Ganga and daily consumption of more than 250 million gallons of river water for multifarious uses, the Hooghly is presently subjected to severe salinisation as evident from the chloride content which, during the low flow period, goes upto 4000 mg/l near the Palta Water Works intake situated in the upper zone of the estuary. During the dry seasons, the tidal limit of the Hooghly extends above Swarupganj which is about 128 km upstream of Calcutta. With a good monsoon flow the impact of tidal influences in the mid-stream is felt upto Akra about 13 km below Calcutta. It is interesting to note that during the monsoon regime, particularly under neap-tide conditions, the flood tide influences are felt only in the marginal areas between the stretch of Akra and Sahagunj. As a result of this, only the mid-stream stretches of the estuary encounter appreciable dilution with the incoming fresh water and, hence, are subjected to minimal pollutional stress during the monsoon flow period. The ebb-tide flow lasts for a longer time than flood-tide flow as generally the duration of ebb-tide flow is 6.5-8.5 hr in the dry season and 7.0-11.5 hr in the monsoon months, while that of flood-tide flow is 4.0-6.0 hr and 2.5-4.0 hr in the dry season and monsoon period respectively.

A characteristic feature of the estuary is that the fresh water discharges into it are generally limited to the four monsoon months of July to October. The flood tides are completely nullified due to such drainage and there is a strong predominance of ebb-tide which results in fresh water domination. During the post-monsoon months of November-February, owing to the banking of fresh water in the estuary during monsoon months, the strength of the flood tide over the ebb-tide is minimum and the estuary exhibits great fluctuations in salinity over a longer stretch. During March to June, due to cessation of practically all fresh water discharge, the effects of flood tides are considerably accentuated over the ebb-tide(1) which result in considerable increase in salinity and create a marine domination particularly in the lower zone of the estuary.

On the basis of fluctuations in salinity, the entire estuary (296 km length) may be classified into three zones, i.e. the lower zone between Frasergunj and Kakdwip, the middle zone between Kakdwip and Konnagar and the upper zone between Konnagar and Nabadwip. Maximum salinity ranging from 23.0 to 32.7‰ are recorded in the lower zone during the summer months and in the monsoon months it fluctuates between 1.4 and 24.7‰. The upper zone shows more or less fresh water conditions practically throughout the year, whereas the middle zone exhibits violent fluctuations in salinity in the dry season ranging between traces and 25.0‰. There is practically no longitudinal temperature gradient from the fresh water to marine zone, though seasonal fluctuations in temperature patterns are observed(2). Temperature distribution during a year is bi-modal with peaks in June and September (2, 3) and with no vertical thermal stratification (4). Turbidity values are the highest in monsoon months due to suspended clay and silt particles in the flood waters, and comparatively low during post-monsoon months. Alkalinity increases gradually towards the fresh water zone, being highest in the winter months of January and February, and lowest in the monsoon months.

The Industries and their Pollution Load

Data obtained from extensive survey carried out in the highly industrialised belt of the estuary indicated that out of 95 factories situated on the bank between Dumurdaha and Birlapore (92 km), there are 6 pulp and paper mills, 5 textile mills, 2 distilleries and one each of yeast, tannery and rubber, 3 oil (petroleum) installations, 6 power stations, 55 jute mills and 15 miscellaneous industries, the details of which have been discussed elsewhere (5). The wastes from pulp and paper, distillery, heavy chemicals, textile and a number of domestic and municipal sewage outfalls contribute substantially to the pollution load.

The total volume of liquid wastes discharged through the various outfalls (domestic, municipal and industrial) is 252 million gallons per day (mgd), of which 77 mgd (30.6% of the total flow) is contributed by various industries. Pulp and paper mills alone contribute 39.29 mgd, i.e., about 50% of the total industrial wastes and 15.5% of the total outflow.

The daily average pollutional load contributed in terms of BOD, total solids, suspended solids and dissolved solids are 106.11, 2308.44, 1057.33 and 1251.11 tonnes respectively, of which 66.03, 904.08, 411.93 and 482.15 tonnes are contributed by industries alone, rest being contributed by the domestic and municipal wastes.

Extent of Pollution around the Outfall Regions of Some Major Industries

The extent of pollution with reference to the hydrobiological conditions around the outfall points of some of the major industries were studied during the dry weather period of January to June. Regular collections were made from a number of points above and below the outfall points during the lowest water level under the neap-tide conditions. The factory wastes were also collected simultaneously to assess their contribution towards the pollutional load. The results of the investigations carried out during the dry season of 1970 are summarised below:

(a) 'Kesoram Rayon Industries' at Nayasarai

This factory produces synthetic rayon and cellophane paper. Th waste water is highly acidic in reaction (pH, 2.0-4.9; average value, 2.8) and it contains the highly toxic metal zinc to the extent of 16-160 mg/l (average, 75 mg/l). The temperature of the waste varies between 27°C and 41°C with low or nil DO content. B.O.D. (5-day, 20°C) and OC (½ hr at 100°C), values are in the ranges of 26 to 1175 mg/l and 40 to 238 mg/l respectively. Acidity is found to range between nil and 297 mg/l as $CaCO_3$ The important chemical factors and their effects on abundance of plankton below the outfall area are indicated in Table I (A). Zinc concentration has been observed to be 25 mg/l few metres below the outfall point. The soil indicates acidic character (pH < 5.0). The benthic organisms are found to be completely absent in this stretch. Recovery with respect to pH and DO takes place within 150 m X 15 m stretch below the outfall but the adverse effects on plankton are felt further down also.

(b) 'Tribeni Tissues' at Tribeni Area

This factory produces tissue paper by soda process. The wastes indicate both acidic and alkaline characters (pH, 6.5-9.5) having high amount of putrescible organic matter as evidenced from OC values ranging between 9 and 1220 mg/l (average 199 mg/l) and BOD values ranging between 12 and 700 mg/l (average 144 mg/l). DO varies between nil and 6.8 mg/l. The lignin content varies between 8.2 and 20.5 mg/l. Heavier suspensoids are deposited a little away from the outfall. Details of the observations made are given in Table I (B).

Benthic organisms are absent in this region also. The recovery of conditions in respect of pH and DO is indicated at 150 m X 15 m below the discharge point and the adverse effects on plankton are found further below.

(c) "India Paper Pulp" at Hazinagar Area

In this factory, sulphite process is adopted for the manufacture of paper and pulp and the wastes are generally acidic in reaction (pH, 5.3-6.9) and highly organic in nature as evidenced from the high average OC values (1899 mg/l at 100°C for ½ hr and 370 mg/l for 3 min at room temperature) and BOD values (average 986 mg/l). DO has always been found to be absent. The waste waters discharged from the bleaching plant contain 125-173 mg/l of available chlorine as Cl^- (average 135 mg/l), which is highly toxic to aquatic life. A summary of the data obtained is presented in Table I (C).

No benthic organisms are found in the outfall region and heavy suspensoids are found to be deposited. Gas bubbles are visible at times on the surface over a vast area, presumably due to decomposition of the bottom sediments whose depth varies from 0.3 m to

1.05 m. The recovery zone extends to about 1 km below the outfall.

(d) "Distillery and Yeast Plant" at Bhadrakali Area

Wastes from both these plants are organically very rich. DO content is nil, but at times, it is present in very low concentration in yeast wastes. OC (30 min.) values range from 1025 to 31300 mg/l and from 130 to 1793 mg/l for distillery and yeast wastes respectively while their corresponding ranges for BOD values are 5760-21600 mg/l and 1460-5760 mg/l. Acidic character (pH, 5.0-6.1) is exhibited by the distillery waste while the yeast waste is moderately acidic to alkaline (pH, 5.4-7.7). Details of observations are given in Table I (D).

No benthic organisms have been observed in this outfall area also and the pollutional zone extends to a stretch of 1000 m X 15 m below the discharge point.

The hydrobiological conditions above the outfall regions during the dry season are shown in Table II and the daily average pollutional load contributed by the different types of wastes are given in Table III.

Ultimate Effects on the Hydrobiological Conditions in the Estuary

Alongwith the samples from the outfall regions, data were also collected simultaneously from 9 selected sampling centres in the stretch of the estuary between Dumurdaha and Birlapore, during the lowest water level under neap-tide conditions of the dry season

TABLE I—CHEMICAL PARAMETERS AND THEIR EFFECT ON ABUNDANCE OF PLANKTON POPULATION

Month	pH	DO (mg/l)	OC ½ hr, 100°C (mg/l)	Total Alkalinity as $CaCO_3$ (mg/l)	Plankton (Unit/l) Phyto-	Plankton (Unit/l) Zoo-
			(A) OUTFALL OF KESORAM RAYON FACTORY			
Feb.	4.7-8.1	5.4-6.7	20-46	0-250	60-150	40-90
Mar.	6.0-8.1	5.6-6.0	25-50	221-249	40-110	20-50
Apr.	6.8-8.2	4.2-6.2	37-46	144-288	0-80	0-20
May	6.7-8.3	1.2-5.0	32-112	115-172	0-50	0-10
Jun.	5.2-8.2	1.5-5.1	56-116	0-256	0-60	0-30
			(B) OUTFALL OF TRIBENI TISSUES FACTORY			
Jan.	7.9-8.5	6.2-7.8	15-46	150-293	1160-2680	160-670
Feb.	7.9-8.5	6.0-6.6	10-35	144-283	20-200	10-80
Mar.	6.9-8.2	4.4-6.9	35-196	81-283	80-260	30-130
Apr.	8.2-9.1	1.1-6.1	31-200	230-341	20-150	10-20
May	8.2-8.3	0-5.2	13-200	158-206	0-20	0-20
Jun.	8.1-9.1	1.8-4.5	30-316	164-216	0-80	0-10
			(C) OUTFALL OF INDIA PAPER PULP FACTORY			
Jan.	5.3-8.1	4.1-7.5	10.1-1017	230-552	110-360	140-290
Feb.	5.5-8.1	0-7.6	10-872	101-248	0-220	10-140
Mar.	7.1-8.3	0-6.0	4.8-708	230-355	0-80	0-60
Apr.	5.9-8.3	0-6.1	11-1034	226-312	0-20	0-10
May	6.7-8.3	0.8-6.8	6.8-612	172-221	0-10	0-20
Jun.	6.5-8.1	0-7.2	26-696	256-384	0-70	0-70
			(D) OUTFALL OF DISTILLERY & YEAST PLANT			
Apr.	7.0-8.3	0-5.2	29-379	101-285	20-90	0-10
May	6.7-8.3	0-5.3	25-200	216-254	0-10	0-8
Jun.	7.1-8.1	0.1-3.6	10-881	344-848	20-60	10-50

TABLE II—HYDROBIOLOGICAL CONDITIONS ABOVE THE OUTFALL OF THE WASTE WATERS

Type of waste	Period	pH	DO mg/l	OC 30 min. at 100°C, mg/l	Total alkalinity as $CaCO_3$ mg/l	Plankton (unit/l)	
						Phyto-	Zoo-
Rayon	Feb-June	8.1-8.3	5.0-6.2	2.9-4.4	153-258	20-110	10-30
Tissue paper (Kraft)	Jan-June	8.0-8.3	6.0-6.8	5.6-6.8	170-270	40-2020	0-300
Paper pulp (Sulphite)	Jan-June	8.0-8.3	6.2-7.6	4.8-26.0	192-272	0-360	0-240
Distillery & Yeast	Apr-June	8.1-8.3	3.5-5.2	35 -60	216-376	0-40	0-30

TABLE III—AVERAGE POLLUTIONAL LOAD CONTRIBUTED BY THE WASTE WATERS UNDER STUDY

Type of waste	Volume of waste discharged mgd	BOD 5-day, 20°C tonnes/day	Total Solids tonnes/day	Suspended Solids tonnes/day	Dissolved Solids tonnes/day
Rayon	3.20	4.77	30.50	8.40	22.10
Tissue paper (Kraft)	4.00	2.10	114.50	110.50	4.00
Paper pulp (Sulphite)	7.21	4.54	98.10	24.30	73.80
Distillery	0.145	10.24	5.20	0.40	4.80
Yeast	0.0035	0.05	0.042	0.002	0.04
Total	14.5585	21.70	248.342	143.602	104.74

TABLE IV—SOME IMPORTANT CHEMICAL PARAMETERS AND THEIR EFFECTS ON THE ABUNDANCE OF PLANKTON IN THE MAIN BODY OF THE ESTUARY

Month	pH	Total alkalinity as $CaCO_3$ mg/l	Chloride as Cl mg/l	DO mg/l	OC 1/2 hr at 100°C mg/l	BOD 5-day 20°C mg/l	Plankton (unit/l)	
							Phyto-	Zoo
Jan	8.0-8.1	211-293	11-72	3.9-8.0	2.9-10.0	0.9-3.6	167-2095	69-370
Feb	8.0-8.1	241-291	13-291	4.4-7.1	6.2-9.6	1.1-3.9	37-200	5-93
March	8.0-8.2	216-279	11-3224	3.6-6.6	8.5-20.2	1.1-2.7	35-132	0-52
April	8.1-8.3	174-221	15-6324	4.9-6.5	4.9-6.5	1.6-3.9	7-152	0-25
May	8.0-8.2	196-245	14-7734	5.4-6.2	4.3-15.6	0.5-2.9	0-27	0-37
June	8.0-8.3	201-250	20-8072	3.8-7.0	5.4-15.4	1.3-2.7	0-80	0-37

and the results obtained are shown in Table IV.

Discussion

The parameters of estuarine pollution have their own special features as the estuarine ecosystem is constantly influenced by tidal regimes. As such it is rather difficult to precisely assess the extent of estuarine pollution unless one is well-equipped with the knowledge of the dynamics of estuarine system which may vary from one region to another. Dilution, mixing pattern, duration of tides, tidal phase, natural purification and seasonal influences are some of the important factors which warrant proper consideration in estuarine pollution studies. Lateral, vertical and longitudinal mixing govern the rate at which pollutants spread or diffuse from one bank to the other. The mechanism of water movements in tidal estuaries is complex and not yet properly understood. Formerly, the Hooghly was classified as a nonstratified estuary with respect to salinity, but recently Basu and Ghosh (1969) reported it to be a "hybrid", between the vertically and sectionally homogeneous types. A variation in the chloride content with increasing depth has been reported in the stretch between Titagarh and Birlapore while no such variation is seen in the fresh water zone between Ichapore and Tribeni (6). The most unfavourable hydrological conditions are experienced at the lowest water level during neap-tide in the dry season, when the dilution is minimum. This situation prevails for 13-15 days in a month. With the flood tides the waste waters already discharged return back to the outfall region with certain amount of dilution by sea water, but they are fortified with fresh waste discharges (7).

It is apparent that because of the high dilution (1:263) in the month of January, the pollutional effect is not appreciable as evident from the high concentration of phytoplankton in the outfall region (110-2680 unit/l) as well as in the estuary (69-2095 unit/l) in general. During the hot summer months of May and June when the dilution ratio narrows down considerably (1:17-18) the effects of pollution are conspicuous from the drastic decline in the phytoplankton counts ranging between nil and 80 unit/l in the outfall region as well as in the main waters. In general the chemical conditions below the outfall area, are found to be adversely affected during May and June. The pH ranges between 5.2 and 9.1, DO comes down to zero level and OC values go upto 881 mg/l in the vicinity of the outfall areas during these months while recovery of the chemical conditions is effected within 150 m—1 km below the discharge points. Excepting a high value of OC, to the level of 20 mg/l, the main body of the estuary seems to be unaffected chemically which is also reflected from the low BOD value (4.0 mg/l). The lowest limit of DO in the estuary being 3.6 mg/l, is slightly above the critical level. Although the outfall areas show wide fluctuations in the pH value (4.7-9.1), high buffering action is exhibited in the main estuary as a good reserve of methyl orange alkalinity in the range of 174-293 mg/l as $CaCO_3$ and a pH range of 8.0-8.3 is found to be maintained over the entire stretch. However, the existence of a poor biological condition in the outfall regions as well as in the main estuary during the summer months of May and June indicate the existence of pollutants in sublethel level which are not detectable easily, but are injurious to organisms due to their cumulative effect. Further, the pollution complex developing in estuaries may not show any apparent adverse effects in the earlier stages, but is bound to seriously reflect its deleterious action on the biomass as the pace of municipal and industrial development of the surrounding region advances (7). Pollution in sub-lethal doses may not immediately kill or seriously affect the adult fishes, but may cause mortality of fish food organisms, fish eggs and larvae. There are evidences to show that the spawning grounds, fish eggs, larval population and fish food organisms of the estuary get destroyed by the pollutants. Cumulative effects of pollutants on the fishery resources of the estuary are yet to be properly understood. An abrupt fall in plankton content starts from February in the main body of the estuary as well as in almost all the outfall regions which is probably due to narrowing down of the dilution ratio from 1:263 to 1:57. Basu *et al.* (8, 9) reported that the general trend of phytoplankton concentration in the Hooghly was much lower (83 unit/l) than that of the Matlah (159 unit/l) and most of the discharge points exhibited a very low concentration of phytoplankton (0-90/l).

The industrial establishments on both the banks of the Hooghly, by and large, are releasing their effluents into the estuarine waters thereby vitiating the aquatic ecosystem. Domestic and municipal sewage is not treated in most of the cities of the country and it is well known that such waste in quantities above the safe limit have either direct or indirect adverse effects on the fishery resources. The unfavourable effects on fish life are mainly caused by asphyxiation arising out of low oxygen or completely deoxygenated water. The toxicants brought from industrial plants as well as those generated during the process of anaerobic digestion of the wastes also result in such conditions. Plankton and bottom biota are also drastically affected in such polluted waters. The observations made on the Hooghly estuary, as pointed above, clearly indicate that it is necessary to evolve methods of treatment of effluents for each major type of pollutant and the water quality standards under estuarine conditions should be laid down for abatement of pollution from the fisheries point of view. For this purpose, tolerance limits for the important toxicants should be determined by bioassay experiments. The cumulative effects of the sublethal doses of toxic chemicals on important species and prawns in the estuarine system have also to be urgently studied which will involve physiological and histological determinations.

Acknowledgement

The authors wish to express their thanks to Dr. V. G. Jhingran, Director, Central Inland Fisheries Research Institute, for his keen interest and encouragement.

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DISCUSSION

Shri N. V. Ramamohana Rao (Hyderabad): Have the authors observed the toxicity of the wastes on different varieties of fish present. If so, what are their results?

Dr. V. Gopalakrishnan: The toxicity of wastes on different species of fish present in the Hooghly has not yet been determined. However, bio-assay studies in this direction are being initiated. In this connection, it may be stated that toxicity of some industrial effluents on fish have already been studied in some of the river systems in India and the important findings are listed below:

For tannery wastes, 24 hr TLm values with *Puntius sophore* were: (i) **Chrome tan liquor**—9.55 in December and 6.9 in May; (ii) **Sulphide tan liquor**—7.77 in December and 10.2 in May; and (iii) **Vegetable tan liquor**—10.03 in December and 6.9 in May. These values are expressed as percentage volume of effluent.

The 24 hr TLm values for other wastes in terms of percent effluent have been worked out as under :

Waste		TLm Value	Test Fish
Sugar		No mortality	—
Distillery		6.7	*Puntius sophore*
Pulp	(i)	25.4	*P. sophore*
	(ii)	34.7	*Mystus vittatus*
Paper	(i)	24.5	*P. sophore*
	(ii)	26.5	*M. vittatus*
Combined pulp & paper	(i)	20.8	*P sophore*
	(ii)	20.6	*M. vittatus*

Dr. A. V. S. Prabhakar Rao (Kanpur) : What is the quality of the fish affected by the pollution?

Dr. V. Gopalakrishnan : It has been known that the quality of fish is affected by some pollutants. The chlorinated hydrocarbons are relatively non-degradable and they are cumulative in the body tissues of fishes. In New Delhi area, some human beings have been reported to have higher levels of DDT, or its breakdown products, in their visceral fat than persons anywhere else in the world and it is possible that this build-up of DDT is the direct result of eating fish from the Jamuna river into which a factory manufacturing DDT discharges the waste products.

Dr. H. S. Vasisht (Chandigarh) : What is the effect on the concentration of plankton during the rainy season?

Dr. V. Gopalakrishnan : During the rainy season, the dilution factor is very high and hence no apparent effect is noticed on the plankton at the polluted zones of the estuary.

Dr. K. P. Krishnamoorthi (Nagpur) : What are the dilution factors in Hooghly estuary and the fish landing figures with reference to Prawn and Molluscan fishes to show the pollution effect?

Dr. V. Gopalakrishnan : The dilution factors are : (i) In January—1:263, (ii) In May and June —1 : 17-18.

As regards the fish landings, although we have got elaborate data on the same for the whole estuarine system, it is not possible to have specific landing figures for the individual pollution zones. However, the data so far collected indicate that as a result of pollution the abundance and distribution of fish eggs and larvae and plankton are adversely affected. Further, it is also known that pollution is likely to be a contributory cause for the decline in hilsa fisheries.

Dr. A. K. Basu (Calcutta) : May I draw the attention of this House to a question directed to Dr. Gopalakrishnan by Dr. Krishnamoorthy of CPHERI about the dilution available in Hooghly to reduce the pollutional effect? It is relevant to mention here that WHO and Engineering Consortium while working for CMPO, submitted a point about the need to treat the domestic and other community wastewater in the report "Project 170". If I remember correctly, they maintained that if a minimum DO of 4 mg/l is to be kept at all time in all seasons, then with the flow available in Hooghly it would be very necessary to treat about 60% of community wastewater that goes to the Hooghly

Dr. T. R. Bhaskaran (New Delhi) : Are there sufficient evidences to show that the variations in the plankton content observed are due to pollution and not due to seasonal variations in the abundance and distribution of the concerned organisms?

Dr. V. Gopalakrishnan : We have gathered data regarding the plankton of the estuarine system for the past 10 years and information on the normal seasonal abundance and distribution of the important constituent organisms is available. The data indicate that considerable reduction in the plankton, as discussed in the paper, is due to the pollutional effect.

Prof. B. R. Sesachar (New Delhi): Are data available to show whether the pollution affects the fish production in the estuary?

Dr. V. Gopalakrishnan : It has been observed that although no fish kills have yet been reported from this estuary, the pollution has been found to be responsible for reduction in the extent of some important spawning grounds, reduced quantities of fish eggs and larvae and fish food organisms at the polluted regions and formation of pollution barriers which might affect the migration of some of the important fishes like hilsa. As already indicated, the data available show that pollution must be one of the important factors which have led to general decline in the fishery of hilsa in this estuary.

PROC. SYMP. ON ENVIRONMENTAL POLLUTION (1973)

Water Pollution in Relation to the Biology of Fishes

Part I—A Comparative Study of the Toxicity of Synthetic Detergents to Fresh Water Organisms

C. L. MAHAJAN* and J. J SINGH,*

A comparative study of the toxicity of I-Det-10 to freshwater organisms ranging from protozoa to fishes is presented in the paper. The investigations contain certain new lines of approach to the problem, viz., (i) longterm experiments with very low levels of syndets, (ii) toxicity of very small quantities of syndets when these constitute a part of the fish food, and (iii) effect of small changes in temperature.

The importance of fishes in aquatic ecosystem has been pointed out and the effect of syndets as water pollutants on some commercially important Indian fishes, directly or indirectly have been discussed. In view of the increased dangers encountered by the synergistic action of such pollutants as oil or those due to thermal pollution, the desirability of completely switching over to soft (i.e., more readily degradable) synthetic detergents has been emphasized.

Introduction

Coulsen and Frobes (1) defined water pollution as the addition of something to water which changes its natural qualities. Alternatively, it has been defined as the addition of anything causing or inducing objectionable conditions in any water and affecting adversely any use or uses to which the water thereof may be put to (2). Water pollution of many kinds can harm the fish.

During the last three decades synthetic detergents (heretofore referred as syndets) have become an important addition to chemical wastes discharged into water in every developed as well as developing country. This is evident from the fact that the world production of syndets has been estimated to be 8.05 x 10^5 tonnes (3). This is remarkable when we consider that the first syndet was marketed only fifteen years ago in India. Further, in India the production of syndets was only 150 tonnes in 1957 and it rose to 18,000 tonnes in 1968 and was 30,200 tonnes by the end of 1970 (Fig. 1). The target for 1975-76 is more than one lakh tonnes. The relative increase in the production of syndets in recent years in developed countries like U.S.A., U.K. and Japan has been even more phenomenal. The relative role of syndets (in which surface active agents are the toxic components) as contributory factors in water pollution can be judged from the following figures (4).

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* Department of Zoology, University of Rajasthan, Jaipur-4.

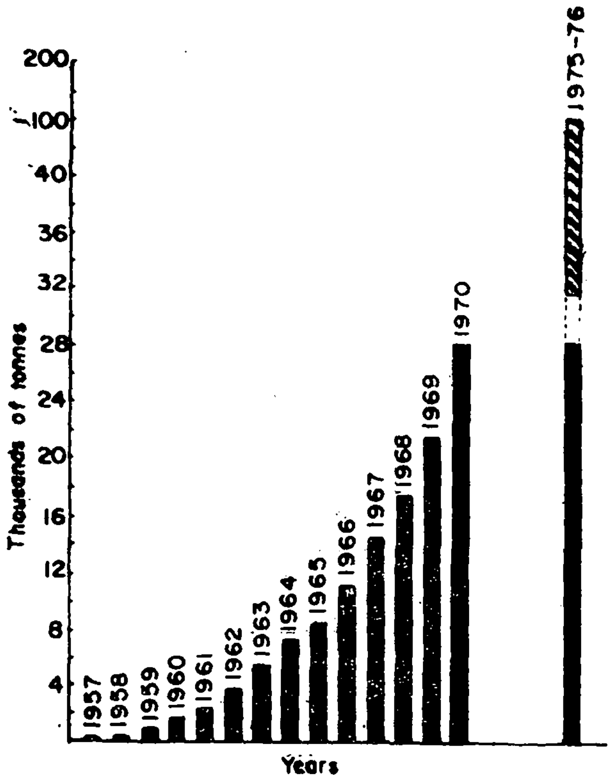

Fig. 1—A histogram showing rapid increase in the production of synthetic detergents in India during recent years and the anticipated production in 1975-76.

PRODUCTION OF SYNTHETIC ORGANIC CHEMICALS*

(Millions of lb/yr.)

Sr. No.	Item	Year		
		1938	**1958**	**1966**
1.	Plastics	130	4,500	13,585
2.	Synthetic rubber	5	2,200	3,929
3.	Surface active agents	—	1,355	3,321
4.	Insecticides and agricultural chemicals@	8	540	1,013

* U. S. Tarriff Commission reports.
@ excluding fertilizers.

Fishes are often used to investigate the effects of chemical wastes on aquatic environment because they are of economic importance, reasonably easy to procure and a representative of the aquatic community. In fact, fishes are one of the excellent barometers of the real state of the purity of water.

A review of the literature revealed that practically no information was available on the effects of syndets on any of the great variety of aquatic life in Indian fresh waters on which fish depends for its food and growth, much less on the fishes. It was necessary, therefore, to establish some basic parameters such as TLm values or survival times under different levels of concentration. The present investigation, therefore, is concerned with the comparative study of the toxicity of syndets to some common fresh water organisms representing major animal groups.

Experimental Procedures

Toxicity experiments were conducted on the following organisms :

Sr. No.	Phylum	Class	Genera
1	Protozoa	Ciliata	*Paramecium caudatum*
2	Arthropoda	Crustacea	*Daphnia*
		Insecta	*Chironomus larvae*
3	Chordata	Pisces	*Cyprinus carpio* *Labeo rohita* *Barbus ticto* *Heteropneustes fossilis* *Clarias batrachus* *Channa punctatus*
		Amphibia	Tadpoles of *Rana tigrina*

Paramecium Caudatum

Fifteen ml of culture containing *Paramecium caudatum* was kept in small petri dishes and concentrations ranging from 0.1 to 10 mg/l of I-Det-10 were prepared and tested for 6; 12, and 24 hr.

Daphnia

In small petri dishes of 50 ml capacity, concentrations ranging from 1 to 30 mg/l of I-Det-10 were tested to determine the TLm values for 24 hr and 48 hr. One hundred animals constituted an experimental unit.

Chironomus larvae

In small glass aquaria of 4 l capacity *Chironomus larvae* were acclimatized. Concentrations ranging from 5 to 30 mg/l of the syndet were tested. There were 50 larvae in each test.

Fishes

In order to study the toxicity of the syndet to fishes the following treatment methods were followed :

(a) Toxicity Studies when Syndet is dissolved in Water

The experiments were carried out in glass aquaria (150 l capacity) where the required concentrations of the syndet were maintained and a parallel control was always kept. The fishes, both under treatment and control, were fed regularly on minced liver and/or food pellets made out of dried fish-cum-prawn powder mixed with wheat flour in the ratio of 4:1.

(b) Toxicity Studies when Syndet is a constituent of Fish Food

The feeding of *Heteropneustes fossilis* was done by mixing the syndet with the food pellets, prepared as above. The fishes were conditioned to taking the food pellets within a few minutes of their addition to the aquarium. The feeding was done daily in the morning. The weight of the dried food pellets fed daily to the fishes was 2% of their body weight. After a fortnight of conditioning to the feeding, fish food was mixed with I-Det-10 in three different proportions, *viz* 0.01, 0.001 and 0.0001% by weight of the total food before the preparation of pellets.

Tadpoles of *Rana tigrina*

Tadpoles of *Rana tigrina* of medium size (length, 16 mm ± 4 mm) were selected from the mixed stock of tadpoles and concentrations of I-Det-10 ranging from 40 to 60 mg/l were tested to determine TLm values for 24 and 48 hr.

The Syndet used in the Experiments

Syndet used for all the experiments was I-Det-10, the technical formula of which is as follows :

Alkyl benzene sulphonate (ABS)	37 ± 1%
Inorganic salts predominently sodium sulphate (Na_2SO_4)	60 ± 2%
Moisture content	3 ± 1

Observations and Results

1. Toxicity Studies when Syndet is dissolved in Water

These have been divided into following different heads :

(a) Determination of TLm values.

(b) Determination of the effects of long term treatment at very low levels of toxicity.

(c) Effect of temperature changes in relation to toxicity.

(d) Behavioural response.

(a) Determination of TLm Values :

A series of experiments were conducted to determine TLm values for 24, 48 and 96 hr. The temperature of water, dissolved oxygen and average pH after addition of the syndet was also determined to account for any variation. The results are shown in Table I. The invertebrates and vertebrates tested for toxicity have been arranged in the ascending order of tolerance. The results are also graphically shown in the form of a histogram (Fig. 2). It apears that protozoans among the invertebrates and fish fries of carp among the vertebrates tested are most sensitive to ABS pollution, whereas the larvae of *Chironomus* among the invertebrates and *Channa punctatus* (snake headed fish, *saul*) among the fishes are least so.

(b) Determination of the Effects of Long Term Treatment at very low Levels of Toxicity :

In order to simulate conditions such as are likely to exist in rivers, streams, lakes or ponds receiving a continuous supply of the syndet at a low level from municipal or industrial effluent, long term experiments were set up in the laboratory where 10, 1

TABLE I—COMPARATIVE TLm VALUES FOR I-DET-10 FOR 24, 48 AND 96 HR

Sl. No.	Species	TLm values for ABS (mg/l)			pH	DO	Temperature (°C)	
		24 hr	48 hr	96 hr.			Water	Room
1	*Paramecium caudatum*	0.072	—	—	—	—	—	—
2	*Daphnia* sp.	1.8	1.44	—	—	—	28.0	30.0
3	*Chironomus larvae*	5.4	—	3.24-3.60	—	—	29.0	31.0
4	Fries of *Cyprinus carpio*	4.68	3.60	2.88	—	—	28.5	31.0
5	*Labeo rohita* (8-9 months old)	9.2-13.0	—	—	7.6	9.9	16.5	18.0
6	*Barbus ticto*	14.4	14.07	—	7.8	7.5	29.0	30.0
7	*Clarias batrachus*	18.8	14.07	13.0	7.6	9.6	16.0	17.8
8	Tadpoles of *Rana tigrina*	19.6	19.2	—	—	—	28.5	30.5
9	*Heteropneustes fossilis*	22.2	20.3	16.6	7.6	9.5	16.5	18.0
10	*Channa punctatus*	27.7	25.9	22.2	7.6	9.8	15.5	18.5

Note : The ABS values have been calculated from the technical formula.

and 0.1 mg/l of I-Det-10 was added every day for twenty four weeks. It was found that *Clarias batrachus* could withstand daily additions of 1 and 0.1 mg/l concentrations for a longer time as compared to *Channa punctatus* There was 50% mortality in 1 mg/l experimental group after 12 weeks of exposure in case of *Clarias batrachus* whereas with *Channa punctatus* 50% mortality was recorded within 10 weeks of exposure. Similarly, in 0.1 mg/l experimental group, 50% mortality in *Clarias batrachus* was observed after 19 weeks of exposure and in case of *Channa punctatus*, after 14 weeks of exposure only.

(c) Effect of Temperature Change in relation to Toxicity :

Experiments on the role of temperature in relation to toxicity were conducted only in the case of *Cyprinus carpio*. TLm values in case of fries of *Cyprinus carpio* were found to be very much influenced by slight increase or decrease in water temperature. It was observed that at 26°C there was no mortality when fishes were exposed to 10 mg/l of the syndet, whereas a further rise of 2.5°C in water temperature caused 20% mortality in 24 hr. Similarly, even in higher concentrations of 15 mg/l of the syndet at 26°C, there was no mortality upto 24 hr and when water temperature rose by another 2.5°C (i.e., 28.5°C), there was 100% mortality in 96 hr for the same dose level of 15 mg/l of the syndet.

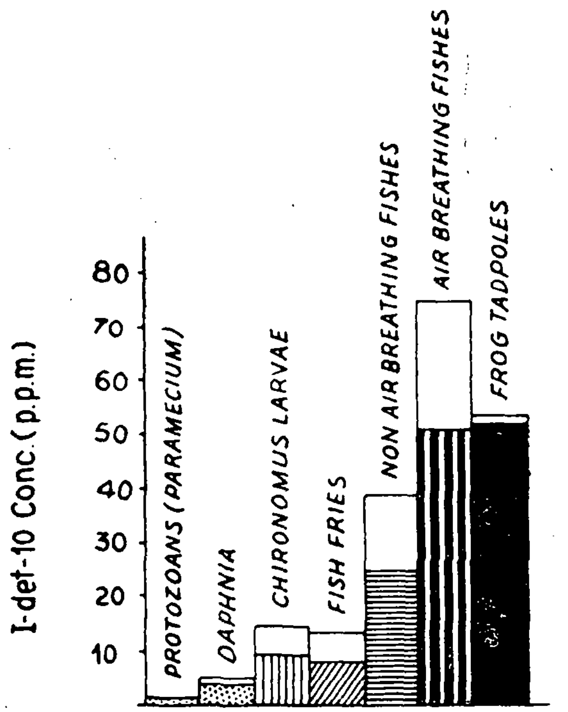

Fig. 2—A histogram showing the range of TLm values (indicated by blank area in each column) in different groups of fresh water animals tested.

(d) Behavioural Response :

The main behavioural responses were: (i) disturbed movements of the animals, particularly fish, followed by loss of activity and equilibrium, depending on dosage, (ii) a gradual slowing down and stabalizing of opercular movements at sub-normal level (These clearly indicate irritation to the integument, cutaneous sense organs and irritability of gill epithelium); and (iii) sub-normal feeding and, in many cases, complete abstinence from food at doses around TLm values and above.

2. Toxicity Studies in Heteropneustes fossilis when Syndet is a constituent of the Fish Food

The fishes receiving I-Det-10 at the rate of 0.01% of the food appeared to feed normally for the first three days, but subsequently, they stopped eating and preferred to starve for the rest of the experimental period (6 weeks). On the other hand, fishes receiving lower doses, namely, 0.001% and 0.0001% of I-Det-10 as a part of the food did not show any obvious change in their feeding behaviour. They were, however, observed to lose weight in spite of regular feeding. The controls were seen not only to feed normally but also did not lose any weight. There was no mortality in the last two experimental groups including controls. However, there was a solitary death in the case of the first group (*viz.*, those receiving I-Det-10 at 0.01% of the food by weight) during the last week.

Discussion

From the observations recorded above, it is quite obvious that syndets affect different forms of aquatic life at different levels of concentration, the TLm values ranging from as low as 0.2 mg/l in case of protozoa to as high as 75 mg/l in case of certain airbreathing fishes, perhaps the hardiest known allover the world. A glance at Table II will give a more comprehensive picture of the present day knowledge of the comparative levels of the sensitivity to syndets by different aquatic organisms from plants onwards to amphibians.

TABLE II—COMPARATIVE TOXICITY LEVELS OF SYNDETS TO DIFFERENT GROUPS OF AQUATIC ORGANISMS

Sr. No.	Group	Type of syndet tested	Toxicity levels (range and TLm values)	Reference
1.	**PLANTS**			
	i) *Ranunculus aquatilis*	Santomerse of ABS type	Affected even by as little as 1 mg/l	Evens and Roberts (5)
	ii) *Potamogeton pectinus*	—do—	Unable to grow in 2.5 mg/l	—do—
	iii) *Potamogeton densus*	—do—	—do—	—do—
	iv) **Aquatic plants in general**	Surfactant (ABS)	10-20 mg/l	Roberts (6)
2.	**PROTOZOANS**			
	Paramecium caudatum	I-Det-10	0.2 mg/l stops the movements within 24 hr.	Mahajan and Singh (present communication)
3.	**ARTHROPODS**			
	i) *Gammarus pulex* (Water Shrimp)	ABS	2.5-10 mg/l	Roberts (6)
	ii) *Daphnia* sp.	i) I-Det-10	i) TLm values for 24 and 48 hr. are 5 and 4 mg/l respectively.	Mahajan and Singh (present communication)
		ii) Surfactant (ABS)	ii) 5 mg/l of Surfactant is toxic.	Degens *et al* (7)
	iii) Turbificides.	Syndet	10-25 mg/l	Mann (8)
	iv) Chironomids.	—do—	—do—	—do—

Sr. No.	Group	Type of syndet tested	Toxicity levels (range and TLm values)	Reference
	v) *Chironomus larvaes*	I-Det-10	TLm values for 24 and 48 hr. are 15 mg/l and 9-10 mg/l respectively.	Mahajan and Singh (present communication)
4.	**FRESH WATER FISHES**			
a)	**Fish fries:**			
	Fries of *Cyprinus carpio*	I-Det-10	TLm values for 24, 48 and 96 hr. are 13, 10, and 8 mg/l respectively.	Mahajan and Singh (present communication)
b)	**Non-airbreathing fishes:**			
	i) *Salmo gairdneri* (rainbow trout)	i) Manoxol O. T.	i) 3 mg/l causes 50% mortality in 12 weeks.	Herbert (9)
		ii) ABS	ii) 3.48 mg/l causes 50% mortality in 24 hr. and 2.53 mg/l causes 50% motality in 120 hr.	Hassler *et al.* (10)
	ii) *Lepomis macrochirus* (blue gill)	ABS	TLm value for 30 days ranges between 15.5–18.3 mg/l. Differentiation between 30 days and 24 hrs TLm values is 6.5-0.5 mg/l.	Lemuke and Mount (11)
	iii) *Labeo rohita*	I-Det-10	TLm value for 24 hr. is between 25-35 mg/l	Mahajan and Singh (present communication)
	iv) *Barbus ticto*	—do—	TLm values for 24 and 48 hr. are 39 and 38 mg/l respectively.	—do—
	v) Silver salmon	Surfactant	5.6-10 mg/l	Henderson *et al.* (12)
	vi) *Pimephales promelas* (Fat head minnow)	i) Syndet	i) TLm values for 24, 48 and 96 hr. are 63, 62 and 61 mg/l respectively.	—do—
		ii) ABS	ii) TLm values for 24, 48 and 96 hr. are 4.5; 4.5 and 4.5 mg/l respectively.	—do—
c)	**Air-breathing fishes**			
	i) *Clarias batrachus*	I-Det-10	TLm values for 24, 48 and 96 hr. are 51, 38 and 35 mg/l respectively.	Mahajan and Singh (present communication)
	ii) *Heteropneustes fossilis*	—do—	TLm values for 24, 48 and 96 hr are 60, 55 and 45 mg/l respectively.	—do—
	iii) *Channa punctatus*	—do—	TLm values for 24, 48 and 96 hr. are 75, 70 and 60 mg/l respectively.	—do—
5.	**ESTURINE FISHES**			
	i) *Fundulus heteroclitus* (Mummichogs)	ABS	TLm value for 96 hr. is 22.5 mg/l.	Ronald (13)
	ii) *Mugil cephalus* (Mullet)	—do—	TLm value for 96 hr. is 10 mg/l.	—do—

Sr. No.	Group	Type of syndet tested	Toxicity levels (range and TLm values)	Reference
iii)	*Mendia Mendina* (Silver sides)	ABS	TLm value for 96 hr. is 7 mg/l.	Ronald (13)
iv)	*Pseudo pleuronectes americanus*	—do—	TLm value for 96 hr. is 8.2 mg/l.	—do—
v)	*Anguilla rostrata* (Eels)	—do—	TLm value for 96 hr. is 75 mg/l.	—do—
6.	**FROG TADPOLES**			
	Tadpoles of *Rana tigrina*	I-Det-10	TLm values for 24 and 48 hr. are 53 and 52 mg/l respectively.	Mahajan and Singh (present communication)

It is, however, to be noted that the organisms of any fresh water ecosystem, whether a pond, a lake or a stream, are interconnected through a complicated but delicate web of food chain. Fishes form an important part of this ecosystem and, so far as man is concerned, they constitute a useful and commercially important product. Thus, although fishes in general are more tolerant to higher concentrations of surfactants than most of the other aquatic plants and animals (Table II), they are indirectly affected as these very lower invertebrates and plants constitute their food either directly or indirectly. As the feeding experiments reported in the paper have clearly shown, the fishes are likely to be affected by very small proportion of the syndets becoming a part of their food (as would necessarily happen when some of these surfactants get absorbed into body systems of the lower organisms constituting the fish food). Thus, a more dangerous aspect of the pollution of any water area with surface active agents is that even though the organisms inhabiting polluted ecosystem may not show mortality, there may be impairment of growth followed subsequently by adverse changes in reproductive capacity, breeding behaviour etc. Ultimately, the population pattern within the community may be affected. Slowly but surely, continued pollution of this kind is likely to eliminate many groups of organisms, thus disturbing the food chain within the ecosystem with unpredictable, nevertheless, adverse effects on the remaining components of the community within the ecosystem.

From the number and variety of the organisms listed in Table II, it is quite clear that we know little about the tolerance of most of the organisms to surface active agents and this points to a need for more systematic, detailed and scientific approach to the study of the effects of these pollutants on aquatic life. Even with regard to organisms listed in Table II, very little information is available except the toxicity levels. Physiological and behavioural responses are also not studied, particularly at sublethal levels. Similarly long term low level dose studies simulating conditions such as are likely to occur in nature are conspicious by their absence. The long term experiments reported here are of particular significance in that they indicate the dangers to which even the hardiest of fresh water fishes are exposed—not to speak of the more sensitive non-air-breathing fishes and further, the food on which they are dependent.

The effect of small changes in temperature on the sensitivity of the fish shows how dangerous a pollutant can be under slightly changed environmental conditions. In this country, a special note has to be taken of these variables, as many parts of the country experience extreme climatic conditions.

The effects of syndets in combination with other pollutants e.g. oil, have not been worked out by the authors, but reports made by others (14) show that detergents mixed with oil may be 60 times more toxic than the oil alone. This fact should be an eye opener, because it shows how dangerous a situation can become when the effects of two pollutants is synergistic. The main warning, therefore, for those responsible for the management of natural waters is that the pollutants such as synthetic detergents and oil, not to speak of heavy metal compounds, pesticides, fertilizers, radioactive substances etc., should be neutralised before any effluent containing them is allowed to get into these waters. Similarly, thermal pollution through any source whatsoever, should be checked.

The general problem of pollution by synthetic detergents with particular reference to India has recently been summarised by Kale (15), and on a general basis by Milwidsky (16). Kale *(op cit.)* has particularly emphasised the aspect of sewage disposal on land and its possible repercussions. The present investigation on aquatic organisms further strengthens the view held by Kale *(op cit.)* that this country should also switch over to the manufacture and marketing of the soft (easily biodegradable) type of detergents, a step already taken by developed countries like U.K. and U.S.A. At present, the hard type of detergents (resistant to biodegradation) are the only ones that are manufactured in this country. I-Det-10 which is the basis of present investigation. is only a representative of this type.

Acknowledgements

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DISCUSSION

Dr. C. K. Ramachandar (Ranipet): Were any constituents of chemical industries effluents found in the body of the fish? Table I gave the impression that the phosphates do not affect the fish population. Please clarify.

Prof. C. L. Mahajan: So far as ABS, the surface active and toxic component in syndets is concerned, its absorption by the body of the fish from water has been demonstrated by Hassler et al. in 1967 by using ABS lebelled with tracer isotope S-35. Absorption, retention and in fact, preferential accumulation of some other pollutants, particularly heavy metal compounds and pesticides, has been well documented by several workers in various tissues of the body of the fish. As is well-known, the disastrous effects of eating fish with such accumulations has prompted some countries to declare fish from such water areas unfit for human consumption and further fishing has been prohibited by law.

The phosphates act as fertilisers and are, therefore, useful so long as they are present in optimum quantity for greater production of phyto- and zoo- plankton which serve as food for fish, thus contributing to greater productivity. However, when phosphates are present in excess they cause eutrophication with all its accompanying problems. This problem is particularly acute in North American lakes which receive huge quantities of phosphates from industrial and municipal wastes. In this connection, I should like to invite your attention to an article entitled 'Eutrophication Problem' in a special issue on Environment Canada issued by the J. Fisheries Res. Ed. Canada, Vol. 29, No. 6, June 1972.

Shri D. Balasubramaniam (Akola): To conserve edible oil resources, it is stipulated that the use of edible oils in soap manufacture is reduced and non-edible oils are substituted, i. e., like neem, karauja, salseed oils, etc. As these oils are not produced in required quantity, the manufacture of synthetic detergents is bound to go up. So the treatment of effluents from syndets producing units as well as the problem of fresh water pollution due to use of detergents has assumed urgency.

Prof. C. L. Mahajan: Yes, we agree.

PROC. SYMP. ON ENVIRONMENTAL POLLUTION (1973)

Water Pollution in Relation to the Biology of Fishes

Part II–Histopathological changes induced by synthetic detergents in the gills of *Heteropneustes fossilis (Bloch)*

C. L. MAHAJAN* and J. J. SINGH*

Histopathological changes induced by different levels (both lethal and sublethal) of the synthetic detergent I-Det-10 in the gills of *Heteropneustes fossilis* have been worked out in detail.

An interesting finding is that much smaller dose levels, when constituting a part of the food, can produce pathological changes in the gills to the same extent as are produced by much greater quantities of the pollutant dissolved in water. The significance of this has been discussed in relation to the problem of water pollution in general and the synthetic detergents in particular.

Introduction

Integument and gills are the two parts of the body which come in direct contact with the pollutant if it is dissolved in water. The toxic effects of a pollutant, which has surface active properties are, therefore, most likely to be felt by these parts. The gills of fishes are not only respiratory but are also excretory in function to some extent. They are, therefore, the most sensitive index of the toxicity due to synthetic detergents. Hence, it was thought worthwhile to investigate the effect produced on the gills by synthetic detergents (syndets) at sublethal and lethal levels.

Lemuke and Mount (1) demonstrated that 6.5 mg/l of ABS reduces the growth rate of the fish and causes the thickening of gill epithelium of *Lepomis macrochrius* after 30 days of exposure. Similarly, Cairns *et al* (2) and Swisher *et al* (3) have also shown that even 3 mg/l of ABS can cause thickening of the gill epithelium of sunfishes (*Lepomis gibbosus and Lepomis macrochrius*). In this paper, results of a detailed investigation of the general histopathological responses in specialised as well as general cells of the gills of *Heteropneustes fossilis* are reported.

Materials and Methods

Heteropneustes fossilis of one year old group was obtained from waters around Jaipur with the help of the State Fisheries Department and the local fishermen. The fishes were acclimatised to the aquarium conditions. After a fortnight of acclimatisation the fishes were counted and separated into different aquaria (150 l capacity) in groups of 50 in each aquarium. One of the aquaria served as the control where normal conditions of the feeding and water (to which fishes had already been acclimatised) were maintained. In other aquaria, fishes were given a single treatment of I-Det-10 at sub-lethal doses *i.e.* below 60 mg/l (TLm value for this fish), and lethal doses ranging from 200 to 450 mg/l. Two fishes from each

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* Department of Zoology, University of Rajasthan, Jaipur-4.

tank were sacrificed at regular intervals from each of the tanks and the gills were removed, fixed and processed using standard histological procedures (4, 5) for histopathological studies. The details of feeding experiment have already been given in the first part of the paper.

Observations and Results

1. Normal Histology of the Gills: (Plate 1, Fig. 1-4)

Histology of a normal fish gill has been reported by several workers (6, 7) and that of *Heteropneustes fossilis* by Datta Munshi (8). Histology of a normal gill of *Heteropneustes fossilis* may be studied under the following heads (Fig. 1 a and b) : (i) Gill arch region, (ii) Gill filament region, and (iii) Gill lamellae region.

(i) *Gill arch region:* (Fig. 1 b and 2)

This region includes mucous gland cells (mgc), epidermal or epithelial cells (epc), taste buds (tsb) and large acidophil glandular cells (agc).

(ii) *Gill filament region:* (Fig. 1 b, 3 and 4)

It includes respiratory epithelial cells (rcl), blood cells (bc), basement membrane (bm), cartilagenous axis cells (cac) and mucous gland cells (mgc) at the tip of the filament.

(iii) *Gill lamellae region:* (Fig. 1 b, 3 and 4)

It includes respiratory epithelial cells (rc2), blood cells (bc), pilaster cells (pc) and acidophil mast cells (amc) at the bases of lamellae.

2. Histopathological Changes in Treated Fishes: (Plate 2-4)

When *Heteropneustes fossilis* was exposed to different sublethal and lethal concentrations of I-Det-10, the gill tissue showed marked pathological changes. This was so even when the detergent was fed alongwith the fish food. The changes observed under different experimental conditions are detailed below :

(i) *Response to Exposure for two days to a Sublethal Level of 50 mg/1 of I-Det-10* (Plate 2; Fig. 5 and 6).

Histological picture of a gill taken from a live fish which had been exposed to 50 mg/l of I-Det-10 for two days showed the following pathological changes :

(a) Loss of cell wall by different types of cells of all the regions *viz.* gill arch, gill filament and gill lamellae (Fig. 5 and 6). This is generally preceded by signs of inflamation at initial stages of treatment within few minutes of the start of the experiment.

(b) Degeneration (partial or total liquification) of blood cells and respiratory cells., (Fig. 6, de).

(c) Gradual loss of the definite nature and identity of basement membrane (Fig. 6, bm).

(d) Increase in the number of cells of the cartilagenous axis at the tip of gill filament (Fig. 5).

(e) Erosion of tips of gill filaments which are generally seen with empty mucous gland cells (Fig. 5 ert).

(f) Fusion of adjacent gill lamellae (Fig. 5 and 6, fu).

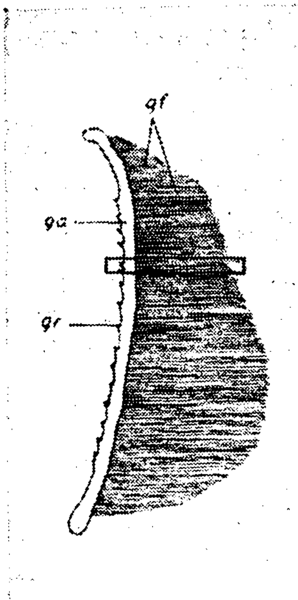
(g) Localised necrosis of some parts of the tissue (Fig. 6, ne).

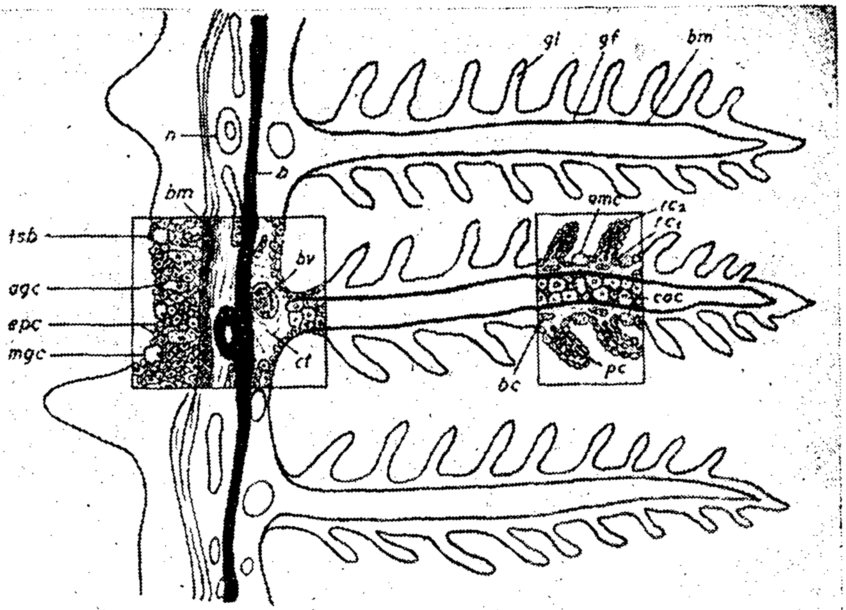
(ii) *Response to Exposure for Short Duration (3-6 hr) to I-Det-10 at Concentration of 200-450 mg/1:* (Plate 2, 3, Fig 7-10) :

The following pathological changes are noteworthy in addition to those listed in (i) above :

(h) Separation of respiratory gill epithelium from the basement membrane with the appearance of a space in between (Fig. 9 and 10).

(i) Formation of a bud-like process by accumulation of cartilagenous axis cells (Fig. 9).





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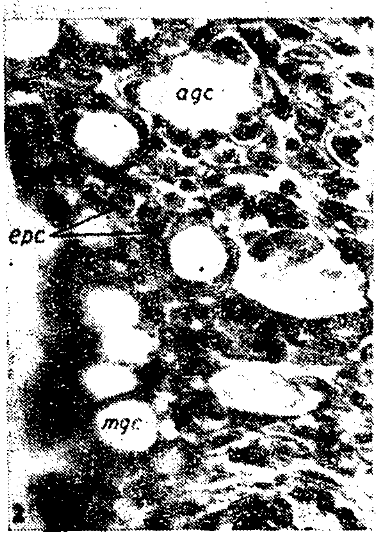


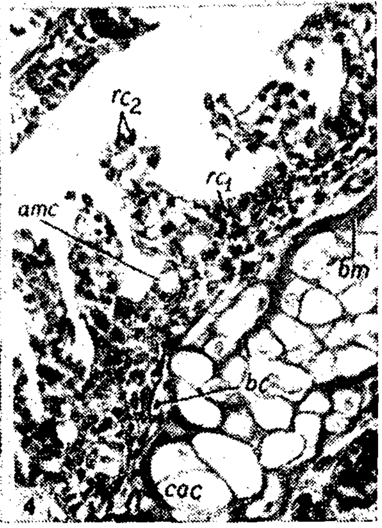


Plate I

Fig. 1 'a' and 'b'—A diagramatic representation of the gill, its various regions and cell types as seen in Heteropneustes fossilis.

Fig. 2—Photomicrograph of a horizontal section of the gill arch region in a control fish (x 1000).

Fig. 3—Photomicrograph of a horizontal section of the gill passing through gill filaments and gill lamellae in a control fish (x 100).

Fig. 4—Photomicrograph of a part of the gill in Fig. 3 enlarged to show the detailed structure (x 400).

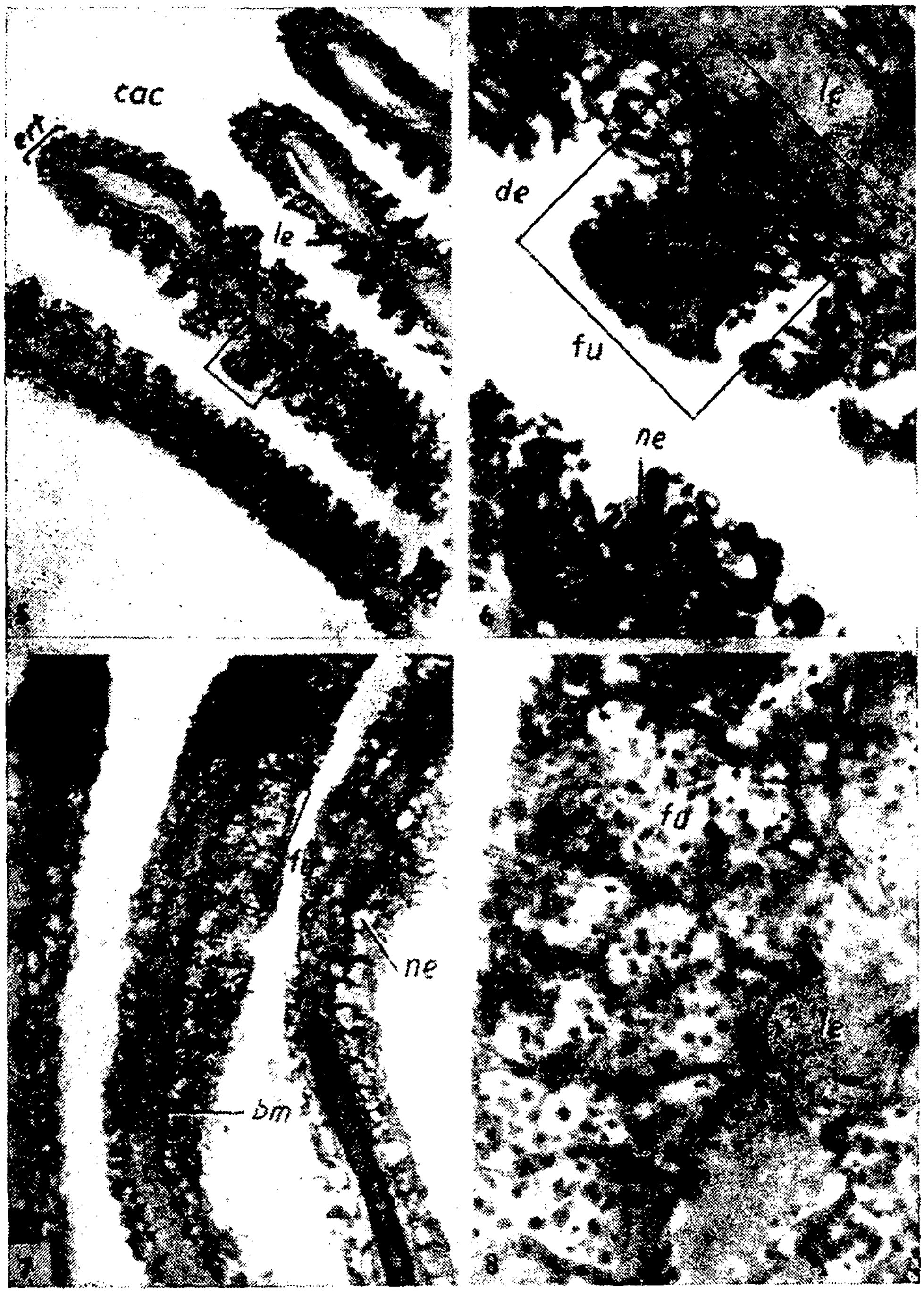


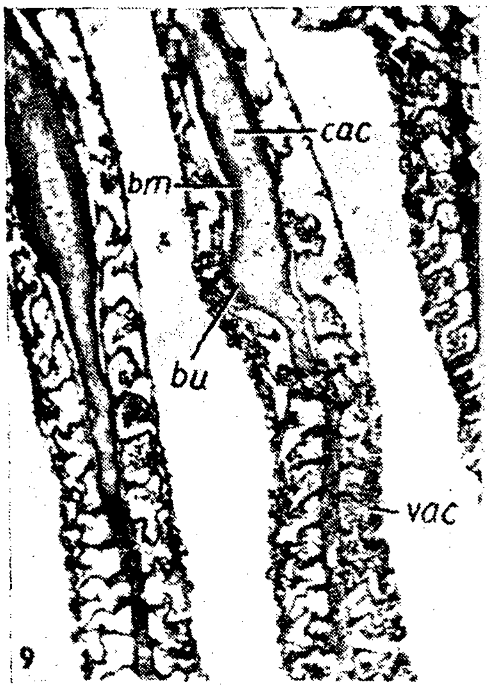
Plate II

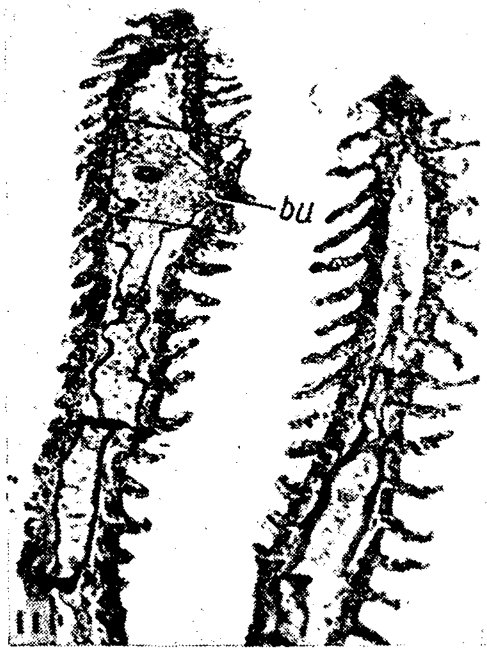
Fig. 5—Photomicrograph of the horizontal section of the gill filament and gill lamellae, after 48 hr exposure to 50 mg/l of I-Det-10 (x 100).

Fig. 6—Photomicrograph of a small part of the gill filament (marked by a square in Fig. 5) enlarged to show the fusion of adjacent gill lamellae (x 400).

Fig. 7—Photomicrograph of a horizontal section of the gill filament after 6 hr of exposure to 200 mg/l of I-Det-10 (x 100).

Fig. 8—Photomicrograph of a small part of the gill filament (marked by a square in Fig. 7) enlarged to show fusion of gill lamellae and liquification of the tissue (x 400).





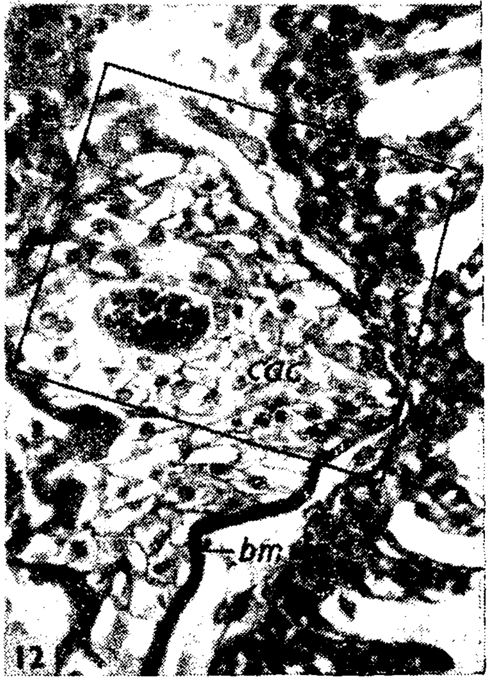


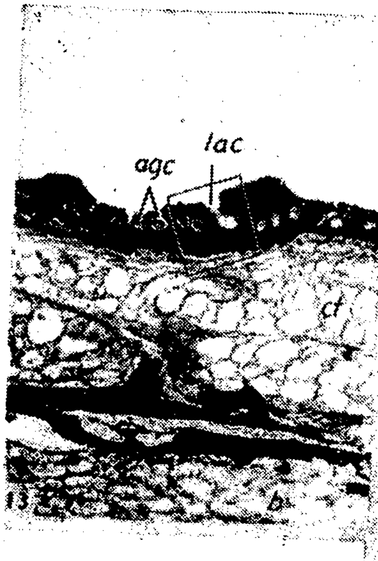
Plate III

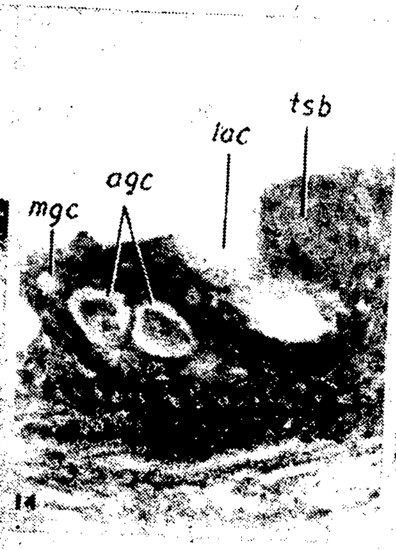
Fig. 9—Photomicrograph of a horizontal section of a gill filament after 6 hr exposure to 300 mg/l of I-Det-10 (x 400).

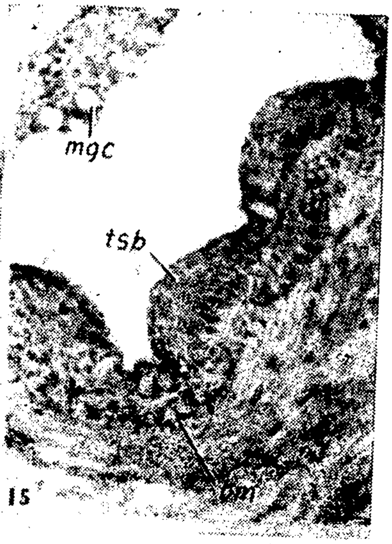
Fig. 10—Photomicrograph of a small part of the gill filament seen in Fig. 9 enlarged to show the details (x 400).

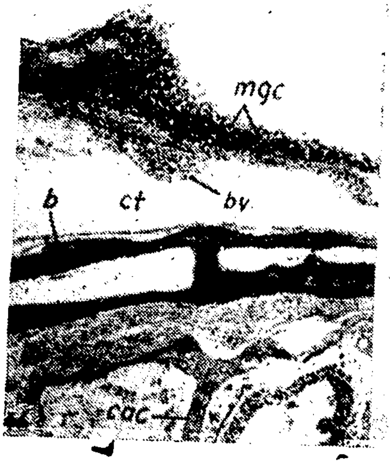
Fig. 11—Photomicrograph of a horizontal section of a gill filament from the fish fed with 0.001% of I-Det-10 as a part of the food for 3 days (x 100).

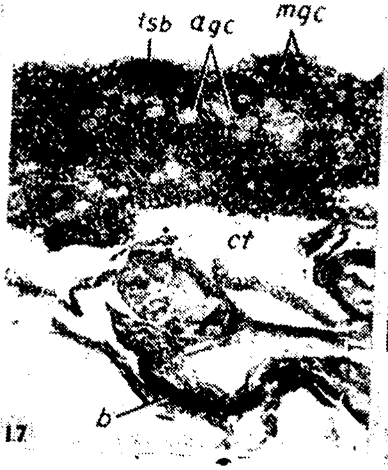
Fig. 12—Photomicrograph of a small part of the gill filament (marked by square in Fig. 11) enlarged to show the details (x 400).











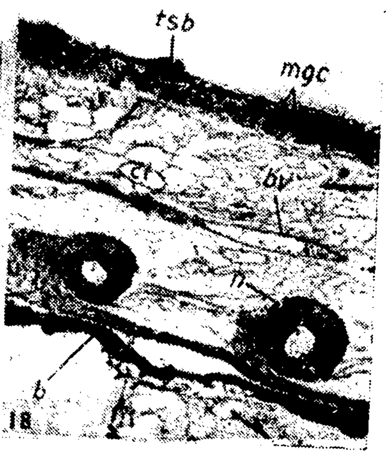


Plate IV

Fig. 13—Photomicrograph of the horizontal section of the gill arch region after 3 days of feeding at 0.01% of I-Det-10 in fish food (note the damaged taste bud) (x 100).

Fig. 14—Photomicrograph of a small part of the gill arch (marked by a square in Fig. 13) to show the details of the damage to taste bud (x 400).

Fig. 15—Photomicrograph of the horizontal section of gill arch region after 3 days of feeding at 0.0001% of I-Det-10 in fish food (note the relatively undamaged taste bud) (x 400).

Fig. 16—Photomicrograph of the horizontal section of gill arch region after 2 weeks of feeding at 0.01% of I-Det-10 in fish food (note the large number of mucous cells and the nature and extent of the damage) (x 100).

Fig. 17—Photomicrograph of the horizontal section of gill arch region after 2 weeks of feeding at 0.001% of I-Det-10 in fish food (note the large number of mucous cells and the disorganised and damaged nature of both the epidermis and the dermis) (x 100).

Fig. 18—Photomicrograph of the horizontal section of gill arch region after 3-weeks of feeding at 0.01% of I-Det-10 in fish food (note the extent of repair when compared to the damage in Fig. 16) (x 100).

(j) A more pronounced hyperemia (hyp) and fusion of gill lamellae (Fig. 7-10, fu, hyp) followed by necrosis (ne).

(k) Lacunae appearing at number of places (Fig. 9).

(iii) *Response to Feeding of I-Det-10 mixed with Normal Fish Food:* (Plates 3 and 4, Fig. 11-18) :

When I-Det-10 was mixed at the rate of 0.01, 0.001 and 0.0001% of the fish food and fed to the fishes, all the changes noted in (i) and (ii) above were evident to a greater or lesser extent within three days after feeding the detergent mixed food, as is evident from the Fig. 11-18. In particular, the tendency for bud formation in gill filament was quite prominent (Fig. 11 and 12). Another noteworthy feature was that in the experimental group, fishes fed with detergent mixed food at the rate of 0.01% showed maximum damage within three days of the feeding. There were signs of repair after this period, probably because fishes started avoiding detergent mixed food. They appeared to prefer starvation rather than feeding on detergent mixed food at that level. In contrast, the fishes fed on detergent mixed food at the rate of 0.001 and 0.0001% continued to feed upto six weeks, the duration of experiment. As a consequence, after two weeks of feeding the detergent mixed diet, the 0.001 and 0.0001% groups showed damage to gill tissue whereas the 0.01% group was observed to have repaired the damage initially caused in the first three days of feeding. Apparently, the reserve body food had been metabolised for both survival and repair of the damaged tissues, during the subsequent days of starvation (Fig. 13-18).

In addition to the changes noted in (i) and (ii) above, the following pathological changes were also recorded in this experiment :

(l) Atrophy of large acidophil glandular cells (Fig. 13 & 14).

(m) More pronounced bud-formation by accumulation of cartilagenous cells in the central axis of the gill filament (Fig. 11 & 12).

(n) Taste buds are damaged (Fig. 13 & 14)

Discussion

It is well known that ABS is the main toxic component in synthetic detergents, being the surface active agent. The mode of penetration of synthetic detergents to cell membrane depends upon its lipid soluble property. The detergent molecule can penetrate and solubilize the lipid content of cell membrane and may reduce its permeability. The synthetic detergents also affect indirectly the cell permeability by reducing the oxygen content of water, as lack of oxygen decreases cell permeability for water accompanied by a loss of selective permeability (9).

Hassler *et al* (10) have demonstrated through tracer experiments using S_{35} labelled ABS, that ABS is absorbed by the fish blood from the aquarium water and thus is carried to the other organs and organ systems in the body of the fish. The effect on the gills produced by syndet when it is a constituent of the food shows that this absorption can take place through the intestinal epithelium also and gills tend to remove the ABS so absorbed. This is quite evident from the fact that even small quantities of the syndet (0.01% of the food) affect the gills adversely within 24 hr, so much so that the effect is almost the same as 50 mg/l of the syndet dissolved in water. So far as the authors are aware, the effect of small quantities of this pollutant as a part of food has not so far been worked out by anybody and, therefore, it is the first report of its kind. Invertebrates (Zooplanktons such as ciliates, crustaceans and bryozoans etc.) and plants which constitute the food of fishes are likely to absorb ABS, if present, in their body system. When such contaminated food is eaten by the fish, the adverse effects are quite obvious. It is, therefore, important that in any study of water pollution the effect on the whole biotic community as an ecosystem is worked out.

Work is in progress in this laboratory on the histopathological responses induced in other organs and organ systems in fishes living in waters polluted with different levels of synthetic detergents and other water pollutants.

Acknowledgement

Grateful thanks are due to the University of Rajasthan for granting scholarship during the course of this investigation to Shri J. J. Singh and to Profs. L. S. Ramaswami and P. N. Srivastava, for the facilities in the Zoology Department. The authors are also grateful to M/s Swastik Oil Mills Ltd., Bombay for providing technical samples of I-Det-10.

ABBREVIATIONS

agc : large acidophil glandular cells
amc : acidophil mast cells
at : atrophy
b : bone
bc : blood cell
bm : basement membrane
bu : bud
bv : blood vessel
cac : cartilagenous cells
ct : connective tissue
de : degenerating cells
epc : epidermal or epithelial cells
ert : erroded tips
fu : fusion of gill lamellae
ga : gill arch region
gf : gill filament
gl : gill lamellae
gr : gill rakers
hyp : hyperemia
le : liquification
mgc : mucous gland cells
n : nerve
nc : necrosis
pc : pilaster cells
rc 1 : respiratory cells of gill filament
rc 2 : respiratory cells of gill lamellae
tsb : taste bud

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PROC. SYMP. ON ENVIRONMENTAL POLLUTION (1973)

Studies on Hooghly Estuarine Pollution in the Vicinity of Tissue Mill

A. K. BASU,* C. S. G. RAO,* R. S. DHANESHWAR,* (Mrs.) G. MUKHERJEE*
M. K. A. KUTTY,* (Mrs.) D. RAY* and R. C. TRIVEDI+

An extensive survey was conducted into the physico-chemical aspects of the Hooghly estuarine water from eight sampling stations located near two discharge outlets of a tissue mill in the CMD area.

The existing physico-chemical characteristics are such that the water quality is undesirable not only near discharge points but also at the northern and southern points. The width of the river, flow pattern and topography of this dynamic water regime are, however, such that the pollution inflow does not extend to the middle reach of the estuary.

The provision of proper treatment and disposal of wastewater from this factory has been suggested to improve the present water quality conditions of this area and save the risk of water contamination by organic waste to nearby water head works.

Introduction

A tissue mill is located in the village called Chandra Rati, about 60 km north-west of Calcutta and on the right bank of the Hooghly river (Fig. 1) The factory manufactures 18—20 tons/day of different grades of tissue papers by employing sulphide process.

The raw materials used include raw hemp, rejected hemp ropes and gunny cuttings. Hemp, gunny cuttings are first steam cooked in closed digesters with solution of caustic soda and sodium sulphide, under controlled temperature and pressure. After cooking is completed, the charge is blown into a breaker where the spent liquor known as "black liquor" is drained out from the pulp. In the breakers, the pulp is washed. The washed pulp after passing through screen is bleached with calcium hypochlorite and washed The bleached pulp after being mixed with the required quantity of precipitated chalk is sent to Fourdrinier machine, where it is converted to a continuous sheet of paper.

The wastewaters from this factory are presently discharged into the Hooghly river. In view of the small quantity of production, chemical recovery is not practised. Hence, black liquor is also discharged into the estuary.

The River Survey

The present survey was done between May, 1970 and May, 1971. The survey, however, could not be undertaken in January, 1971 owing to the closure of the factory during this period. Most of the samples were collected bimonthly for 24 hr periods at different tide conditions. In general, during 24 hr period, 2 high and 2 low tide conditions were observed to exist. 'Slack' or 'zero' tide conditions were insignificantly

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* CPHERI Zonal Laboratory, 23, R. N. Mukherjee Rd., Calcutta-1.

\+ Present Address: Public Health Engineering Laboratory, Baroda.

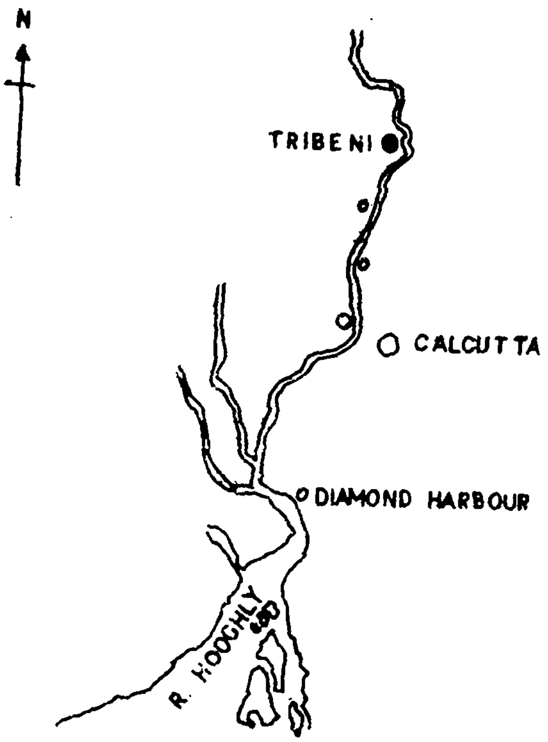

Fig. 1—Hooghly Estuary

small as compared to the duration of 'high' and 'low' tide conditions.

Sampling Stations

In all, 8 sampling stations were selected: 2 located in close proximity to the 2 discharge outlet points from the tissue factory and others between far southern location of M/s Keshoram Rayon Ltd., Nayasarai and northern location of Bandel Thermal Power Station of the West Bengal State Electricity Board. Sampling stations were so chosen as to ascertain that the effects caused were entirely by the wastewater discharged from this tissue mill and no other industry. The distance between most northern and far southern stations was approximately 1250 m.

Negligible quantities of sullage water and cattle farm wastewater percolation were, however, observed in between the extreme stations. Details of the sampling stations are shown in Fig. 2. The length-wise distance between the sampling points 1 and 2, was about 200 m and between sampling points 2 & 3, 3 & 4, 4 & 5, and 5 & 6, about 250 m each. Sampling points 7 and 8 were about 15 m and 80 m apart from sampling point 3. Water samples were also collected from the bank from points about 3—5 m away from the water edge depending on the tidal conditions.

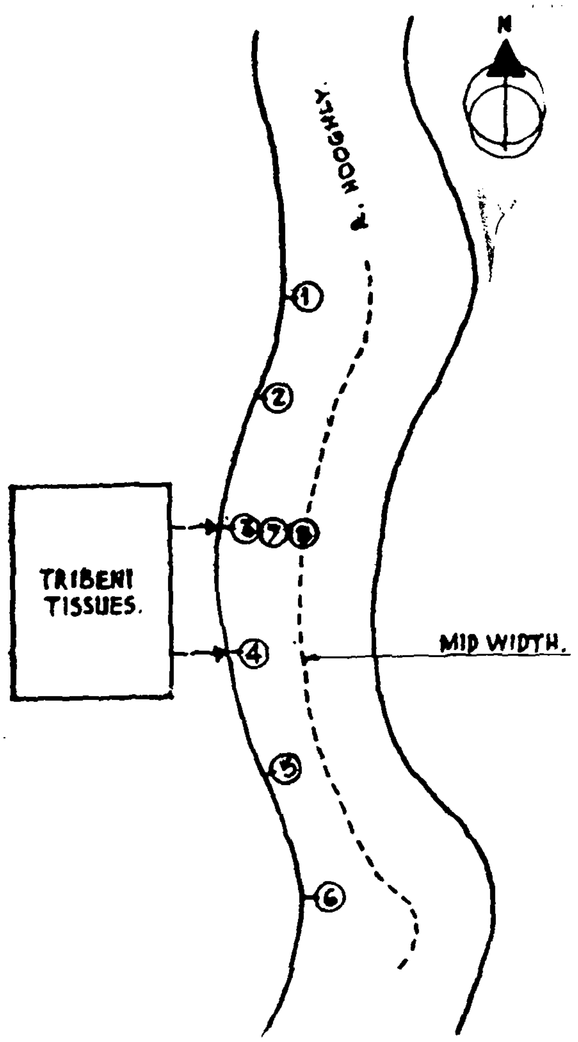

Fig. 2—Sampling Points

Materials and Methods

The Hooghly estuary being a "vertically homogeneous estuary", water samples at all the sampling stations were collected from depth of about 15—20 cm from the surface of water level at the existing tide conditions. Part of the river samples so collected were subjected to spot determination of pH, temperature, DO, alkalinity, etc. and to laboratory analysis for BOD, COD, chloride, solids, lignin, etc. All physico-chemical tests were done as per the "Standard Methods for the Examination of Water and Wastewater, APHA (12th Edn.)". Bottom muds from sampling stations were collected by the use of Ekman dredge.

Observations

During the period under review, 6 surveys were conducted. In each survey, attempts were made to cover all the extreme high and low tide samplings at all the stations and also to cover zero tide conditions at least from the stations 3, 7 and 8.

The main objective of the programme was to know the physico-chemical conditions of the estuarine water. At subsequent stages, however, the programme was extended to the studies on the bottom mud also.

(a) Physico-chemical Conditions of the Water

The physico-chemical characteristics such as temperature (ambient, water), pH, solids (total, suspended), chloride, phosphate, lignin, nitrite, nitrate, alkalinity, dissolved oxygen, COD and BOD (5 day at 20°C) were estimated.

Results of each item of analysis are shown in Tables I to XIV. Most of the results shown are averages on the basis of two low and two high tides in a 24 hr period. Slack or zero tide results at each point are based on a single value only.

TABLE I—pH VALUES

Tide	Sampling Points	May 1970	July 1970	Sept. 1970	Nov. 1970	March 1971	May 1971
Average of Low Tide	1	7.4	8.2	6.4	7.5	7.5	8.0
	2	7.5	8.2	6.4	7.5	7.5	8.0
	3	7.5	8.6	5.5	8.3	7.5	8.0
	4	7.5	8.6	6.3	8.2	7.5	8.2
	5	7.5	8.3	6.3	7.5	7.5	8.2
	6	7.6	8.5	6.5	7.5	7.4	8.4
	7	7.4	8.1	6.5	7.6	7.5	8.3
	8	7.5	8.3	6.5	7.5	7.6	8.3
Zero or Slack Tide	1	—	8.3	—	—	7.6	7.9
	2	—	8.4	—	—	7.5	7.9
	3	7.5	8.5	—	—	7.4	8.3
	4	—	8.0	—	—	7.3	8.3
	5	—	8.1	—	—	7.4	8.3
	6	—	8.1	—	—	7.4	8.2
	7	7.5	8.4	—	—	7.0	7.8
	8	7.5	8.4	—	—	7.4	8.2
Average of High Tide	1	7.5	8.1	6.0	8.5	7.6	8.2
	2	7.5	8.2	6.0	8.5	7.6	8.2
	3	7.7	8.5	5.4	8.2	7.4	7.9
	4	7.7	8.7	5.4	8.2	7.5	8.3
	5	7.5	8.3	5.7	7.1	7.6	8.3
	6	7.5	8.2	5.8	7.1	7.6	8.3
	7	7.5	8.4	6.0	7.2	7.5	8.2
	8	7.5	8.2	6.0	7.0	7.5	8.3

— not done

TABLE II—AMBIENT TEMPERATURE (°C)

Tide	Sampling Points	May 1970	July 1970	Sept. 1970	Nov. 1970	March 1971	May 1971
Average of Low Tide	1	30.5	31.0	31.0	22.0	27.0	32.0
	2	31.5	32.5	23.5	23.5	27.5	32.0
	3	31.0	31.0	31.5	23.5	29.0	32.0
	4	31.0	31.0	31.0	23.0	28.5	32.0
	5	30.5	31.0	31.5	23.0	27.0	32.0
	6	30.7	31.0	32.0	23.0	22.5	32.0
	7	31.5	31.0	31.5	23.5	27.5	32.0
	8	31.0	31.0	32.5	23.0	26.0	32.0
Zero or Slack Tide	1	—	27.0	—	—	36.5	31.0
	2	—	26.5	—	—	36.0	31.0
	3	31.0	27.0	—	—	35.0	31.0
	4	—	—	—	—	34.0	31.0
	5	—	—	—	—	34.0	31.0
	6	—	—	—	—	31.5	30.0
	7	31.5	26.0	—	—	35.0	31.0
	8	31.5	26.0	—	—	34.0	31.0
Average of High Tide	1	30.5	28.0	31.5	27.0	22.5	30.0
	2	31.5	28.0	33.0	28.0	22.5	29.5
	3	31.0	28.0	33.0	37.0	22.5	29.5
	4	31.0	27.5	32.0	29.5	22.5	29.5
	5	31.5	27.0	32.0	29.0	23.0	29.5
	6	32.0	27.5	32.0	29.0	22.5	29.5
	7	31.0	27.5	33.0	27.0	22.5	29.5
	8	31.0	28.0	32.0	28.0	23.5	30.0

TABLE III—WATER TEMPERATURE (°C)

Tide	Sampling Points	May 1970	July 1970	Sept. 1970	Nov. 1970	March 1971	May 1971
Average of Low Tide	1	32.0	29.0	30.5	23.5	27.5	34.0
	2	31.5	29.5	30.5	22.0	27.0	34.0
	3	31.5	—	30.5	23.5	27.5	35.5
	4	31.5	—	31.5	23.5	27.0	32.5
	5	31.0	—	30.5	22.0	27.5	32.0
	6	31.0	—	31.5	22.0	26.5	32.5
	7	31.5	—	30.5	22.5	27.0	32.5
	8	31.0	—	31.5	22.0	27.0	32.0
Zero or Slack Tide	1	—	30.5	—	—	27.5	32.5
	2	—	30.5	—	—	28.0	32.5
	3	32.0	30.5	—	—	27.0	34.0
	4	—	—	—	—	27.0	33.5
	5	—	—	—	—	26.0	32.0
	6	—	—	—	—	26.0	32.0
	7	32.0	30.5	—	—	27.0	33.0
	8	31.5	30.5	—	—	27.0	32.0
Average of High Tide	1	31.5	31.0	30.5	26.0	27.0	32.5
	2	31.5	31.0	30.5	25.5	26.5	32.0
	3	31.5	30.5	31.5	26.5	26.5	34.0
	4	31.5	31.0	30.5	26.0	26.0	31.0
	5	31.5	33.5	30.0	26.0	26.5	31.0
	6	31.5	33.5	30.0	26.0	26.5	31.0
	7	31.5	31.0	31.5	25.0	26.5	32.5
	8	31.0	31.0	30.5	25.0	26.5	31.5

— not done

TABLE IV—CHLORIDE AS Cl (mg/l)

Tide	Sampling Points	May 1970	July 1970	Sept. 1970	Nov. 1970	March 1971	May 1971
Average of Low Tide	1	39.0	8.7	2.0	3.0	40.0	56.0
	2	43.5	8.7	2.5	6.5	45.0	28.0
	3	21.0	14.9	6.0	12.5	52.0	15.0
	4	14.0	12.1	1.0	14.0	42.0	10.0
	5	22.0	10.0	1.0	16.5	39.0	9.0
	6	16.5	10.0	1.0	20.0	43.0	9.0
	7	23.0	10.0	1.0	5.0	30.0	9.0
	8	16.5	8.7	1.0	3.0	29.0	7.5
Zero or Slack Tide	1	—	6.9	—	—	36.0	13.0
	2	—	10.0	—	—	36.0	9.0
	3	34.0	19.1	—	—	28.0	23.0
	4	—	14.9	—	—	16.0	9.0
	5	—	10.0	—	—	28.0	8.0
	6	—	8.7	—	—	32.0	9.0
	7	27.0	8.7	—	—	30.0	14.0
	8	32.0	10.0	—	—	34.0	9.0
Average of High Tide	1	20.0	8.5	1.0	7.0	50.0	10.5
	2	19.5	12.0	1.0	7.0	34.0	8.5
	3	19.5	20.0	3.0	30.0	33.0	13.5
	4	21.5	25.0	5.0	2.0	32.0	10.5
	5	21.0	12.5	1.5	5.0	28.0	8.0
	6	19.5	9.4	2.0	4.0	37.0	9.5
	7	22.5	8.5	1.0	5.0	32.0	9.0
	8	25.0	10.0	1.0	3.0	31.0	8.5

— not done

TABLE V—ALKALINITY AS $CaCO_3$ (mg/l)

Tide	Sampling Points	May 1970	July 1970	Sept. 1970	Nov. 1970	March 1971	May 1971
Average of Low Tide	1	207.0	80.0	77.0	167.0	231.0	181.0
	2	220.0	80.0	82.0	186.0	244.0	165.0
	3	262.0	102.0	138.0	192.0	313.0	197.0
	4	247.0	90.0	134.0	329.0	262.0	185.0
	5	248.0	78.0	85.0	194.0	262.0	186.0
	6	248.0	84.0	81.0	198.0	288.0	184.0
	7	244.0	78.0	81.0	186.0	262.0	185.0
	8	246.0	78.0	81.0	209.0	262.0	190.0
Zero or Slack Tide	1	—	8.0	—	—	308.0	216.0
	2	—	78.0	—	—	262.0	202.0
	3	258.0	103.0	—	—	250.0	246.0
	4	—	106.0	—	—	260.0	182.0
	5	—	82.0	—	—	252.0	188.0
	6	—	80.0	—	—	262.0	186.0
	7	248.0	84.0	—	—	254.0	194.0
	8	246.0	74.0	—	—	248.0	188.0
Average of High Tide	1	250.0	50.0	85.0	208.0	266.0	200.0
	2	244.0	78.0	84.0	212.0	266.0	196.0
	3	253.0	83.0	92.0	204.0	252.0	232.0
	4	255.0	176.0	100.0	236.0	256.0	191.0
	5	252.0	88.0	96.0	192.0	257.0	183.0
	6	253.0	82.0	87.0	188.0	255.0	191.0
	7	257.0	70.0	86.0	192.0	246.0	187.0
	8	262.0	78.0	85.0	304.0	268.0	188.0

— not done

TABLE VI—PHOSPHATES AS PO_4 (mg/l)

Tide	Sampling Points	May 1970	July 1970	Sept. 1970	Nov. 1970	March 1971	May 1971
Average of Slack Tide	1	1.875	0	0.20	0	0	0.60
	2	1.750	0	0.15	0	0	0.25
	3	1.150	0	0.60	0	0	1.00
	4	0.35	0	0.40	0	0	0.20
	5	0.85	0	0.55	0	0.25	0.95
	6	2.20	0	0.65	0	0	0.20
	7	0.30	0	—	0	0	0.15
	8	0.45	0	0.35	0	0.10	0.20
Zero or Slack Tide	1	—	0	—	—	0	0.9
	2	—	0	—	—	0	0.6
	3	—	0	—	—	0	0.9
	4	—	0	—	—	0	0.4
	5	—	0	—	—	0.10	0.5
	6	—	0	—	—	0.10	0.5
	7	—	0	—	—	0	0.6
	8	—	0	—	—	0	0.4
Average of High Tide	1	0.50	0	0.30	—	0.35	0.55
	2	2.95	0	0.25	—	0	0.20
	3	1.37	0	0.30	—	0	1.30
	4	2.17	0	0.20	—	0.20	0
	5	1.75	0	0.15	—	0.20	0
	6	1.75	0	0.15	—	0.05	0
	7	0.65	0	0.30	—	0	0.35
	8	1.45	0	0.25	—	0	0.30

— not done

TABLE VII—TOTAL SOLIDS (mg/l)

Tide	Sampling Points	May 1970	July 1970	Sept. 1970	Nov. 1970	March 1971	May 1971
Average of Low Tide	1	729.0	1027.0	605.0	307.0	511.0	795.0
	2	557.0	975.0	644.0	357.0	528.0	1306.0
	3	581.0	1828.0	1009.0	891.0	691.0	839.0
	4	706.0	1392.0	953.0	1012.0	545.0	642.0
	5	817.0	1513.0	505.0	336.0	443.0	694.0
	6	522.0	1945.0	759.0	322.0	470.0	644.0
	7	432.0	1385.0	719.0	253.0	355.0	435.0
	8	652.0	1650.0	812.0	315.0	471.0	669.0
Zero or Slack Tide	1	—	1560.0	—	—	442.0	452.0
	2	—	570.0	—	—	448.0	374.0
	3	1883.0	689.0	—	—	532.0	651.0
	4	—	769.0	—	—	634.0	425.0
	5	—	806.0	—	—	576.0	395.0
	6	—	684.0	—	—	422.0	344.0
	7	1026.0	649.0	—	—	440.0	429.0
	8	430.0	606.0	—	—	512.0	357.0
Average of High Tide	1	410.0	726.0	600.0	396.0	504.0	493.0
	2	1196.0	744.0	580.0	406.0	478.0	546.0
	3	2406.0	1043.0	674.0	995.0	578.0	977.0
	4	1557.0	1034.0	703.0	464.0	615.0	648 0
	5	1453.0	978.0	578.0	161.0	642.0	724.0
	6	1433.0	1610.0	580.0	174.0	568.0	572.0
	7	1808.0	728.0	574.0	307.0	660.0	684.0
	8	1580.0	1250.0	695.0	275.0	716.0	832.0

—Not done

TABLE VIII—SUSPENDED SOLIDS (mg/l)

Tide	Sampling Points	May 1970	July 1970	Sept. 1970	Nov. 1970	March 1971	May 1971
Average of Low Tide	1	239.0	815.0	495.0	90.0	114.0	251.0
	2	312.0	770.0	436.0	141.0	318.0	964.0
	3	422.0	1591.0	602.0	85.0	271.0	532.0
	4	284.0	284.0	1151.0	631.0	524.0	244.0
	5	537.0	1354.0	331.0	89.0	190.0	420.0
	6	247.0	1774.0	598.0	118.0	281.0	427.0
	7	285.0	1190.0	554.0	65.0	207.0	213.0
	8	365.0	1454.0	663.0	155.0	240.0	463.0
Zero or Slack Tide	1	—	1345.0	—	—	130.0	139.0
	2	—	362.0	—	—	322.0	147.0
	3	1579.0	447.0	—	—	478.0	309.0
	4	—	559.0	—	—	332.0	192.0
	5	—	615.0	—	—	334.0	160.0
	6	—	528.0	—	—	370.0	99.0
	7	848.0	429.0	—	—	136.0	169.0
	8	146.0	396.0	—	—	334.0	67.0
Average of High Tide	1	186.0	535.0	418.0	321.0	187.0	198.0
	2	886.0	563.0	424.0	171.0	164.0	316.0
	3	1973.0	653.0	513.0	311.0	263.0	665.0
	4	1197.0	744.0	451.0	162.0	365.0	400.0
	5	1185.0	773.0	408.0	6.0	341.0	488.0
	6	1174.0	1391.0	426.0	33.0	424.0	337.0
	7	1567.0	588.0	401.0	132.0	358.0	466.0
	8	1101.0	1070.0	560.0	117.0	444.0	594.0

TABLE IX—LIGNIN (mg/l)

Tide	Sampling Points	May 1970	July 1970	Sept. 1970	Nov. 1970	March 1971	May 1971
Average of Low Tide	1	0.09	—	0.70	tr	tr	tr
	2	0.08	—	0.60	0.01	"	"
	3	0.09	0	4.00	0.02	"	0.02
	4	0.15	0	2.50	0.04	"	tr
	5	0.10	0	0.75	0.01	"	0.01
	6	0.11	—	0.70	0.01	"	tr
	7	0.09	0.19	0.80	tr	"	"
	8	0.08	0.10	0.70	"	"	"
Zero or Slack Tide	1	0	—	—	—	tr	tr
	2	0	—	—	—	"	"
	3	0.12	—	—	—	"	"
	4	0	0.40	—	—	"	"
	5	0	—	—	—	"	"
	6	0	—	—	—	"	"
	7	0.09	0.10	—	—	"	0.03
	8	0.09	0.8	—	—	"	tr
Average of High Tide	1	0.10	0.10	1.10	0.04	0.02	tr
	2	0.09	0.10	0.50	0.03	0.02	"
	3	0.48	0.30	1.60	0.06	tr	0.08
	4	0.09	—	2.00	0.03	"	tr
	5	0.10	1.30	0.75	tr	"	"
	6	0.08	—	0.70	"	"	"
	7	0.10	0.64	0.60	"	"	"
	8	0.11	0.30	0.45	"	"	"

— not done

tr = traces

pH

The pH range varied between 5.4 and 8.7. All throughout the season the estuarine water was observed to be alkaline except at the fag end of the monsoon period (Sept., 1970) when pH was observed to be acidic (5.4 to 6.5) at all stations irrespective of the tides. The addition of wastewater from this factory brought about slight change in the pH value.

Temperature

The variation in ambient temperature was between 22.5 and 36.5°C and that in water temperature between 22 and 35.5°C, on an average. Except for the month of September, all throughout the year the temperature of the estuarine water at the bank side was higher by about 2.0 to 2.5°C than at the mid-width of the estuary.

Chloride (as Cl)

The chloride (as Cl) content varied between 1.0 and 56.0 mg/l at the bank side and ranged between 1.0 and 34.0 mg/l at the centre of the estuary. The high values of chloride at low tide condition at the sampling point 1, when compared with the values at the centre, indicated the possibilities of existence of a sewage outlet around the sampling point. Tidal influence at this point was quite evident but rise in the chloride content owing to saline water intrusion from the sea seemed insignificant in this area.

Alkalinity (as $CaCO_3$)

Total alkalinity (as $CaCO_3$) ranged between 50.0 and 329.0 mg/l. Except during July-September, 1970, alkalinity values were observed to be higher. This variation may be due to the monsoon conditions which normally exist during July-September every year.

Phosphates (as PO_4)

The range of values of total phosphates was from 0 to 2.95 mg/l. Most of the times, the phosphate values near the bank side were higher than the values observed at the centre of the estuary irrespective of the different tide conditions.

Total Solids

The total solids were observed to be between 253.0 and 1945.0 mg/l during slack and low tide conditions and the values were between 161.0 and 2406.0 mg/l during high tide conditions.

Suspended Solids

A good fraction of the solids present in the estuarine water was in suspended form. Part of these were in colloidal form and it took long time to settle. The range of the suspended solids was from 6.0 to 1973 mg/l. Physical inspection of this area revealed foam and froth all throughout between the sampling stations 1 and 7 and the condition of this dangling floating matter disturbed the aesthetic sense of the water users in this area.

Colour

In addition to the floating froth and foam throughout the bank, it was also observed that the estuarine water became highly coloured owing to the discharges from this factory. The colour imparted was mainly due to release of dilute black spent liquor and various dyes used in the paper making.

Lignin

The lignin values are reported in Table IX. In the month of September, estuarine water exhibited highest concentration of lignin. As compared to this, lignin was found in traces most of the time during March-May, 1971. How much of the lignin present during May-September is attributable to the tissue mill waste remains an open issue for further investigation. But it would not be unrealistic to assume that at least a part of the lignin present in estuarine water during May to September has its source in flood water, which may contain naturally occurring substances like lignin (and phosphate compounds). Nevertheless, it seems true that certain amount of lignin is going out with wastewater despite many steps of washings and recovery, and causing increment to the natural lignin, if any. It is, therefore, desirable to limit this constituent at the outlets to barest minimum for ecological reasons.

Oxidised Nitrogen

The average values, at different tide conditions, of nitrites (NO_2) and nitrates (NO_3) are given in Tables X and XI respectively.

Except during May, 1970, nitrites were most of the time either absent or present in trace quantities. In contrast to this, nitrates were present appreciably in estuarine water. NO_3 values at the centre were in the range of 0—0.54 mg/l as compared to 0—0.90 mg/l near the bank.

With the observed DO levels, the presence of NO_2 and NO_3 in this estuarine water near right bank is quite realistic, but the occurrence of low NO_3 at the centre of the estuary despite moderate (average) DO values, is difficult to account.

Dissolved Oxygen (DO)

The average DO levels in the selected points of this estuary at low, high and slack tides are shown in Table XII. The distribution of DO in the area is not same at high water as at low water. This warranted a condition where it is necessary to reduce all the data to a common basis. The best method would have been to adjust all the positions at which the samples were taken to the positions which the same bodies of water would have occupied at half tide. But the available data were rather insignificant for this purpose. Hence, only a casual picture could be obtained from the estimations.

The DO near the bank varied between 1.0 and 7.3 mg/l and that at the centre of the estuary between 4.3 and 7.4 mg/l. No regular pattern in DO values was observed either at high or at low tide conditions. However, the data did reveal that the DO near the sampling point 3 was the lowest. On the basis of yearly average, the value comes to be about 4.26 mg/l despite mixing with high volume of water. Lowest DO was observed to be equal to 1.0 mg/l during November, 1970, near the sampling point 3. The solubilities of oxygen, at the available temperature and salinity were low in the entire sampling region.

TABLE X—NITRITE AS N (mg/l)

Tide	Sampling Points	May 1970	July 1970	Sept. 1970	Nov. 1970	March 1971	May 1971
Average of Low Tide	1	0.03	tr	0	0	0	tr
	2	0.02	„	0	0.05	0	„
	3	0.02	0.04	0	0	0	„
	4	0.03	tr	0	0.04	0	„
	5	0.04	„	0	0	0	„
	6	0.04	„	0	0	0	„
	7	0.02	„	0	0.34	0	„
	8	0.04	„	0	0.35	0	„
Zero or Slack Tide	1	—	tr	—	—	0	tr
	2	—	„	—	—	0	„
	3	0.06	0	—	—	0	„
	4	—	0	—	—	0	„
	5	—	0	—	—	0	„
	6	—	0	—	—	0	„
	7	0.04	0	—	—	0	„
	8	0.04	0	—	—	0	„
Average of High Tide	1	0.04	0.01	0	0	0	tr
	2	0.05	tr	0	0	0	„
	3	0.03	„	0	0	0	„
	4	0.04	„	0	0	0	„
	5	0.03	„	0	0	0	„
	6	0.04	„	0	0	0	„
	7	0.04	„	0	0	0	„
	8	0.04	„	0	0.07	0	„

— not done tr = traces

TABLE XI—NITRATE AS N (mg/l)

Tide	Sampling Points	May 1970	July 1970	Sept. 1970	Nov. 1970	March 1971	May 1971
Average of Low Tide	1	0.04	0.44	0.24	0.08	0	0.08
	2	0.00	0.57	0.22	0.06	0.10	0.06
	3	0.05	0.50	0.23	0.33	0.02	0.08
	4	0.01	0.28	0.21	—	0.10	0.07
	5	0.04	0.55	0.22	0.15	0.03	0.02
	6	0.00	0.42	0.30	0.12	0.03	0.08
	7	0.03	0.24	0.34	0.12	0	0.09
	8	0.05	0.54	0.23	0.12	0.12	0.03
Zero or Slack Tide	1	—	0.37	—	—	0	0.08
	2	—	0.43	—	—	0	0.65
	3	0.06	0.10	—	—	0	0.90
	4	—	0.29	—	—	0.02	0.06
	5	—	0.14	—	—	0.02	0.05
	6	—	0.29	—	—	0.03	0.38
	7	0.00	0.37	—	—	0.03	0.18
	8	0.00	0.34	—	—	0	0.06
Average of High Tide	1	0.00	0.44	0.31	0.28	0.01	0.17
	2	0.04	0.30	0.25	—	0.10	0.27
	3	0.11	0.43	0.19	—	0.03	0.19
	4	0.00	0.35	0.15	0.54	0.04	0.33
	5	0.53	0.21	0.21	0.12	0.05	0.06
	6	0.07	0.47	0.21	0.12	0.05	0.06
	7	0.15	0.21	0.24	0.24	0.24	0.04
	8	0.10	0.38	0.22	0.18	0.06	0.08

— not done

TABLE XII—DISSOLVED OXYGEN (mg/l)

Tide	Sampling Points	May 1970	July 1970	Sept. 1970	Nov. 1970	March 1971	May 1971
Average of Low Tide	1	4.6	4.6	5.6	6.7	6.0	4.0
	2	4.7	5.2	5.5	7.0	5.6	5.2
	3	3.0	4.9	3.9	3.4	5.6	4.4
	4	4.0	5.1	5.5	3.7	5.2	5.2
	5	3.6	5.4	5.4	7.0	5.6	5.5
	6	4.4	5.5	5.8	7.1	5.6	5.6
	7	5.0	5.3	5.1	7.0	6.3	5.7
	8	5.2	5.2	5.4	7.4	6.0	5.9
Zero or Slack Tide	1	—	5.2	—	—	6.4	4.2
	2	—	5.3	—	—	6.6	4.7
	3	4.3	5.3	—	—	6.7	3.7
	4	—	5.4	—	—	6.7	4.8
	5	—	5.3	—	—	7.1	4.7
	6	—	5.4	—	—	6.9	4.8
	7	4.2	5.0	—	—	7.0	4.4
	8	4.3	5.2	—	—	7.2	4.4
Average of High Tide	1	4.1	5.4	6.0	4.9	6.0	4.4
	2	4.4	5.2	6.0	4.7	5.5	4.9
	3	4.1	4.9	5.5	1.0	6.0	4.5
	4	4.6	5.2	5.4	5.1	6.4	5.1
	5	4.4	5.3	5.7	7.2	6.6	5.2
	6	4.5	5.3	5.8	7.3	6.3	5.2
	7	4.3	5.1	6.0	7.1	6.5	5.1
	8	4.3	5.5	6.0	7.4	6.5	4.9

— not done

Chemical Oxygen Demand (COD)

The average values of low and high tide as well as at slack tide are given in Table XIII.

COD values at the centre of the estuary were observed to vary between 5.0 and 51.5 mg/l. In contrast to this, COD values near the right bank were from 7.5 to 320.0 mg/l.

Further, the data also revealed that COD values were generally highest during September-November, 1970 and lowest during July, 1970.

Biochemical Oxygen Demand (BOD)

The average values of BOD at low and high tides are given in Table XIV. It can be said that the values (irrespective of tides) varied between 0 to 1.0 mg/l at the centre all throughout the year except during September, 1970 when the BOD values rose to 2.6 mg/l and 6.5 mg/l at low and high tide conditions respectively. In contrast, the BOD values at the points 1 to 7 near the right bank of the estuary were high all throughout, especially near sampling points 4 and 5. In September-November, 1970, the average BOD in heavily polluted reach of the estuary was of the order of 68.0 to 70.0 mg/l, almost equivalent to BOD of weak raw sewage.

(b) Bottom Mud

During the earlier course of the survey, gas bubbles were emitted from locations near the sampling points 1, 2 and 3. The emission and its break-down at the water air interface prompted probe into the bottom mud conditions.

The mud samples collected subsequently from the sampling stations 1 to 6 were analysed for organic carbon and nitrogen fraction The results are given in Table XV.

TABLE XIII—COD (mg/l)

Tide	Sampling Points	May 1970	July 1970	Sept. 1970	Nov. 1970	March 1971	May 1971
Average of Low Tide	1	42.8	16.8	80.0	14.5	12.0	70.0
	2	39.0	11.8	46.0	39.0	9.5	59.0
	3	33.0	35.2	214.0	197.0	79.5	111.0
	4	40.5	27.6	102.0	76.5	43.5	40.5
	5	22.5	26.7	38.5	24.0	24.5	30.0
	6	22.5	23.7	35.0	10.0	18.5	20.0
	7	39.5	15.8	37.5	26.0	7.5	18.0
	8	24.5	21.7	21.0	5.0	11.0	45.0
Zero or Slack Tide	1	—	10.0	—	—	14.7	34.0
	2	—	12.8	—	—	9.2	11.4
	3	53.0	57.3	—	—	20.2	—
	4	—	19.8	—	—	24.8	5.0
	5	—	12.8	—	—	11.0	8.0
	6	—	14.8	—	—	13.8	20.0
	7	12.0	10.0	—	—	12.8	70.0
	8	9.0	12.8	—	—	6.4	7.0
Average of High Tide	1	32.0	13.6	29.0	—	43.5	32.5
	2	30.5	13.5	26.0	49.0	35.5	41.5
	3	51.0	43.5	79.0	320.0	12.0	155.0
	4	40.0	64.5	94.0	68.0	24.5	39.5
	5	38.0	20.0	33.0	10.0	11.0	42.0
	6	26.5	17.5	28.0	20.0	17.0	27.0
	7	30.5	12.5	40.5	50.0	15.0	22.0
	8	51.5	14.5	41.0	10.0	16.5	17.0

— not done

TABLE XIV—BOD (mg/l)

Tide	Sampling Points	May 1970	July 1970	Sept. 1970	Nov. 1970	March 1971	May 1971
Average of Low Tide	1	1.6	—	6.5	1.8	4.5	10.8
	2	1.2	—	6.8	3.3	2.7	2.7
	3	1.7	5.0	15.0	40.0	5.8	10.5
	4	6.0	5.5	5.8	15.5	8.1	3.0
	5	1.5	0.3	2.8	2.8	4.8	1.5
	6	2.0	3.5	3.0	2.5	2.8	1.2
	7	0.6	—	6.5	1.0	0.5	5.6
	8	0.5	—	2.6	1.0	0.8	1.2
Zero or Slack Tide	1	—	0.3	—	—	3.2	5.6
	2	—	0.4	—	—	2.8	2.6
	3	4.5	0.65	—	—	2.4	80.0
	4	—	1.8	—	—	4.0	68.0
	5	—	1.3	—	—	1.6	1.3
	6	—	1.3	—	—	2.6	1.2
	7	0.7	5.0	—	—	1.3	15.6
	8	0.0	0.5	—	—	0.7	1.0
Average of High Tide	1	3.0	0.65	5.6	4.7	13.7	4.9
	2	3.0	0	6.6	4.7	16.6	4.6
	3	4.0	4.5	68.0	64.0	2.45	15.5
	4	0.6	3.0	70.0	15.0	1.0	2.6
	5	1.3	2.1	36.0	1.5	1.5	1.2
	6	1.5	1.2	6.9	2.0	5.6	1.0
	7	1.0	0.7	7.1	2.7	6.1	0.8
	8	0.7	0	6.5	1.0	0.6	1.0

— not done

TABLE XV—ANALYSIS OF BOTTOM SEDIMENTS

Item	Date of Sampling	Sampling Points					
		1	2	3	4	5	6
Organic Carbon (%)	Nov., 1970	0.39	0.75	0.24	0.51	0.12	0.51
N (%)		0.0336	0.0336	0.112	0.1008	0.112	0.1008
C/N ratio		11.61	22.32	2.14	5.05	1.07	5.06
Organic Carbon (%)	May, 1971	0.51	0.315	0.375	0.36	0.375	0.406
N (%)		0.112	0.28	0.056	0.056	0.056	0.29
C/N ratio		4.554	1.125	6.696	6.429	6.96	1.39

Mud sampling with Ekman dredge were not possible at the sampling stations 7 and 8 owing to the high velocity and the depth of water. Further, it was physically observed that at all points between 1 and 6 (except 5), the bed of the estuary consisted mainly of mud with lot of fine clay.

As is well known, the highest proportions of organic matter in an estuarine system are generally found in those bottom deposits which contain the greatest amounts of fine clay particles. The values obtained revealed that C/N ratios were higher at sampling points 1 and 2 during November, 1970 than in May, 1971. These data are, of course, quite inadequate for any conclusion though it gives some basic information about C/N ratio of this area.

Discussion

The study on the discharge of effluents to the nearby flowing Hooghly estuary presented complex problems because of fluctuating nature of water quality daily, seasonally and geographically, within the estuary. The physico-chemical conditions of the environment was usually fluctuating and frequently of unexpected nature. The ability of this estuary to dilute and disperse the pollutants in this area seems unpredictable.

Critical observations of the condition of the estuary in and around Tribeni Tissues discharge points revealed that the entire region was aesthetically not of pleasing nature. Floating debris, scum and other matter which are liable to produce undesirable odour, objectionable colour and bad taste were present in perceptible concentrations The protection of aesthetic values has an important role in water quality management. The remedial measures to protect the aesthetic quality should, therefore, get due place. This points out that adequate treatment of trade effluents from this factory need to be done before these are let out to the adjoining oscillating water regime.

The data obtained on DO, COD and BOD estimations are quite dispersed. An interesting picture emerges out if all the available data on these estimations are condensed by average values, irrespective of low or high tide conditions. The data are plotted in the form of qualigrams (Fig. 3). It is apparent that at the centre of the estuary (sampling point 8), opposite to the sampling point 3, the values of DO, COD and BOD were 5.8 mg/l, 23.0 mg/l and 1.6 mg/l respectively. In contrast to this, DO, COD and BOD values at the points 1 to 6 near the bank were in the range of 4.2 to 5.7 mg/l, 22.0 to 114.0 mg/l and 3.0 to 20.0 mg/l respectively. At the sampling point 7 which is about 15 m away from the bank, the corresponding values were 5.7 mg/l, 26.0 mg/l and 3.0 mg/l respectively. Extreme pollutional conditions were seen near the sampling points 3 and 4 where the values of COD were to the extent of 114.0 mg/l and 55.0 mg/l, and BOD values were 20.0 mg/l and 11.0 mg/l respectively, despite high dilution of the waste by the estuarine water. The condition, however, improved at the northern and the southern points to some extent but never to the comfortable limits.

To examine the DO values more precisely it is necessary to know the standard of the water quality criteria of estuarine water. In absence of any Indian Standards on this point, this precise examination becomes arbitrary. However, it is pertinent to mention here that the Federal Water Pollution Control Administration (U.S.A.) recommended the following DO values to be the criteria for coastal and estuarine water.

"(i) Surface DO concentrations in coastal waters shall not be less than 5 mg/l except when natural phenomena cause this value to be depressed.

(ii) Dissolved oxygen concentration in estuaries and tidal tributaries shall not be less than 4.0 mg/l at any time or place except in dystropic water or where natural conditions cause this value to be depressed."

If these values are taken as the criteria the level of DO was almost near the threshold. This is unsatisfactory. From Indian Standards point of view, what is true of DO is also true of BOD and COD values. Both BOD and COD values, as could be seen from the accompanying qualigrams, were high throughout the year, the maximum being at the sampling points 3 and 4. It is also interesting to note from the Tables XIII and XIV that both COD and BOD values were higher most of the time during high tide conditions. The following may be the reasons: (i) During high tide condition, there is a greater scouring of bottom mud which

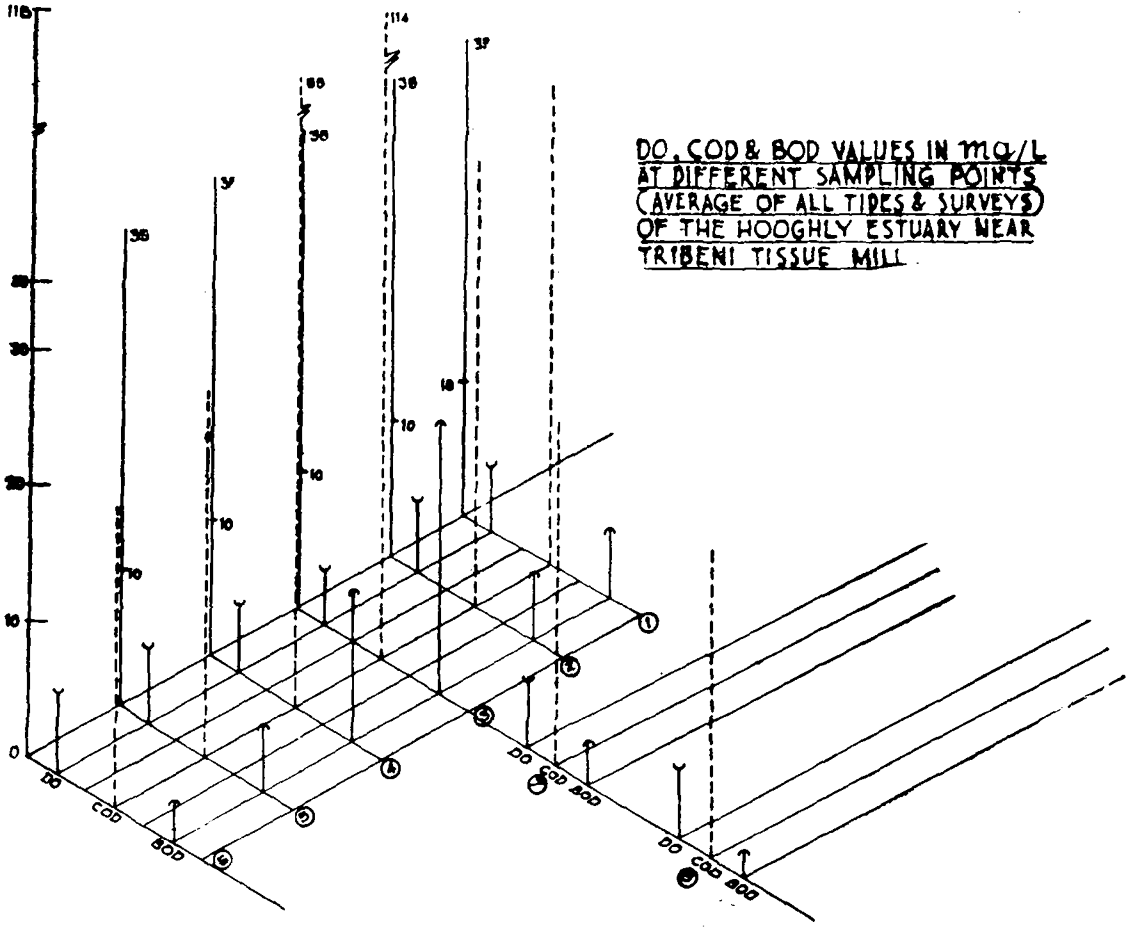

Fig. 3

contributes to the COD or BOD demands; (ii) It may be due to concentration of left over BOD or COD which moves from one place to another with the oscillating water; (iii) The BOD-COD load contributed by industrial wastes and surface drainage discharges beyond the sampling point 6 is brought back to this region by the ingress of high volume of water at high tide condition; (iv) It could be due to the combined actions of either or two or all of the above possibilities.

Conclusions

The data on physico-chemical analysis of the Hooghly estuarine water near M/s Tribeni Tissues Ltd. revealed that the water near the right bank is not of desirable quality despite high dilution. However, the flow pattern, tidal mixing, current distribution and volume of the estuarine water are such that the pollution does not travel to the central reach of the estuary and it limits itself only to the right bank region.

To minimise the pollutional effects in the estuary, it is necessary to treat the trade effluents before these are let out to the Hooghly. Waste treatment methods need be directed particularly towards reducing suspended solids, BOD, COD, etc.

Acknowledgements

The authors are thankful to the management of the Tribeni Tissues Ltd. for extending all facilities in carrying out the work.

DISCUSSION

Shri A. G. Pandit (Bombay): What was the method of sampling used (frequency with reference to tide conditions)? Whether the sampling was carried out at various depths? What was the particular parameter used to know whether there was flushing of the estuarine water or only the oscillation of the water mass?

Dr. A. K. Basu: There are normally two high tides and two low tides during 24 hr period. As sampling was round-the-clock, at an interval of two hr, we took samples both at two high and two low tide conditions. As regards sampling at various depths, I would like to mention that the Hooghly is considered to be a vertically homogeneous estuary. Hence sampling at different depths was not considered necessary.

Further, the work done by the Port Commissioner of Calcutta and other allied organisations goes to establish that the upland flow exists mostly during monsoon period and about 3/4th of the year fresh water upland flow is almost non-existent. Hence what we see as high tide and low tide water is actually the bulk of the oscillating water and this causes poor flushing thereby causing concern from pollution point of view.

Dr. G. K. Seth (Nagpur): I would like to support the studies that have been carried out by Dr. Basu in regard to the pattern of spread of pollution in the Hooghly river. Although our studies were carried out about 22 years ago, still in general, pattern remains the same. The studies carried out in 1950 related to Paper Mill and Shellac industries, and not to the Tissue Mill waste.

Dr. A. K. Basu: Dr. Seth's comment about their work is noted. I would agree that even though general pattern of studies continue to be same yet during last twenty years the pollutional effecs have started being felt, at least in some restricted areas. The flora and fauna of the bottom muds as well as the biology of water have indicated deterioration. The physico-chemical conditions of estuarine water has also become worse in some localised pockets.

Dr. H. S. Vasisht: Has the absence of stratification been investigated in Hooghly estuary? How is that the results obtained with an interval of twenty years are more or less identical particularly when many more industries have come into being during this span?

Dr. A. K. Basu: Absence of stratification has been investigated by the Calcutta Port Commissioner's Office. While at Central Inland Fisheries Research Institute, I have also undertaken some studies and it was found that stratification did not exist. The other question has already been answered above.

Dr. T. J. Boman (Baroda): Whether dissolved oxygen was determined on-the-spot? There were 8 points from where 24 hr samples were drawn to make composite samples. Whether all these samples were proportionate?

Dr. A. K. Basu: All the DO tests were done on-the-spot as referred to in the text. There was no question of compositing the samples from the 8 sampling sites during 24 hr sample collection period. All that we could do was to collect samples from 8 of these sampling points at each of the low and high tide conditions during 24 hr sampling period and analyse them for various parameters as indicated. The sampling proportionate to flow is possible only if we are dealing with industrial wastewater collection. As we were doing work only with the river water it was almost impossible to sample in proportion to the flow of the estuary.

Prof. S. V. Patwardhan (Roorkee): What treatment is given by the industry? What is the particle size of suspension? Whether data on biological life was collected to correlate the physico-chemical data?

Dr. A. K. Basu: As far as we know, none of the factories are giving any treatment whatsoever to their wastewater. Particle size of suspension was not determined. Data on biological life was also not collected.

Shri V. Raman (Bombay): Hooghly estuary during non-monsoon period does not receive more of fresh water inflow than Thana creek near Bombay which has the same characteristics. In contrast to Hooghly estuary, the central portion of Thana creek water is polluted as shown by BOD values varying from 15 to 50 mg/l and DO varying from 3 to 4.2 mg/l.

The author may explain why the pollution does not travel to the middle of Hooghly estuary? Is it because of power diffusion characteristics of the estuary? Or, is there some channeling effect of the effluent in the estuary?

Dr. A. K. Basu: In current work, no detailed study in these respects has been attempted. But the present study did show that the pollution does not travel upto the centre of the estuary and the effects are confined only towards the right bank of the estuary. It is possible that the mixing and dilution of waste discharged by estuarine water are complete and adequate and by the time a part of the wastewater goes to centre, no effect is visible.

PROC. SYMP. ON ENVIRONMENTAL POLLUTION (1973)

Some Aspects of the Biochemical Assessment of Water Pollution

J. J. GHOSH,* A. K. BHATTACHARYYA* and D. SARKAR*

The paper presents investigations on the assessment of water environment in terms of biochemical changes in the metabolic activity of fish induced by different concentrations of insecticides, and other well-known pollutants. It has been found that certain enzymes like acetylcholinesterase, Mg-activated ATPase, Na-K-activated ATPase, and purine nucleotide catabolizing enzymes of brain and liver tissues of fish are very susceptible to inhibition in presence of different toxic chemicals. Similar studies, although preliminary in nature, have been conducted on the effects of different insecticides and pesticides on the oxidative metabolism and purine nucleotide metabolism of eggs and larvae of different fishes.

The observations are discussed in relation to their importance in the biochemical assessment of water pollution.

Introduction

It is well-documented that inland and coastal waters are subject to pollutions from two different sources *viz*., (i) organic materials like faecal matter, sewage, fertilizers, etc., and (ii) industrial wastes containing several types of corrosive chemicals, heavy metals, pesticides etc. The natural organic pollutants and non-toxic inorganic salts, if adequately diluted, are known to have beneficial effects on the biological productivity. On the other hand, pollution from industrial wastes poses a serious problem not only by adversely affecting the adequate food chain system but also by contaminating the fish population which constitute a source of immediate human health hazard. The industrial wastes exert their toxic effects on fish populations by depleting the dissolved oxygen in water, by changing the CO_2 content, by altering the pH, salinity, etc. and thereby directly or indirectly affecting the life cycle as well as the metabolic activity of fish at the biochemical level. The present paper is concerned with investigations on the assessment of aquatic environment in terms of biochemical changes in the metabolic activity of fish induced by different concentrations of insecticides and surfactants.

Materials and Methods

Two major varieties of fish *viz* Rohu and Carp, 10 to 14 cm long, were used in this study. The fishes were kept in glass aquaria with running recirculated distilled water at 30°C. The experimental group contained the different chemical agents in appropriate concentrations. The control group was placed in identical conditions except addition of chemical agents.

After 48 hr of exposure, the fishes were collected by hand nets and were killed, first by dashing against the ground followed by decapitation. The gills were cut out, collected, washed with water and then homogenized in isotonic sucrose media at 0° to 2°C. The homogenization was done in a waring blender. The homogenate was squeezed through a gauze cloth. The filtered, crude homogenate was centrifuged at 12,000 g for

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* Department of Biochemistry, Calcutta University, Calcutta

TABLE I—ENZYMATIC ACTIVITIES IN MICROSOMAL FRACTIONS OF GILLS OF FISH EXPOSED TO WATER CONTAINING DIFFERENT INSECTICIDES AND SURFACTANTS.*

Sr. No.	Additions	Final concentration in circulating water	% Inhibition (—) or stimulation (+) with reference to control		
			Mg^{++}-ATPase	$Na^{+}K^{+}$ -ATPase	Chloinesterase
1.	DDT	5 μM	—40	—17	—25
		10 μM	—70	—32	—58
2.	Lindane	5 μM	—38	—8	—22
		10 μM	—55	—20	—37
3.	Na-lauryl sulphate	2 μM	—25	—15	+7
		5 μM	—65	—35	—3
4.	Na-desoxycholate	2 μM	—25	—13	—5
		5 μM	—53	—22	—7

* Based on three separate experiments.

45 min. to remove cell debris, nuclei and mitochondrial fractions. The supernatant was further centrifuged at 90,000 g for 1 hr and the sediment known as microsomal fraction was resuspended and homogenized in ice-cold isotonic sucrose solutions. Samples of microsomal suspensions were used for enzyme assay.

ATPase activities were determined by the procedure developed by Skou (1). Total activity was measured in presence of Mg^{++} Na^{+} and K^{+} ions in the reaction mixture. Mg^{++} —ATPase activity was measured in presence of added Mg^{++} ions only. Na^{+}—K^{+} —ATPase activity is the total ATPase activity *minus* Mg^{++}–ATPase activity. Cholinesterase activity was measured by using acetylthiocholine as substrate, according to the method of Ellman *et al.* (2)

Results and Conclusions

From the data shown in Table I, it will be evident that Mg^{++} —ATPase, Na^{+}—K^{+}—ATPase and cholinesterase activities in the gills of both the varieties of fishes examined were found to be inhibited by DDT and Lindane. The exposure to lauryl sulphate as well as to desoxycholate, on the other-hand, produced a significant inhibitory effect on the Na^{+}--K^{+} —ATPase activity in the gill tissue whereas cholinesterase activity was not affected by these two surfactants.

In view of the involvement of ATPase and cholinesterase activities in the ion transport and other important active transport processes in fish tissues, the observed inhibitory effects of pesticides and surfactants on these enzymes in gills of fish may serve as a measure for preliminary assessment or monitoring of the extent of water pollution in rivers or lakes.

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DISCUSSION

Dr. A. V. S. Prabhakar Rao: The detoxifying enzymes are the transaminase enzymes. Why was ATPase chosen? Was there any study on the water soluble toxins?

Prof. J. J. Ghosh: The transaminase is not included in the list of detoxifying enzymes. It is a catabolic enzyme concerned with the utilization of aminoacids. ATPase is a membrane bound enzyme and is easily susceptible to toxins because of membrane disruption. No studies were done with water soluble toxins.

Dr. T. R. Bhaskaran: A change in plankton concentration has been observed in different seasons. How far this is due to (i) industrial wastes and (ii) season?

Prof. J. J. Ghosh: To know the relative effects, proper control experiments need to be done.

Dr. (Smt.) S. M. Vachha (Poona): Does fish develop resistance to various synthetic chemicals, DDT and other pesticides? Please state if any studies in the past 15 to 20 years have been done in this area in India.

Prof. J. J. Ghosh: My information in this matter is inadequate. I think some systematic studies in this line are desirable.

Dr. N. U. Rao (Nagpur): One of the studies showed that only lipid-soluble pollutants can enter the tissue cells. Does it mean that all the water soluble pollutants cannot enter fish cells?

Prof. J. J. Ghosh: Lipid soluble pollutants are more toxic because they stick to the tissue and become persistent. Water soluble pollutants are easily detoxified and hence less dangerous.

Dr. W. M. Deshpande (Nagpur): Kindly clarify whether the rate of lipid metabolism is slower in fishes?

Prof. J. J. Ghosh: I do not know.

Dr. K. P. Krishnamoorthi: How far the laboratory experiments on bioassay are applicable in the field?

Prof. J. J. Ghosh: The laboratory experiments on bioassay give us the results in controlled conditions; whereas field study results do not give such data.

Shri K. Mohan (New Delhi): Were the toxic DDT concentrations of 2 mg/l and 10 mg/l in birds determined in surviving specimen or dead? What is the maximum DDT concentration that the surviving organisms could withstand?

Prof. J. J. Ghosh: The concentrations of DDT shown to accumulate in birds may not be fatal but these concentrations may upset the normal metabolic activity. The maximum lethal concentrations of DDT has been found to vary from species to species.

Shri B. N. Patil (Nasik): Which species of fish have you used in your experiments? There are many species of fishes with different resistivity towards the attack of chemicals. Can some aquatic plant species be substituted to fishes as a standard to evaluate water quality? Just like fins of the fish, leaves of the plants like *Mimosa pudica* are quite sensitive.

Prof. J. J. Ghosh: We used Carp and Rohu varieties for the present study. Plant species can also be used.

PROC. SYMP. ON ENVIRONMENTAL POLLUTION (1973)

A Short Term Study on the Eutrophication of Gomti River in Lucknow Region

H. C. ARORA,+ S. N. CHATTOPADHAYA,+ V. P. SHARMA,+
TAPAN ROUTH + and S. I. ELYAS*

A survey was conducted on the river Gomti, near Lucknow Region during the summer months of 1971. The survey covered a stretch of about 85 km and physico-chemical and biological quality of the river water from 11 selected points is presented in the paper. It was seen that about 40 mgd (approx.) of sewage and industrial wastes find its way into the river through 17 nallahs. Self purification capacity of the river was 2.5 which was a clear indication of pollution. Chemical tests could not give a clear picture of pollution status of the river but biological indicators like MPN, coliforms, molluscs and sludge worms population clearly showed pollution. The recovery of the river is not complete even after a flow of 65 km.

Treatment of the effluents discharged into river has been suggested to mitigate pollution and to keep the river clean and useful.

Introduction

River Gomti originates from a village called Madho-Tanda, about 35 km from Pilibhit. The source of the river is the overflow of a pond which is fed by natural aqueducts. The pond has religious significance and has a temple on its brim. The river begins with a small stream as usual and during the course of its travel receives several tributaries till at Mohammadi, about 100 km from its origin, it is a full-fledged river. It travels a total stretch of about a thousand km before it ultimately joins the Ganga river at Varanasi. Its terrain is mostly smooth, bottom being of sand or clay. The major towns located along its course of a thousand km are, Lucknow, Sultanpur and Jaunpur. However, among the three, Lucknow is the most populous, industrialised and urbanised city. It is, therefore, the biggest subscriber of pollution to the river. There is a host of open wastewater carrying nallas (mostly domestic wastes) which end up into the river.

River Gomti is used for bathing and other recreational purposes like boating, picnicking, fishing, etc., apart from being the source of raw water for Lucknow city. The sight of various open nallas discharging into the river and grossly contaminating it, is highly repulsive and mars the beauty of this historical city of tourist attraction. It is unfortunate that in the present times of awakening towards environmental pollution control, such a situation should be existing, especially when foreign tourists visit this city in large numbers.

The objective of the study incorporated in this paper was to evaluate the extent of eutrophication, the river is subjected to. A short term survey of the river in Lucknow region was, therefore, carried out during the summer months of March-June, 1971. It

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+CPHERI Zonal Laboratory, 633, Civil Lines, Kanpur.

* Present Address: Central Public Health Engineering Research Institute, Nagpur-20.

TABLE I—LIST OF OUTFALLS WITH THEIR AVERAGE HOURLY DISCHARGES

Sr. No.	Name of the Outfall	Discharge	
		(cu m/hr)	(gal/hr)
1	Nagaria Nalla	161	35516
2	Sarkata Nalla	515	113609
3	Pata Nalla	675	148905
4	Sitapur Road Nalla (I)	—	—
5	—do— (II)	72	15883
6	Mohan Maekin's Brewery Nalla	241	53164
7	Daliganj Nalla (I)	—	—
8	Shahamina Road Nalla	11	2426
9	Medical College Nalla	3	661
10	Nalla near Iron Bridge	—	—
11	Habibullah Road Nalla	9	1985
12	Wazirganj Nalla	900	198540
13	Daliganj Nalla (II)	180	39708
14	Kubpur Nalla	70	15442
15	Mukarim Nagar Nalla	—	—
16	Art College Nalla	—	—
17	Ghasiari Mandi Nalla	800	176480
18	Cheena Bazar Nalla	140	30880
19	Laplace Nalla	210	46326
20	Hassanganj Nalla	—	—
21	Hyderabad Nalla	20	4412
22	Kedarnath Road Nalla	280	61768
23	Nishatganj Nalla	280	61768
24	Bypass of Sewage Pumping Stn.	—	—
25	Kukrail Nalla	1600	352960
26	Jauplin Road Nalla	20	4412
27	Ghiasuddin Hyder Canal	1400	308840
28	Mahanagar Nalla	100	22239
29	Rahimnagar Nalla	87	19317
30	Hewett Poly. Nalla	70	15442
31	Faizabad Road Nalla	70	15442
32	Railway Colony Nalla	20	4412
33	Paper Mill Colony Nalla	40	8895

was also the objective to assess the extent of self-purification of the river, downstream of the town of Lucknow so that the quality of water which is used by the people in this area could be known.

The Outfalls

In order to achieve the aforesaid objective, it is imperative that the details of the outfalls are known.

There are in all 33 outfalls emerging from various parts of the town and joining the river both on the left and the right banks. These outfalls have been listed in Table I, alongwith other relevant information. The locations of the outfalls have been indicated in Fig. 1. Out of the list, there are seven nallas which are major outfalls both in terms of their discharge and concentrations of the pollutants: (i) Sarkata nalla, (ii) Pata nalla, (iii) Mohan Maekins Brewery nalla, (iv) Wazir Ganj nalla (Photograph-1), (v) Ghasiari Mandi nalla (Photograph-2), (vi) Ghiasuddin Hyder canal (Photograph-3), and (vii) Kukrail nalla (Photograph-4). These seven outfalls have been indicated in solid lines in Fig. 1. Out of these, Mohan Maekins Brewery nalla which brings in distillery wastes from the Brewery deserves a special mention here. Even though its flow is the minimum amongst the seven, its effects are long lasting. It is observed that even though the river has recovered considerably at Nepuria

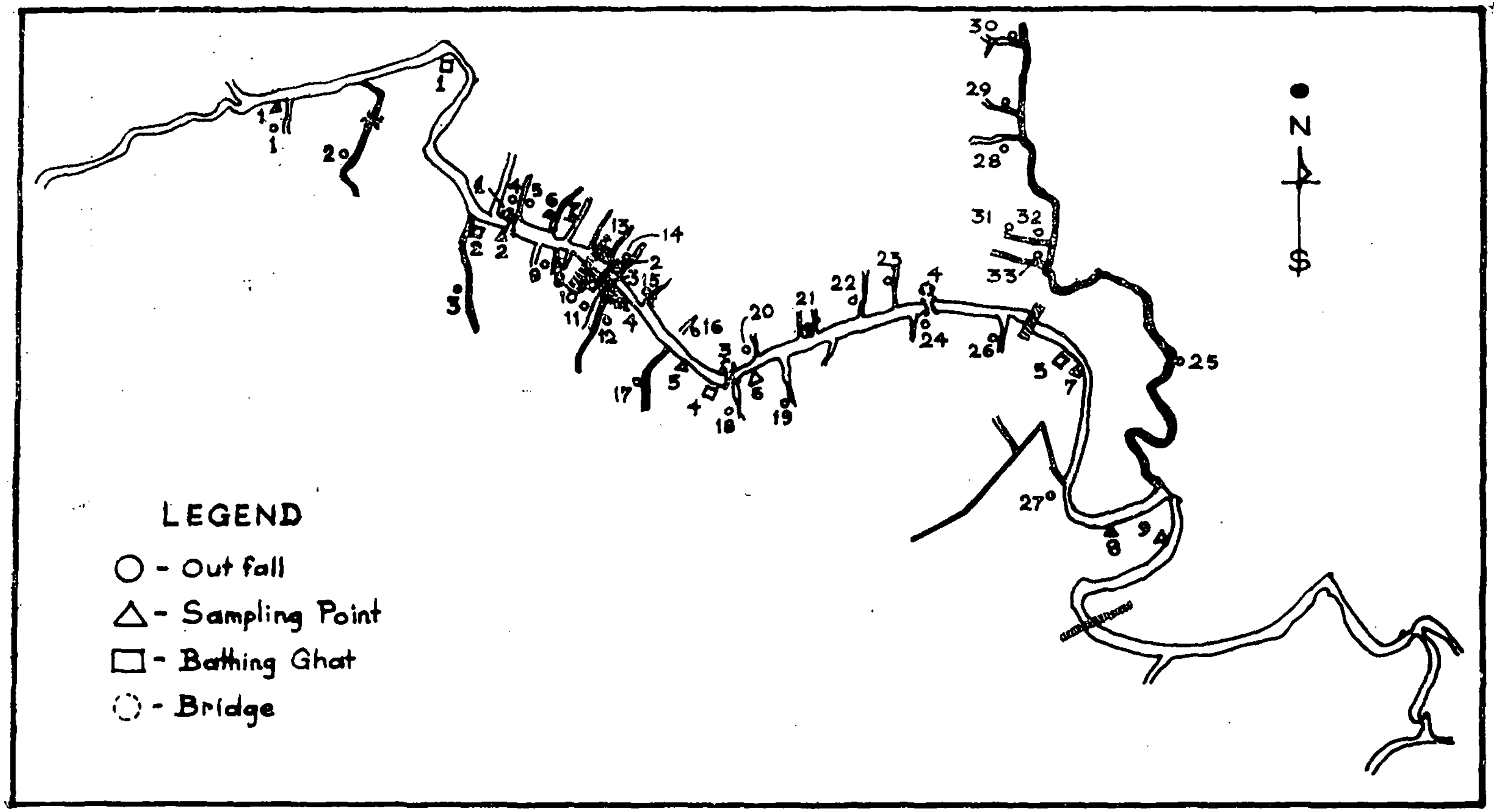
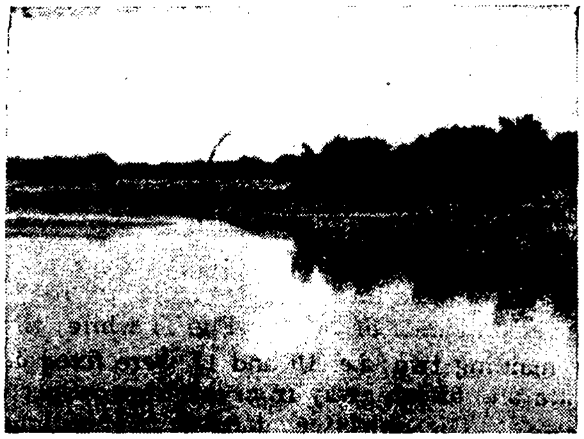


Fig. 1—Gomti River in Lucknow Region—Location of Outfalls and Sampling Points.

Photograph—1. Wazirganj Nalla *(shown with arrow)* entering Gomti River.

Photograph—2. *Ghasiari Mandi Nalla* (shown with arrow) entering Gomti river.

Photograph—3. Ghiasuddin Hyder Canal as it passes through the town, before joining Gomti.



Photograph—4. Kukrail Nalla (shown with arrow) entering Gomti river.

Ghat (near Hydergarh) from the pollutional effects at Lucknow (distance, 65 km; travelling time, 35.8 hr), the water still carries a brown hue imparted by this nalla.

Wastewater Characteristics

Whereas grab samples of wastewater from all the outfalls were collected, compositing of samples from three of the outfalls at Sl. Nos. (iii), (iv) and (v) was also done with a view to see the variation, if any, in the waste characteristics between grab and composite samples. Compositing was done over a period of 16 hr (5 A.M. to 9 P.M.) on equal volume basis at intervals of $\frac{1}{2}$ hr. Characteristics of wastewaters have been given in Table II.

Sampling Stations

In all, eleven sampling stations were fixed, keeping in view the accessibility of the place and the location of outfalls. Samples were drawn from the mainstream either from a bridge or from a boat arranged locally.

TABLE II—CHARACTERISTICS OF WASTEWATERS@

Sr. No.	Name of the outfall	Temp. °C	pH	COD	BOD	Total solids	Total volatile solids	Susp. solids	Susp volatile solids	Total nitrogen
1.	Sarkata Nalla	25.5	8.0	27.8	17	600	324	526	102	—
2.	Pata Nalla	25.5	7.6	448.9	310	1168	360	650	42	—
3.	Medical College Nalla	27.0	8.0	41.8	36	614	402	50	28	—
4.	Shahamina Road Nalla	27.0	7.6	202.1	120	662	260	60	44	—
5.	Habibulla Road Nalla	25.5	8.3	6.9	5	1332	582	82	10	—
6.	Wazirganj Nalla	27.0	7.7	383.3	160	756	394	200	38	—
6A.*	Wazirganj Nalla	—	7.8	299.0	120	800	—	290	—	30.8
7.	Ghasiari Mandi Nalla	27.0	7.6	634.2	450	1094	438	502	142	—
7A.*	Ghasiari Mandi Nalla	—	7.6	185.0	115	792	—	74	—	44.8
8.	Cheena Bazaar Nalla	22.5	7.5	376.3	170	672	262	168	14	—
9.	Laplace Nalla	26.5	7.5	432.1	180	866	374	368	202	—
10.	Jauplin Road Nalla	29.0	8.0	139.4	130	1302	326	248	154	—
11.	Haider Nalla	28.5	7.6	299.7	200	746	340	246	36	—
12.*	Mohan Maekin's Brewery Nalla	37.0	6.2	4129.0	2000	6322	3408	64	—	117.6
13.	Daliganj Nalla	30.5	7.9	840.0	400	1054	—	246	—	39.2
14.	Kedar Nath Road Nalla	30.5	7.6	285	116	326	—	67	—	70.0
15.	Nishatganj Nalla	30.5	7.9	382	140	822	236	56	36	39.2
16.	Haiderabad Nalla	30.5	7.9	85	40	1490	1230	964	822	19.6
17.	Kukrail Nalla	30.0	8.0	427	140	622	322	90	38	11.2

Note— @ All values except temperature and pH are in mg/l.
* Half-hourly composite samples on equal volume basis, for 16 hr.

Nine of the eleven sampling stations, *viz.*, 1-9 were fixed in the limits of the city itself, over a stretch of 14 km (Fig. 1) while the remaining two *i.e.* 10 and 11 were fixed 35 km and 65 km away from the town respectively. The objective of fixing the stations at different distances from the town was to evaluate the extent of recovery of the river after receiving the pollutional load. While fixing the sampling points, main current had been taken into account and care had been taken that the waste, as far as possible, had mixed with the river water so as to give a representative sample. The desirability of greater number of samples after station 9 was realised but it could not be possible due to inaccessibility of the river in this stretch.

It would be pertinent to mention here that there is a wier over the river 9.5 km downstream of Gaughat (Fig. 1) and that the sampling stations were distributed up and downstream of the wier.

The sampling stations have been listed below : (i) Gaughat (Raw water intake), (ii) Lucknow-Sitapur Bridge, (iii) Dalli Ganj Bridge (Iron Bridge), (iv) At Shaheed Smarak, (v) Downstream of Shaheed Smarak,. (vi) Moti Mahal Bridge, (vii) Bhainsakund, (viii) Downstream of Ghiasuddin Hyder Canal, (ix) Pipria Ghat (downstream of confluence with Kukrail Nalla), (x) Ganga Ganj (35 km downstream of Lucknow on Lucknow-Sultanpur Road), and (xi) Nepuria Ghat Bridge, near Hydergarh. (65 km downstream of Lucknow on Lucknow-Sultanpur Road).

Materials and Methods

The samples were collected for physico-chemical, bacteriological and biological analysis. All the necessary precautions were taken in collecting and transporting the samples from the site to the laboratory. In the physico-chemical analysis, pH and DO values were estimated at the site itself. All other estimations were made in the laboratory. For COD and BOD estimations, samples were pretreated and brought to the laboratory. Standard Methods for the Examination of Water and Wastewater (1) were followed for the analytical techniques. For biological analysis, 150 l of water sample was concentrated to 18 ml through a 200 mesh bolting silk cloth net for the estimation of plankton count. The concentrate was fixed at the site itself with 5% formalin. No analysis of live organisms was made for lack of facilities. Plankton count was made with a Sedgwick Rafter Cell. For the estimation of benthos, bottom mud was collected with Ekman Dredge. The benthos was isolated by washing the mud through B & T sieves nos. 10, 20 and 40. The macro-invertebrates were picked out of the sieves, identified and counted. Chemical analysis of the sludge harbouring the macro-invertebrates was also made.

Under the bacteriological examination, MPN Index (both presumptive and confirmed), *E. coli* and *F. streptococci* (presumptive and confirmed) counts were estimated.

Results and Discussion

1. Outfalls

The analytical results of wastewater samples collected from different outfalls have been given in Table II. As would be observed, BOD values of all the samples are much above 100 mg/l. It may however, be mentioned that the samples drawn were grab ones except those from outfalls 6, 7 and 13 viz., Wazir Ganj nalla, Ghasiari Mandi nalla and Mohan Maekins Brewery nalla, where composite samples were also drawn for the purposes of comparison. In view of the fact that the BOD values of composite samples drawn from the aforesaid three outfalls were considerably less than those of grab samples from the same outfalls, (Table II) it can be reasonably construed that the BOD values of composite samples from other outfalls would also be less than the grab samples, if they had been drawn. For the purpose of calculation of total organic load on the river in a day, therefore, an average BOD value of 160 mg/l except Mohan Maekins Brewery nalla has been taken. For composite samples, however, actual BOD values obtained have been taken into account for calculations.

As has been stated earlier, *conspicuous* among the list of outfalls is the Mohan Maekins Brewery nalla. BOD value of the waste from this outfall was 2,000 mg/l so that this alone subscribed 25,000 lb of BOD to the river in a day, apart from imparting a persistent hue to the water.

2. River

(i) PHYSICO-CHEMICAL QUALITY

Analytical results of river water samples drawn from different stations during different months have been presented in Tables III through VII. However, the important parameters have been discussed in the following paragraphs:

(a) *pH, Total Alkalinity and Total Hardness*

Values of pH, total hardness and total alkalinity at various stations do not show any steady changes from station to station as might be expected due to the discharge of wastewaters into the river. In fact, this situation is true with all the parameters This is because of the location of a large number of outfalls within a relatively short distance. Further, because of the low flow velocity (1 ft/min.) in the river, the mixing in different planes does not reach a stage of completion.

Fluctuations in pH are between 8.0 and 8.6 while those in total alkalinity are between 210 and 225 mg/l and total hardness ranges from 170 to 250 mg/l.

(b) *DO, BOD, and COD*

It would be observed that there is a decline in the DO saturation levels from station 3 onwards. It would be of interest to mention here that five of the seven major outfalls mentioned in the preceding pages open in the short stretch of approximately 7 km of

TABLE III—PHYSICO-CHEMICAL CHARACTERISTICS OF RIVER WATER AT DIFFERENT SAMPLING STATIONS

Period: 18-3-71 to 20-3-71

Sampling Station	Temp. (°C)	pH	Total alk.	Total hardness	Cl	SO_4	PO_4	DO	COD	BOD	Amm. N	NO_3 N	Total nitrogen	Turbidity	Total solids	TVS
1.	26.0	8.6	260	200	12	9	tr.	8.4	26.6	2.4	—	—	—	17.0	278	192
2.	26.0	8.7	288	212	14	11	0.5	8.2	21.3	3.4	—	—	—	10.6	272	106
3.	26.0	8.5	260	212	14	15	tr.	8.0	26.6	5.4	—	—	—	9.9	266	78
4.	26.0	8.1	248	200	14	9	tr.	7.0	53.3	9.2	—	—	—	15.0	255	84
5.	26.0	8.3	260	200	14	11	0.5	6.4	48.0	8.0	—	—	—	13.0	270	74
6.	26.0	8.1	272	220	16	9	0.5	3.8	53.3	6.0	—	—	—	12.5	308	—
7.	23.5	8.3	260	212	16	9	0.5	4.6	26.6	4.8	—	—	—	45.0	352	68
8.	22.5	8.1	264	220	16	9	0.6	3.6	37.3	6.4	—	—	—	13.0	328	60
9.	23.0	8.1	280	212	16	16	0.6	2.4	42.6	4.6	—	—	—	16.0	328	70
10.	23.0	8.1	280	220	16	15	0.5	4.6	21.3	5.2	—	—	—	5.5	290	74
11.	23.0	8.3	264	220	16	16	0.5	7.4	16.0	5.2	—	—	—	5.5	272	82

Note— (1) All values except temperature and pH are in mg/l
(2) tr=traces.

TABLE IV—PHYSICO-CHEMICAL CHARACTERISTICS OF RIVER WATER AT DIFFERENT STATIONS

Period: 23-4-1971 to 25-4-1971

Sampling Station	Temp. (°C)	pH	Total alk.	Total hardness	Cl	SO_4	PO_4	DO	COD	BOD	Amm. N	NO_3 N	Total nitrogen	Turbidity	Total solids	TVS
1.	26.5	8.5	256	192	10	15	0.6	7.2	20.4	2.6	—	0.72	2.0	5.6	348	108
2.	26.5	8.5	272	200	12	15	0.6	5.8	20.4	3.2	—	1.68	5.0	8.4	358	126
3.	26.5	8.5	264	196	12	16	0.6	5.2	34.0	3.6	—	0.88	4.3	15.0	324	106
4.	27.0	8.5	264	200	12	17	0.6	4.6	34.0	4.8	—	2.44	14.0	15.3	308	110
5.	27.0	8.7	280	196	14	17	0.6	5.0	40.8	4.8	—	3.20	10.3	14.0	322	95
6.	27.0	8.6	272	208	14	17	0.6	4.6	34.0	6.0	—	2.24	13.4	14.0	333	136
7.	30.0	8.5	256	212	16	18	0.6	5.2	20.4	5.3	—	2.24	5.4	12.0	329	91
8.	29.5	8.3	256	212	16	18	0.7	4.2	27.2	6.0	—	2.40	4.2	14.0	343	98
9.	29.5	8.3	264	196	16	20	0.7	4.6	30.0	6.8	—	2.24	3.0	17.0	383	71
10.	29.0	8.5	272	188	16	20	0.6	4.0	20.4	4.8	—	1.68	5.0	15.0	314	49
11.	26.5	8.6	256	188	16	20	0.6	5.2	20.4	3.2	—	1.6	3.6	9.0	311	113

Note— All values except temperature and pH are in mg/l

TABLE V—PHYSICO-CHEMICAL CHARACTERISTICS OF RIVER WATER AT DIFFERENT SAMPLING STATIONS

Period: 12-5-1971 to 15-5-1971

Sampling Station	Temp. (°C)	pH	Total alk.	Total hardness	Cl	SO_4	PO_4	DO	COD	BOD	Amm. N	NO_3 N	Total nitrogen	Turbidity	Total solids	TVS
1.	27.0	8.6	256	192	12	—	tr.	7.0	18.9	3.6	0.05	1.8	—	32.0	270	100
2.	27.0	8.5	244	196	12	—	tr.	6.0	18.9	5.1	0.3	5.0	—	32.0	253	85
3.	27.0	8.6	228	180	12	—	tr.	6.6	18.9	2.1	0.05	2.5	—	34.0	235	29
4.	27.5	8.4	224	176	12	—	tr.	5.2	17.4	5.2	0.4	2.3	—	18.0	223	25
5.	29.0	8.5	236	168	16	—	tr.	6.4	18.9	3.1	0.05	4.2	—	32.0	260	47
6.	29.5	8.5	244	184	16	—	tr.	6.0	15.8	3.3	0.05	1.8	—	32.0	236	69
7.	29.0	8.0	196	192	16	—	tr.	5.0	15.8	5.6	0.4	3.5	—	20.0	253	88
8.	28.5	7.9	168	192	16	—	tr.	4.8	25.2	7.7	0.5	2.8	—	57.0	288	68
9.	28.5	8.0	216	192	16	—	tr.	5.4	50.5	6.1	0.4	5.0	—	34.0	279	24
10.	28.5	8.0	212	188	20	—	tr.	6.0	18.9	4.2	0.25	5.8	—	18.0	251	85
11.	28.0	8.1	204	188	20	—	tr.	6.6	15.8	2.2	0.1	8.2	—	10.0	261	80

Note— (1) All values except temperature and pH are in mg/l
(2) tr=traces.

TABLE VI—PHYSICO-CHEMICAL CHARACTERISTICS OF RIVER WATER AT DIFFERENT SAMPLING STATIONS

Period : 26-5-1971 to 28-5-1971

Sampling Station	Temp. (°C)	pH	Total alk.	Total hardness	Cl	SO$_4$	PO$_4$	DO	COD	BOD	Amm. N	NO$_3$ N	Total nitrogen	Turbidity	Total solids	TVS
1.	31.0	8.3	168	128	7	13	tr.	5.2	38.6	3.0	0.05	3.8	7.0	23	327	124
2.	31.0	8.0	182	140	8	14	tr.	2.6	64.3	3.0	0.6	5.6	—	22	210	171
3.	31.0	8.1	176	140	8	15	tr.	4.4	90.0	3.3	0.05	4.0	8.4	80	318	97
4.	31.0	8.2	182	144	8	17	tr.	5.2	65.2	2.8	0.15	6.5	—	57	290	149
5.	31.0	8.0	176	144	8	15	tr.	4.2	38.6	4.0	0.05	3.8	9.8	82	313	138
6.	31.0	8.1	180	140	8	13	tr.	2.6	64.3	4.4	0.05	5.2	—	62	323	180
7.	31.0	8.1	172	140	9	16	tr.	4.2	102.9	4.5	0.25	5.2	7.4	46	340	117
8.	30.5	8.0	168	136	9	19	tr.	4.2	45.0	5.2	0.40	5.8	—	62	355	186
9.	30.5	8.0	168	140	10	17	tr.	4.0	38.6	4.6	0.2	3.4	7.0	35	327	192
10.	30.5	8.0	174	148	10	20	tr.	3.6	45.0	4.5	0.25	3.2	—	30	349	180
11.	30.0	8.1	184	148	10	18	tr.	4.7	19.3	3.7	0.15	5.6	8.4	30	327	54

Note— (1) All values except temperature and pH are in mg/l
(2) tr=traces.

TABLE VII—PHYSICO-CHEMICAL CHARACTERISTICS OF RIVER WATER AT DIFFERENT SAMPLING STATIONS

Period : 21-6-1971 to 23-6-1971

Sampling Station	Temp. (°C)	pH	Total alk.	Total hardness	Cl	SO$_4$	PO$_4$	DO	COD	BOD	Amm. N	NO$_3$ N	Total nitrogen	Turbidity	Total solids	TVS
1.	30.0	8.2	200	166	7	13	tr.	6.0	28.5	1.7	0.1	7.4	5.6	—	465	224
2.	31.0	8.0	200	162	7	25	tr.	—	85.4	1.9	0.6	7.8	—	—	444	220
3.	30.0	8.1	210	162	8	24	tr.	—	56.9	1.5	0.2	8.2	9.8	—	393	208
4.	30.0	8.0	210	166	8	22	tr.	2.0	85.4	5.6	1.0	7.8	—	—	455	217
5.	31.0	8.1	200	160	8	22	tr.	—	56.9	2.4	0.25	3.0	7.0	—	440	249
6.	31.0	8.0	200	160	8	20	tr.	—	56.9	2.8	0.5	2.6	—	—	435	113
7.	31.0	8.0	180	140	8	24	tr.	4.2	85.4	2.1	0.25	3.8	5.6	—	408	210
8.	31.0	8.0	180	144	10	30	0.5	4.2	56.9	1.9	0.4	10.0	—	—	427	205
9.	31.0	7.8	180	144	12	20	0.5	3.4	—	5.3	0.3	1.6	7.0	—	454	193
10.	31.0	8.1	180	168	12	44	tr.	4.4	56.9	4.0	0.3	7.6	—	—	539	274
11.	31.5	8.2	180	148	12	46	tr.	6.0	28.5	2.0	0.1	3.4	4.0	—	448	294

Note—(1) All values except temperature and pH are in mg/l
(2) tr=traces.

the river between stations 1 and 6. To be precise, a major share of the pollutional load is put into the river between stations 2 and 6, a paltry distance of 2.9 km.

However, from station 6 to 7, there is an improvement in the DO saturation levels. This is because there is a wier between stations 6 and 7. The wier affords certain amount of aeration as the water falls from over it. From station 7 to 9 again, there is a drop in the DO saturation levels as Ghiasuddin Hyder canal and Kukrail nalla discharge their wastes in this stretch of 3 km. From station 9 onwards, there is a steady rise in DO saturation levels as the river moves out of the Lucknow region and pollution ceases.

The crests of percent DO saturation values are accompanied by the troughs of BOD values and vice-versa. It would be observed that BOD profile exhibits two peaks, one in the region of stations 1 to 6 and the other between stations 7 and 9, i.e., one upstream of the wier and the other downstream.

Generally, the same is true of COD profile.

(C) *Remaining DO and BOD*

The remaining DO and BOD profiles in tonnes/day (Fig. 2) indicate that even though the recovery of the river between stations 9 and 11, involving a travel of 35.8 hr over a stretch of 65 km, is considerable, it is yet not complete. A fairly good amount of BOD is still available at station 11. The remaining BOD which is 2.16 tonnes/day to begin with at station 1 climbs to 4.48 tonnes/day at stations 4 and 9, upstream and downstream of the wier respectively and ends up with 3.34 tonnes/day at station 11. Thus, BOD at station 11 is in excess of that at station 1 by 1.18 tonnes/day.

Conversely, the remaining DO at station 1 was recorded to be 5.46 tonnes/day while that at station 11 was 3.34 tonnes/day. The latter is deficit by 2.12 tonnes/day than the former.

It would be pertinent to mention here that there is no tributory to the river within a distance of 65 km. The recorded recovery between stations 9 and 11, therefore, is exclusively due to the reaeration and not dilution, although the recovery of the river is not complete upto Nepuria Ghat (station 11) near Hydergarh.

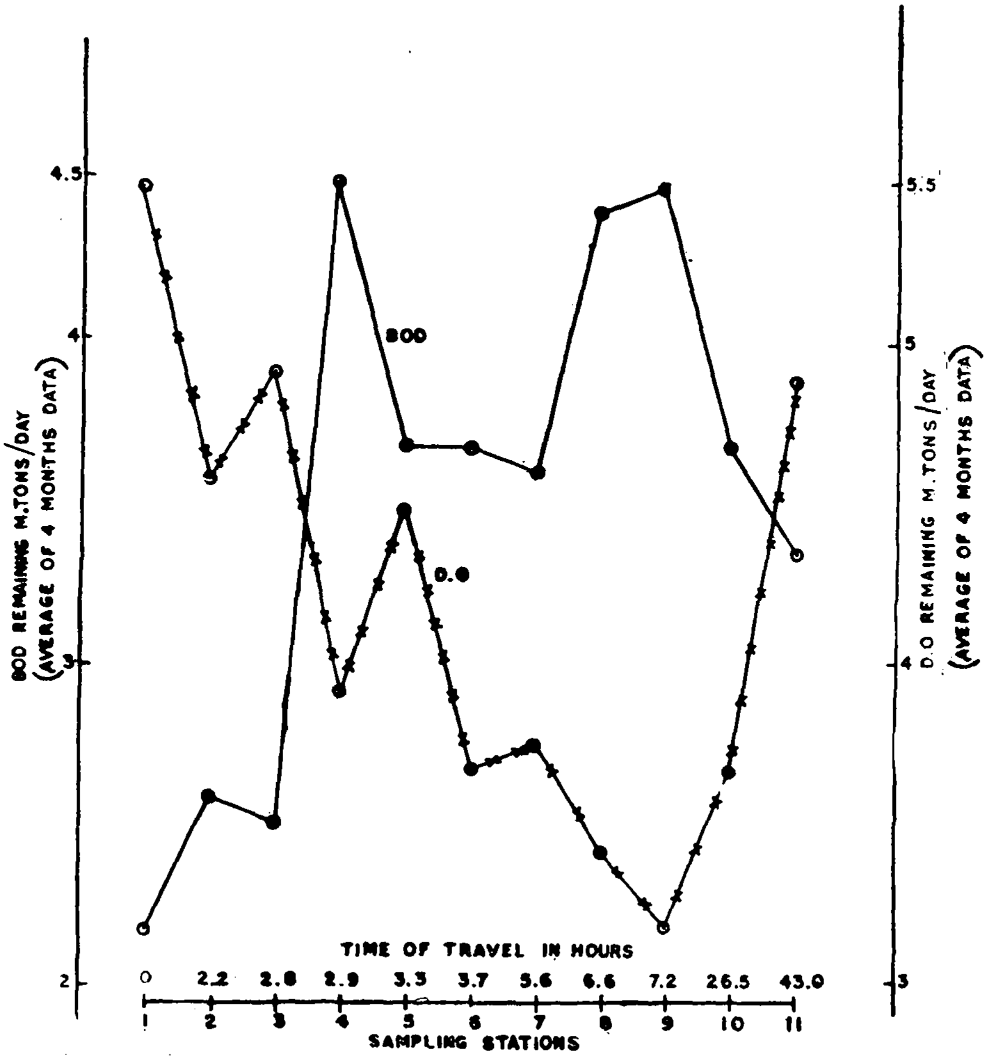


Fig. 2—Remaining BOD and DO Profiles

(d) *COD/BOD Ratio*

The COD/BOD ratio profile has been presented in Fig. 3. It would be observed that the highest ratio has been available at station 3 showing a decline further and a rise again to form another crest at station 7. It is difficult to explain this behaviour. Perhaps, it can be attributed to the wastewater from the outfalls.

(e) *Self-purification capacity of the river*

The self-purification capacity of the river calculated here has been based on the equation given by Streeter and Phelps (2) as under :

$$D_t = \frac{k_1 L_a}{k_2 - k_1}(10^{-k_1 t} - 10^{-k_2 t}) + D_a .10^{-k_2 t}$$

where D_t = deficit in dissolved oxygen i.e. the deficit of actual dissolved oxygen from the saturation at a given temperature; t = the time of travel from the initial point of pollution to the final sampling point;

k_1 = the deoxygenation constant;

k_2 = the reaeration constant;

D_a = the dissolved oxygen deficit at the initial point.

Since, both k_1 and k_2 are unknown in the above equation, k_2 was calculated from the simplified equation of Streeter, (3) which is :

$$k_2 = \frac{r_m}{2.3\, D_m}$$

where $r_m = X_t + (D_a - D_b)$

where X_t = the total oxygen demand between two points, D_a is the dissolved oxygen saturation deficit at the initial Station.

D_b = the dissolved oxygen saturation deficit at the final station and

D_m = the mean dissolved oxygen saturation deficit.

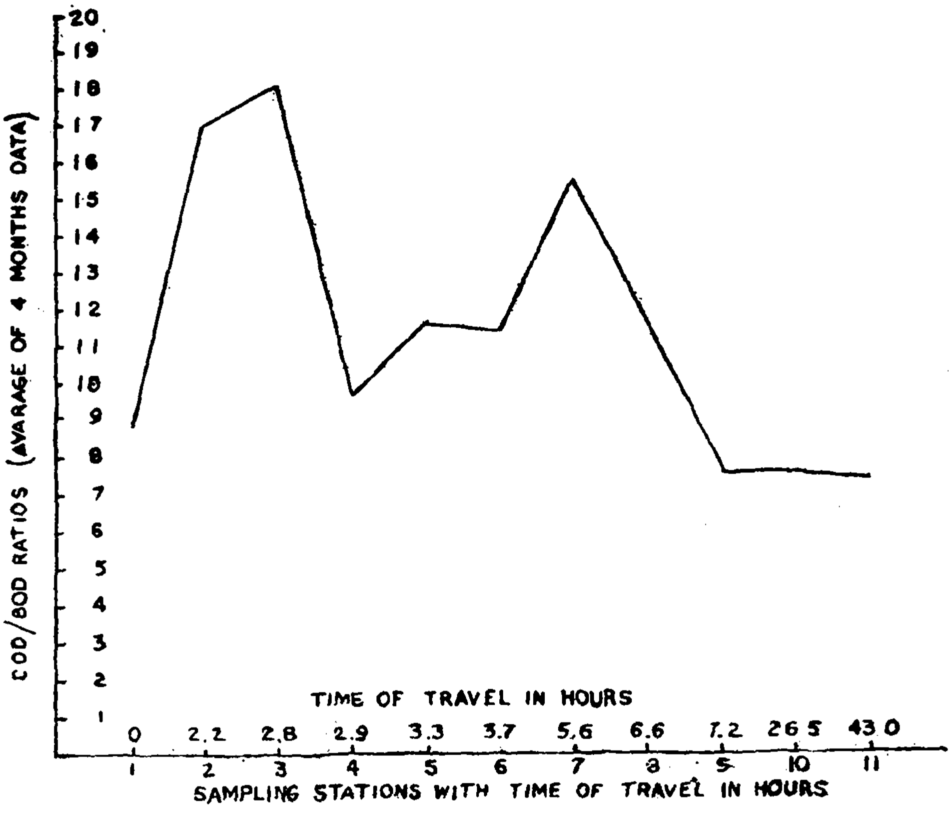


Fig. 3—COD/BOD Ratio Profile

The value k_2 having thus been calculated, the value of k_1 can also be calculated from the first equation. These come to 2.32 and 0.90 respectively. Hence, the self-purification factor, f, can be worked out by the equation :

$$f = \frac{k_2}{k_1} = \frac{2.32}{0.90}$$

which, in this case, comes to 2.5.

(f) *Allowable BOD Loadings on the River*

The allowable loadings on the river can be calculated as under :

(i) **Data on Outfalls :**

Average flow =38 mgd
Average BOD (5 day, 37°C) of wastewater =160 mg/l
Average DO =Nil

(ii) **Data on River :**

Average flow =181 mgd (March to June)
Average BOD (5 day, 37°C) =3.2 mg/l
Average DO =5.9 mg/l
DO saturation value at 30°C =7.6 mg/l
Self-purification constant =2.5

Taking these two sets of data into account,
Ratio of flow of river and wastewater. = 4.7 : 1

BOD values of the mixture of river water and wastewater = 30 mg/l

DO value of the above mixture = 5.5 mg/l
$D_a = 7.7 - 5.5 = 2.2$ mg/l

Since 5.0 mg/l is minimum dissolved oxygen desired in the river water, the critical deficit $D_c = 7.7 - 5.0 = 2.7$ mg/l

$$\therefore \frac{D_a}{D_c} = \frac{2.7}{2.2} = 0.81$$

Referring to the nomogram of Fair and Geyer (4) for allowable loading, the value of $\frac{L_a}{D_c}$ at $f = 2.5$, will be 4.5. Therefore, the allowable loading works out to be 11.25 mg/l.

Using the following equation, the average BOD value of the wastewater that can be put into the river, can be calculated.

$$\text{Average BOD of wastewater} = \frac{11.25\text{x}220 - 181\text{x}3.2}{38}$$
$$= 49.82 \text{ mg/l},$$
$$= \text{say, } 50 \text{ mg/l}.$$

As per the foregoing calculations therefore the following important deductions are made :

Deoxygenation constant, k_1 = 0.9/day
Reoxygenation constant, k_2 = 2.3/day
Self-purification constant, $f = \frac{k_2}{k_1} = 2.5$
Allowable average BOD of wastewater = 50 mg/l

During the pollution study of Gomti river in 1960-61, Bhaskaran *et al* (5) calculated the self-purification constant as 4.07 and the allowable average BOD as 260 mg/l. These results differ since there has been a substantial increase in the population and industries in Lucknow and consequently in the volume of wastewater being discharged into the river.

Looking to the self-purification constants given by Fair & Geyer (4), it would seem that such a constant calculated by Bhaskaran *et al* (5) is on the higher side for a sluggish river like Gomti which all along flows over a smooth terrain and has no rapids and falls. Further, the average BOD values of the wastewater taken as 360 mg/l also seem to be on the higher side.

A study carried out by Bulusu *et al* (6) on Khan river near Indore and Ujjain, revealed the self-purification constants of all categories in different zones of the river stretch.

For a major portion, however, rapids and falls were occurring because of the rocky terrain and hence the constant for this region was 5.0 and above.

With the calculations given in this section of the text, it becomes quite apparent that all the outfalls opening into the river should be trapped and their wastewaters should be treated at least to the tune of 60 per cent. This is true especially of the waste from Mohan Maekins Brewery Nalla. It is then alone that the quality of the river water can be maintained. It becomes a necessity keeping in view the needs of people living downstream of Lucknow.

(ii) BACTERIOLOGICAL QUALITY

The MPN index/100 ml (presumptive) has been presented in Fig. 4, alongwith the BOD curve. The highest count has been recorded at Station 7.

Similar curves for MPN index/100 ml (confirmed), of *F. streptococci* and *E. coli* alongwith the BOD curve have been presented in Fig. 5. There is a substantial uniformity in the behaviour of three types of the curves, the peaks and troughs coinciding with one another. The initial and final counts of *F. streptococci* and *E. coli* at Stations 1 and 11 respectively, are almost the same. Like physico-chemical parameters, the highest bacteriological counts have also been recorded in the regions upstream and downstream of the wier. During the travel of 35.8 hr between Stations 9 and 11, a stretch of 65 km, the counts have dropped sharply to come at par with those at Station 1.

In the case of coliforms, however, the count of Station 11 is considerably higher than that at Station 1. Obviously, the 'die-away' rate of these organisms is slower than those of *F. streptococci* and *E. coli*. It may be recalled that the BOD value at Station 11 is also higher than at Station 1, so that coliform curve has closer resemblence with BOD curve than the curves of *F. streptococci* and *E. coli*.

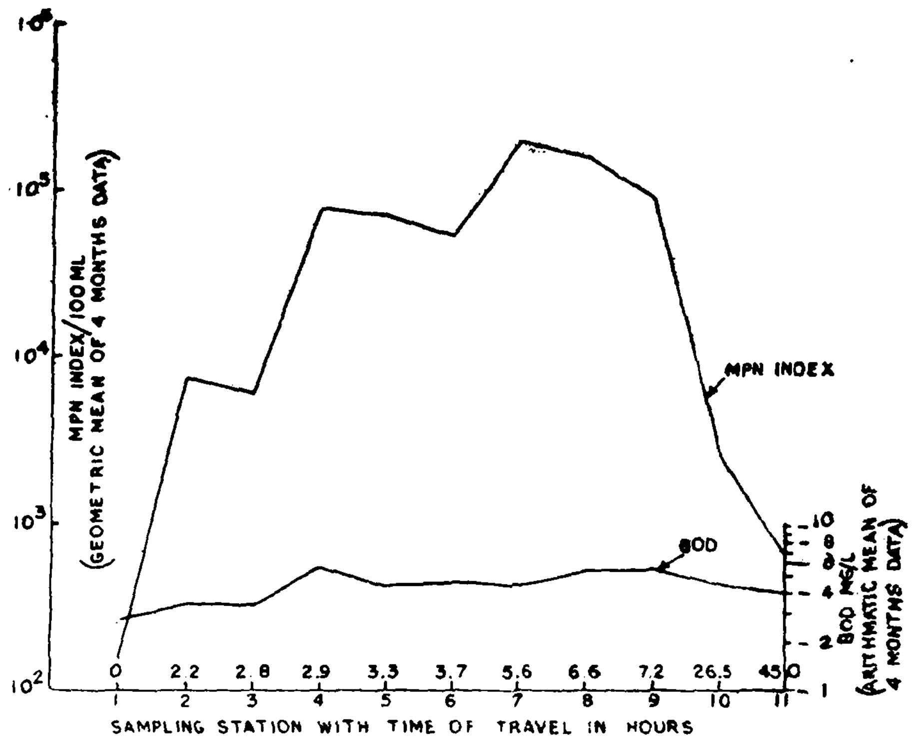


Fig. 4—MPN Index alongwith BOD at different Sampling Stations

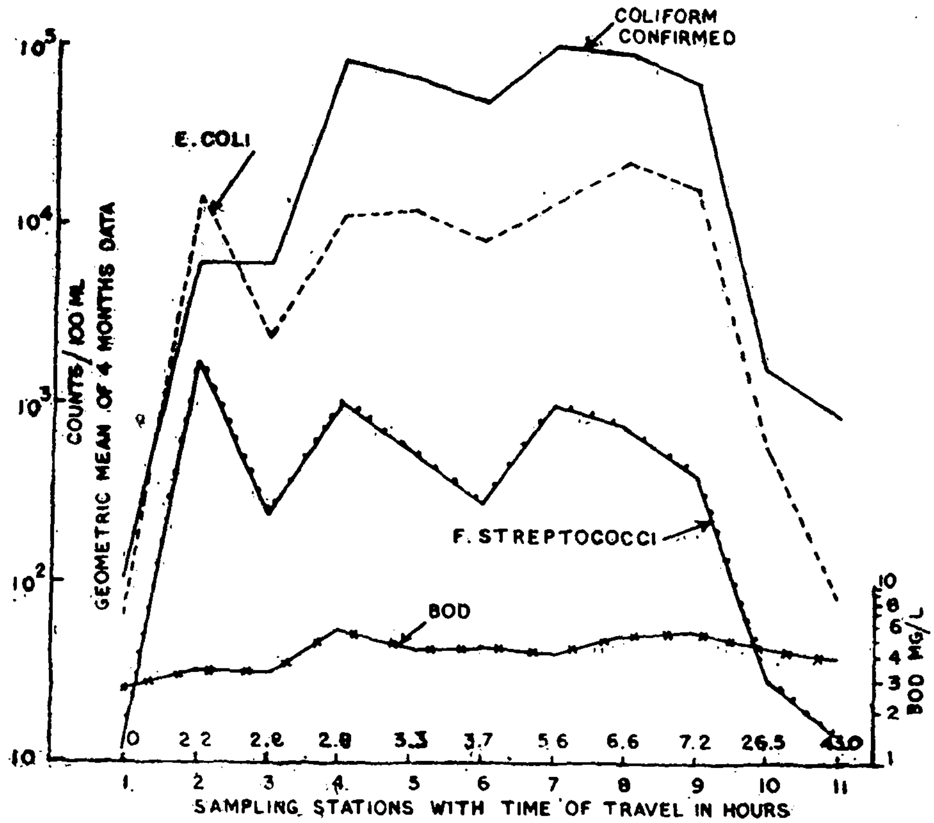


Fig. 5—MPN Index of F. Streptococci and E. Coli alongwith BOD at various Sampling Stations

Since a considerably high coliform (confirmed) count is still persisting at Nepuria Ghat (Station 11), the possibility of the existence of associated potential pathogens cannot be ruled out. The river water could thus be inimical to the population on the banks between Lucknow and Nepuria Ghat, moreso when there is no protected water supply in this stretch.

(iii) BIOLOGICAL QUALITY

(a) Plankton

There has not been any appreciable plankton population in the sample collected at different stations and hence the values have not been given.

(b) Benthos

In cases of streams, like the one here, subjected to gross organic pollution, it is the bottom dwellers which are of significance. (7) Among the benthos, sludgeworms (Oligochaetes, Annelida), bloodworms (Tendipididae, Diptera, Insecta, Arthropoda) and molluscs (Mollusca) indicate the condition of the river, although the status of molluscs is said to be uncertain. (8) However, one thing is clear that the molluscs, specially the branchiopods, greatly diminish in number in reduced dissolved oxygen levels.

Whereas molluscs and sludgeworms have been frequently recorded at various stations, bloodworms have been conspicuously absent. It could be argued that these worms which thrive in α — and β — mesotrophic conditions, could have been available if a sampling station were fixed in the active recovery zone i.e. between Stations 9 and 10. Nonetheless, they were not recorded at Station 10.

From Fig. 6, which presents the counts of molluscs and sludgeworms, it would be observed that the increase in the count of sludgeworms is accompanied by the corres-

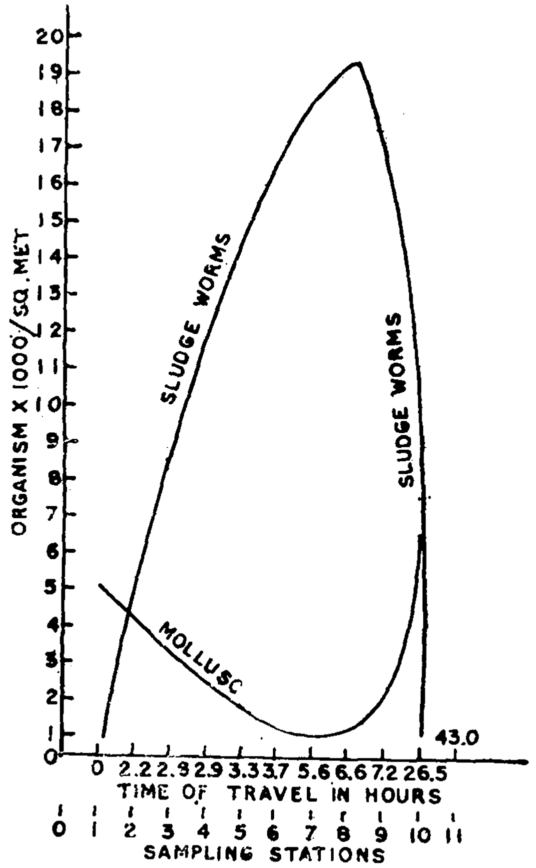


Fig. 6—Molluscs and Sludgeworms at Different Sampling Stations

ponding decline in the counts of molluscs and vice-versa. Highest count of sludgeworms has been recorded at Station 9 while that of molluscs has been at Station 1, both of which represent diametrically opposite water quality conditions, which have a direct bearing on the condition of the bottom of the river.

It would be relevant to point that, whereas the physico-chemical parameters have shown sufficient fluctuations from station to station and thus have failed to indicate the cumulative pollutional effect, may be due to lack of proper mixing, the counts of bottom fauna, specially the sludgeworms do reveal this condition. Furthermore, whereas the addition of wastewaters can bring about an abrupt effect on the physico-chemical quality of the river water, benthic quality remains unchanged for a considerable length of time. It has, therefore, been often rightly stressed that benthos speak the history of a surface water course. (9)

It would certainly have been more revealing if a number of benthic samples had been collected along the cross-section of the stream at a particular station. This could have covered the argument of lack of proper mixing. However, such a detailed work could not be undertaken for lack of certain facilities.

Conclusions

1. Gomti river along its entire stretch of 1000 km receives the maximum pollutional load at Lucknow, through 33 outfalls bringing in sewage and industrial wastes, rendering the water unfit for recreational purposes.
2. A major share of the load is released into the river within a distance of 2.9 km, between stations 2 and 6, upstream of the wier. A considerable load is released downstream of the wier too.
3. Calculations for self-purification capacity indicate that even after travelling a distance of 65 km downstream of Lucknow, the recovery of the river is not complete.
4. In order to maintain the quality of the river water, all the outfalls need to be trapped and their wastewater treated at least to the extent of 60 percent.
5. Even at stations 10 and 11, there is an appreciable amount of BOD left as also the coliform (confirmed) count. This makes the water inimical to the population downstream of Lucknow.

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DISCUSSION

Shri B. B. Mane (Nasik): It was mentioned in the paper that indicators like MPN, coliforms, molluscs, etc. show the pollution. In many of water works, molluscs were found out in filter beds. Is it the sign of pollution?

Dr. H. C. Arora: Presence of molluscs does not necessarily indicate pollution. However, their existence in cases of gross pollution is limited to negligible counts. Findings incorporated in the paper indicate that they were absent or were available in negligible numbers in zone of acute pollution.

PROC. SYMP. ON ENVIRONMENTAL POLLUTION (1973)

Pollution of Ground Water at Bangalore

M. K. C. SRIDHAR* and S. C. PILLAI*

The practice of sewage disposal at Bangalore by allowing it to flow down the gradient land on the outskirts of the city has led to indiscriminate use of the sewage for growing a variety of market garden crops and, in consequence, not only the soil and the crops but also the waters in the wells (used for domestic purposes) around the sewage channels have been polluted. A similar study was made of the waters from the wells near the septic tanks on the campus of the Indian Institute of Science, Bangalore and in the premises of certain industrial establishments around Bangalore.

Since one of the wells near a septic tank on the Institute campus was the source of water for the swimming pool at the Institute and there was excessive algal growth in the pool, further studies including laboratory experiments were carried out which have been of scientific interest and practical importance in the maintenance of the swimming pool in good condition now.

These and other results indicate the necessity for effective treatment of sewage and similar wastes and the utilization of the treated wastes to the fullest extent possible for the production of suitable crops to prevent the pollution of ground water and to ensure the natural circulation of the elements of nutrition in the interests of environmental sanitation and health.

Introduction

The purpose of this paper is to draw attention to the extent of sewage pollution of the well waters in and around Bangalore where raw sewage has for over 50 years been allowed to flow down in open channels without any treatment. This is an unusual method or mode of sewage disposal which has caused pollution of the ground water in the area. A few wells in the vicinity of these channels, from which the waters were used for human consumption, had to be abandoned recently. There has also been the problem of pollution of market garden crops irrigated with the sewage from the channels.

In some localities in Bangalore, as in the premises of some industrial establishments, septic tanks are employed for the treatment of the sewage, and the waters from the wells dug near these areas for domestic use have also indicated sewage pollution. One of the septic tanks on the campus of the Indian Institute of Science has been a source of pollution of the water in the well which feeds a swimming pool. The effluents from some of the septic tanks have also been used for growing vegetables.

These and other conditions at Bangalore (1) prompted the present study in which a large number of samples of sewage, well waters, swimming pool water, and washings of sewage grown crops have been examined. The results, alongwith the related experiments, are briefly described and discussed in this paper.

Materials and Methods

Samples of water from 16 wells were periodically examined. These wells are located in the neighbourhood of (i) the sewage channels on the outskirts of the Bangalore city, (ii) the septic tanks on the campus of the Indian Institute of Science, and (iii) the septic tanks at 4 industrial establishments. In this connection, samples of

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* Department of Biochemistry, Indian Institute of Science, Bangalore.

sewage from the channels at Bangalore and from the sewage works at the Institute were also analysed.

The quality of the water from the tender coconuts of the trees growing near the sewage channels was compared with the quality of the water from the tender coconuts of the trees growing far away from the sewage channels. The quality of the washings of vegetables (five successive washings with distilled water) grown on the effluents from septic tanks was studied.

The daily changes in the quality of the water in the swimming pool were closely followed for over two years and experiments were carried out in the laboratory simulating the conditions in the swimming pool in order to explain the observed changes in the swimming pool. The quality of the water from a large tank near the sewage channels at Bangalore was also studied as this tank is used for recreation.

Sewage, effluents, well waters, washings of vegetables, and the swimming pool water were analysed for pH, turbidity, acidity, alkalinity, oxygen absorption from acidified potassium permanganate in 3 min. and in 4 hr, dissolved oxygen (DO), biochemical oxygen demand (BOD), ammoniacal, nitrite and nitrate nitrogen, water soluble phosphorus, chloride, total bacterial count and coliforms as indicated by the most probable number (MPN). Turbidity was determined by measuring the light transmission in a Klett-Summerson photoelectric colorimeter using a blue filter (maximum transmission 420 mμ). The other items of analysis were carried out by standard methods (2-4).

Microscopic examination of the sediments from the well waters and of the algal and other growths from the sides of the swimming pool was periodically carried out.

Results

1. *Observations on the Flowing Sewage at Bangalore*

Although the conditions and the practice of sewage disposal at Bangalore were described earlier (5, 6), they may be briefly considered here for a proper appraisal of the problem of water pollution at this place. Since the introduction of underground water-carriage system of waste removal in 1922 at Bangalore, the sewage has been taken to three convenient points at the city by underground pipes and from there it is allowed to flow down in the channels on the outskirts; there are two main sewage channels which reach ultimately two large tanks, one of them is about 25 miles away on the south western side and the other is about 10 miles away on the south eastern side from the city. This unique method of sewage disposal has been made possible by the topography of the land in and around Bangalore with unusual undulations which cause rapid, turbulent flow of water in certain directions.

On either side of the two main channels, the sewage is drawn for irrigating extensive areas of land and growing a variety of crops, including market garden crops. Wells are sunk in these areas to supply water for domestic use. Although the sewage, as it flows down with turbulence over stones in the channels, is gradually purified, the atmosphere around the upper regions of the channels is foul smelling and the crops, especially low growing crops, are grossly polluted with the sewage matter and putrefactive and pathogenic bacteria (7).

The waters from the wells dug in these areas were also polluted. A set of results of analysis of the sewage at the outfall for one of the channels (1-in-100 general gradient) and at various points in this channel until the sewage was naturally purified are given in Table I. The factors in this natural purification process have been studied and the most significant feature is the occurrence in large numbers of such Vorticelloid protozoa as the species of *Epistylis* and *Carchesium* in the region of purification.

2 *Pollution of the Water in the Wells in the vicinity of the Flowing Sewage*

Over the years of constant flow of sewage in the channels at Bangalore, the water table in the area has risen. Although, as a result of filtration of the sewage through the soil, the waters in the wells dug in the area were clear, they showed large numbers of coliforms and high concentrations of nitrates, chlorides *and phosphates (Table II). In* a few wells, the increases in these constituents intolerably affected the quality of the waters and they were abandoned by those who had been consuming those waters. The results of analysis of one such well water are given in Table III, the quality of the water on December 24, 1970 and that on August 3, 1972 are indicated. This well was discarded by the people in April, 1972.

TABLE I—RESULTS OF ANALYSIS OF SAMPLES OF SEWAGE TAKEN FROM ONE OF THE CHANNELS (GRADIENT 1-IN-100) AT DIFFERENT POINTS

Sampling point: distance from the outfall (miles)	Turbidity	pH	Acidity	Alkalinity	3-min P.V.	4-hr P.V.	Dissolved Oxygen	BOD	NH_3-N	NO_2-N	Water soluble P	Chloride, Cl
0	142	7.1	60	190	24	71	0	147	39	0	6.5	138.3
1	142	7.3	40	310	34	64	0	227	50	0	6.5	146.2
2	142	7.5	40	390	24	69	0	197	50	0	7.5	191.7
5	114	7.4	40	330	19	48	0	142	37	0	5.1	156.1
6	74	7.7	30	440	18	40	0	82	25	0	3.3	199.6
7	64	7.7	30	490	8	31	0	27	29	0	4.1	187.7
9	64	7.4	30	350	10	30	0	17	29	0	4.1	177.8
10	44	7.7	30	480	5	32	0	20	40	0.1	4.8	167.9
11	102	7.8	30	450	15	37	2.6	52	45	0	4.5	197.6
26	24	7.8	30	490	4	25	5.6	0	29	0.3	3.1	197.6

Note— (1) Results are expressed as mg/l, except turbidity and pH.
(2) NO_3 N was absent in all the samples.

TABLE II—RESULTS OF ANALYSIS OF SAMPLES OF WELL WATER AS AFFECTED BY THE SEWAGE FLOWING IN THE CHANNEL

Characteristics	Sewage in the channel	Sewage drawn into a pit for irrigation	A well about 10 ft away from the sewage pit	A well close to sewage channel in another area*
Turbidity	89	77	11	0
Acidity	130	145	55	—
Alkalinity	400	420	520	—
3-min P.V.	16	18	4	0
4-hr P.V.	39	41	12	—
Dissolved Oxygen	0	0	2.2	—
BOD	150	100	16	—
Ammoniacal N	57	54	5	10.5
Nitrite N	0	0	0	0.05
Nitrate N	0.3	0	0	0
Water soluble P	6.7	6.7	3.0	0
Chloride, Cl	193.7	205.5	403.1	148.2

Note— (1) Results are expressed as mg/l, except turbidity.
(2) The sewage is used for crop irrigation and the well water is used by the farmers for domestic purposes
(3) *Microscopic examination of the water showed the presence of protozoa such as *Vorticella* sp.
(4) —not done

TABLE III—RESULTS OF ANALYSIS OF SAMPLES OF WATER FROM A WELL NEAR THE SEWAGE CHANNEL, WHICH WAS DISCARDED*

Characteristics	On December 24, 1970	On August 3, 1972
Turbidity	0	0
pH	7.1	—
Acidity (mg/l)	20	105
Alkalinity (mg/l)	270	285
3-min P.V. (mg/l)	0	2
4-hr P.V. (mg/l)	3	9
Dissolved oxygen (mg/l)	4.0	4.2
BOD (mg/l)	—	15
Ammoniacal N (mg/l)	0	3
Nitrite N (mg/l)	0	0
Nitrate N (mg/l)	20	4.8
Water soluble P (mg/l)	2.1	0.9
Chloride, Cl (mg/l)	790.4	1,679.6
Total bacterial count (per ml)	21,000	—
MPN (per 100 ml)	220	—

Note— (1) * People were using this water for domestic purposes and recently (April 1972) it was discarded.
(2) — not done.

Apart from these serious cases of pollution, there were other samples of water polluted to various extents, as indicated by the analytical figures for ammoniacal, nitrite and nitrate nitrogen, chloride, phosphorus and for bacteria, including coliforms. The people who were consuming these waters complained about intestinal disorders.

3. *Pollution of the Water in the Tank near the Sewage Channel*

One of the sewage channels runs near a large tank in Bangalore. This tank is still used for recreation by the people. Repeated examination of the samples of the water from this tank (Table IV) indicated that the water was polluted by the sewage in the channel.

4. *Examination of the Water in the Tender Coconuts from Trees growing near the Sewage Channel*

It was thought desirable to have an idea of the effect of the flowing sewage on the quality of the water in the tender coconuts on the trees growing near the sewage channel. The quality of the water from these coconuts was compared to the quality of the water from the tender coconuts on the trees growing in an area about 10 miles away from the sewage channel. The results (Table V) showed that the water from the tender coconuts from the trees growing near the sewage channel contained much more nitrate nitrogen and chloride but much less phosphorus than the water from the tender coconuts from the trees growing away from the sewage channel.

5 *Effect of Septic Tanks on the quality of Water in the Wells in the Neighbourhood*

Samples of water were collected from 6 wells near a septic tank on the Institute campus and from 2 wells near a septic tank in the premises of an industrial establishment and were analysed. The effluent from the septic tank on the Institute campus flows down in a shallow channel and the 6 wells are situated within a radius of about a furlong from this effluent channel.

The effluent from the septic tank at the industrial establishment is allowed to soak through the soil and it goes down, but this provision has not prevented the waters in the wells within a radius of about one furlong from being polluted like the other well waters (Table VI).

6. *Quality of Treated Water from the Well near the Septic Tank for the Swimming Pool at the Institute*

For over two years, samples of (i) water from the well near the septic tank, (ii) this water after treatment with alum and bleaching powder as it was sent to the swimming pool of 175,000 gal capacity, and (iii) the water from the pool were collected and analysed. The nitrate, chloride, phosphorus and bacterial contents of the well water (Table VII) would suggest sewage pollution of the original well water. Treatment of this water with alum (about 20 kg/week) and bleaching powder (about 2½ kg/day) removed the phosphorus and coliforms from the polluted well water. But, secondary pollution continuously occurred in the swimming pool as evidenced by the figures for ammoniacal, nitrite and nitrate nitrogen, phosphorus, chloride and bacteria, including coliforms.

TABLE IV—RESULTS OF ANALYSIS OF THE WATER IN A TANK NEAR THE SEWAGE CHANNEL

Characteristics	Sewage in the channel	Water from the tank		
		Sample I	Sample II	Sample III
Turbidity	147	42	69	74
pH	7.5	9.4	—	—
Acidity	50	0	—	—
Alkalinity	410	90	—	—
3-min P.V.	33	2	6	5
4-hr P.V.	66	5	—	—
Dissolved oxygen	0	9.6	—	—
Ammoniacal N	87	0	5.0	5.8
Nitrite N	0	0	0	0
Nitrate N	0	0.6	0	0
Water soluble P	9.5	1.0	0	0
Chloride, Cl	212.4	51.3	59.3	59.3

Note— (1) Results are expressed as mg/l, except turbidity and pH.
(2) The water in the tank was greenish in colour due to the growth of algae.
(3) Water from the Tank: Sample I was taken on December 24, 1970; Samples II and III were taken at different points in the tank on the same day (August 3, 1972).
(4) — not done.

TABLE V—QUALITY OF THE WATERS FROM TENDER COCONUTS FROM THE TREES GROWING NEAR THE SEWAGE CHANNEL AND AWAY FROM IT

Characteristics	Water from tender coconuts	
	Growing near the sewage channel	Growing away from the sewage channel
Volume of water (ml)	370	320
Turbidity	22	35
pH	5.6	5.8
Acidity (mg/l)	700	820
Alkalinity (mg/l)	360	560
3-min P.V. (mg/l)	325	120
Nitrate N (mg/l)	13.7	0.63
Water soluble P (mg/l)	50.5	109.2
Chloride, Cl (mg/l)	2,462.6	1,486.9

Note—NH_3N was not determined; NO_2 N was absent.

TABLE VI—RESULTS OF ANALYSIS OF WATERS FROM THE WELLS NEAR SEPTIC TANKS

Source	Turbidity	NH_3-N	NO_2-N	NO_3-N	Water soluble P	Chloride, Cl
(A) Wells on the campus of Indian Institute of Science: Well No:						
1	4	0.08	tr	0.02	2.42	79.0
2	6	0.08	tr	0.03	0.90	29.6
3	32	0.28	0.11	0.16	2.43	122.8
4	25	0.28	0.08	0.47	5.25	25.7
5	7	0.10	0.04	1.92	4.38	11.9
6	14	0.14	0.05	1.50	5.06	31.6
(B) Wells in the premises of an industrial establishment: Well No:						
1	0	0	0.03	1.90	0.21	113.6
2	0	0	0	1.10	0.15	73.0

Note— (1) Results are expressed as mg/l, except turbidity.
(2) 3-min. P.V. was absent in all the samples.
(3) tr=traces.

TABLE VII—RESULTS OF ANALYSIS OF WATER SAMPLES FROM THE WELL FEEDING THE SWIMMING POOL, AFTER TREATMENT, AND FROM THE SWIMMING POOL

Characteristics	Well water (average of 37 samples)	Treated water (average of 10 samples)	Water from swimming pool (average of 74 samples)
Turbidity	0	0	0
3-min P.V. (mg/l)	0	0	tr
Ammoniacal N (mg/l)	0	0	0.71
Nitrite N (mg/l)	0.02	0.02	0.05
Nitrate N (mg/l)	0.19	0.13	0.43
Water soluble P (mg/l)	2.84	0.25	0.55
Chloride, Cl (mg/l)	61.5	59.5	125.50
Total bacterial count (per ml)	48,216	2,210	71,054
MPN (per 100 ml)	445	0	32

tr=traces

7. *Experiments with the Swimming Pool Water*

With a view to studying the extent of secondary pollution of the water in the pool caused by the swimmers, an experiment was carried out in the laboratory for a month by keeping 2 l of the treated well water in a rectangular glass jar of 2½ l capacity (exposed to two 20 W fluorescent lamps so that algae might grow) and taking out every day 200 ml of the water for analysis and immediately adding 200 ml of the treated water. This procedure was in conformity with the operation of the pool, i.e. the top layer of the water in the pool is automatically removed by the periodical inflow of the treated water. The results of analysis of the water under the experimental conditions are given in Table VIII.

These results indicate that the quality of the water supplied to the pool was such as to cause the growth of organisms and their eventual decomposition, as might be inferred from the figures for dissolved oxygen, nitro-

TABLE VIII—RESULTS OF ANALYSIS OF THE TREATED WATER UNDER THE EXPERIMENTAL CONDITIONS OF REMOVAL AND ADDITION

Date	pH	Dissolved oxygen	NO_2-N	NO_3-N	Water soluble P	Chloride, Cl
March 4, 1972						
Influent	7.0	6.8	0	0.07	0	—
Effluent	7.0	6.6	0	0.07	0	—
March 8, 1972						
Influent	7.2	6.8	0	0.12	0	—
Effluent	8.8	6.4	0	0.13	0	—
March 9, 1972						
Influent	8.6	7.0	0	0.25	0	—
Effluent	8.2	6.4	0.17	0.07	0	—
March 10, 1972						
Influent	8.2	7.2	0.17	0.17	0	—
Effluent	8.5	6.4	0.01	0.13	tr	—
March 14, 1972						
Influent	8.2	7.2	0.01	0.18	tr	—
Effluent	8.5	6.4	tr	0.15	tr	—
March 15, 1972						
Influent	8.2	7.0	tr	0.32	tr	80.5
Effluent	8.6	7.6	0.05	0.34	tr	128.4
March 18, 1972						
Influent	8.2	7.0	tr	0.42	tr	81.0
Effluent	8.7	6.8	0.05	0.26	tr	127.0
March 24, 1972						
Influent	8.7	7.0	tr	0.40	tr	82.9
Effluent	8.5	7.0	0.07	0.53	tr	141.1
March 27, 1972						
Influent	8.0	7.0	0.01	0.56	tr	94.8
Effluent	8.9	6.4	tr	0.45	tr	158.1
March 29, 1972						
Influent	8.4	7.2	tr	0.51	tr	86.9
Effluent	8.6	7.8	0.04	0.67	0.49	217.4

Note— (1) Results are expressed as mg/l, except pH.
(2) The water was clear throughout and did not show ammoniacal nitrogen.
(3) — not done
(4) tr=traces

gen changes and phosphorus. The increase in the chloride content was apparently due to the evaporation of the water, because at the end of the experimental period of one month, only about 50 per cent of the water was left in the glass jar although, when a sample was taken out for analysis, an equivalent amount of water was added. The species of *Chlorella* and filamentous algae protozoa such as the species of *Colpidium* and of rotifers were found on the sides of the jar.

This experiment would suggest that the considerable increases in the ammoniacal, nitrite and nitrate nitrogen, phosphorus and chloride contents of the water in the swimming pool during its operation were due to secondary pollution presumably from the swimmers themselves.

Another experiment was carried out by removing the algal and other growths from the sides of the swimming pool and keeping the material with the swimming pool water in a glass jar of 2½ l capacity (2 l water and 100 ml algal and other material weighing 2.65 g, dry weight). There was a control jar with the water only, without the algal and other growths. Periodical analysis of these waters (Fig. 1) showed that the algal and other growths underwent decomposition, as

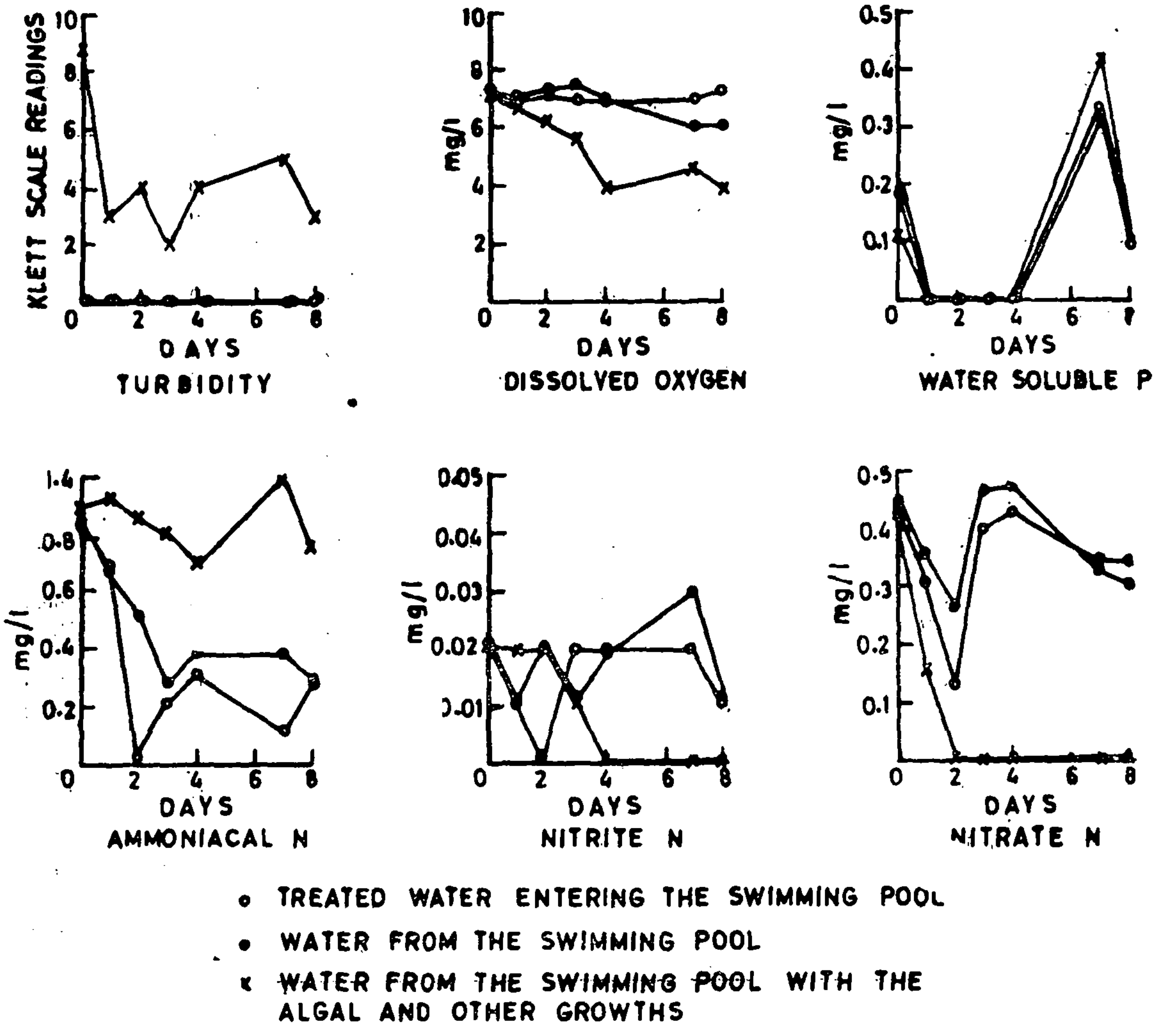

Fig. 1—Effect of the algal and other growths from the swimming pool on the quality of the water.

indicated by the values notably for dissolved oxygen and ammoniacal nitrogen. This would suggest that, under the working conditions of the swimming pool, the quality of the water was also adversely affected by the decomposition of the growths on the sides and possibly at the bottom of shallow region of the pool. The results of periodical examination of the growths showed the following forms of life: algae such as the species of *Chlorella, Cymbella, Gloeotheca, Clostereopsis, Pandorina, Pleodorina,* and *Goleocystis*; protozoa notably ciliates such as the species of *Colpidium, Gonostomum, Spirostomum, Uronema, Lionotus, Vorticella,* and small ciliates (not identified); rotifers and *Chironomus* larvae.

8. *Pollution of the Vegetables irrigated with the Effluent from the Septic Tank*

Samples of amaranthus (*Amarantus* sp.,), cauliflower (*Brassica oleracea),* French beans (*Phaseolus vulgaris),* and chillies (*Capsicum* sp.) grown on the effluent from the septic tank at the Institute were collected and were washed five times successively with distilled water (each time 500 ml water for 110 g amaranthus, 250 ml for 90 g cauliflower, 100 ml for 30 g French beans, and 100 ml for 25 g chillies). The different washings were examined chemically and bacteriologically. The results (Table IX) show that even the fifth washing of the vegetables, particularly of amaranthus, was grossly polluted with the sewage matter and bacteria.

Discussion

This study seems to raise a few points of special and general interest. The continuous flow of crude sewage on the land in and around Bangalore for half a century has naturally polluted the ground water and has also raised the water table in some areas there. Although the favourable topographical conditions have permitted such a mode of sewage disposal, this should be stopped in the interests of environmental sanitation and safe water supply. The use of sewage for growing vegetables, including those eaten in the raw state, should also be prohibited in consideration of public health.

Septic tanks have been generally employed for the disposal of sewage from small communities. But, in view of the growth of population, of industry and of increasing demand for land, it is becoming necessary to treat the effluents from septic tanks so that they would not become a source of pollution of the waters in the neighbourhood. The crops grown on septic tank effluents are also polluted with sewage matter and bacteria.

Again, in the interests of the health of the community, the quality of the waters used for swimming pools should be high as recom-

TABLE IX—RESULTS OF ANALYSIS OF THE FIVE SUCCESSIVE WASHINGS OF THE VEGETABLES GROWN ON EFFLUENTS FROM SEPTIC TANK

Vegetables	Turbidity	3-min P.V. (mg/l)	NH_3-N (mg/l)	NO_3-N (mg/l)	Water soluble P (mg/l)	Chloride, Cl (mg/l)	Total bacterial count at 28°C per ml	MPN per 100 ml
Amaranthus								
1st wash	42	10	0.6	0.788	0.163	14.8	167,000	24,000
2nd wash	20	8	0.4	0.475	0.086	4.9	43,500	16,000
3rd wash	14	9	0.4	0.405	0.068	9.9	45,000	16,000
4th wash	12	8	0.3	0.408	0.074	9.9	22,500	9,200
5th wash	11	7	0.2	0.115	0.061	4.9	11,600	16,000
Cauliflower								
1st wash	3	9	0	0.725	0.104	14.8	2,160,000	24,000
2nd wash	0	2	0	0.335	0.039	4.9	125,000	20
3rd wash	0	4	0	0.090	0.015	9.9	18,800	0
4th wash	0	4	0	0.078	0.015	4.9	8,700	0
5th wash	0	3	0	0.070	0.009	9.9	145	0
French beans								
1st wash	15	8	0	0.200	0.111	9.9	4,500,000	16,000
2nd wash	4	6	0	tr	0.065	9.9	140,000	790
3rd wash	0	4	0	0.050	0.028	9.9	18,700,000	0
4th wash	0	4	0	0.050	0.025	9.9	11,000,000	0
5th wash	0	4	0	0.005	0.022	9.9	112,000	0
Chillies								
1st wash	0	3	0	0	0	9.9	225,000	0
2nd wash	0	3	0	0	0	4.9	194,000	0
3rd wash	0	3	0	0	0	9.9	86,000	0
4th wash	0	4	0	0	0	9.9	180	0
5th wash	0	2	0	0	0	9.9	410	0

Note— (1) None of the washings showed the presence of nitrite nitrogen.

(2) The values for nitrate and phosphorus are given to the third decimal place to ascertain the extent of removal of these by the successive washings.

(3) tr=traces.

mended by the Indian Standards Institution for swimming pool water (8), and the swimmers should be educated about the nature and extent of pollution that may occur in the swimming pools and their own responsibility in the prevention of such pollution. In matters of hygiene and sanitation, as in other matters, the general public require prolonged education until they acquire or develop a sense of personal and public hygiene.

Most of these problems are local or of limited interest; some of them do not exist in other parts of the world or have been solved. There is, however, a point of universal interest and that is the disposal of even the properly treated sewage, which contains the elements of plant nutrition derived from the soil by the crops. Conditions should be created for efficient and hygienic utilization of treated sewage by selected crops (and for fish farming wherever possible) which would ensure circulation of the elements of nutrition for the benefit of man and animals and of the environment.

Summary

Over 200 samples of water from the wells located in the neighbourhood of channels carrying raw sewage and in the neighbourhood of septic tanks were examined and were found unfit for human consumption, although the waters from some of the wells were consumed until they became intolerable.

The water from one of the wells near a septic tank, after treatment, was used for a swimming pool, but the quality of this treated water did not conform to the ISI standard.

Examinations of the crops grown on sewage and on effluents from septic tanks showed evidence of sewage pollution.

While it is necessary to bring back the elements of plant nutrition in sewage into the cycle of life and food, it is also necessary to treat the waste material properly before it is utilized for the control of water pollution and for the promotion of environmental health.

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DISCUSSION

Shri S. Mukherjee (Calcutta): The speaker has shown in the table the quality of water in a well which is situated only 10 ft away from sewage soak pits. It is usual practice to make drinking water wells at least 50 ft away from sewage soak pits. Whether any study has been carried out for this distance of 50 ft and above. People should be discouraged to make drinking wells within 50 ft from sewage soak pits.

Dr. M. K. C. Sridhar: The distance between the location of the soak pits and the wells is well documented. This distance depends on the type of soil. The people who had dug well near the sewage channel had apparently ignored the hygienic aspect but had required a constant supply of water throughout the year.

Shri S. R. Joshi (Nagpur): In India, all uncovered and dug wells are normally polluted. It may be due to ground water which will be contaminated by percolation of sewage or due to unhygienic conditions of wells. How did you differentiate the pollution by ground water and by extraneous matter like fecal matter from birds? Whether wells were covered or not? Were they dug wells or tube wells?

Dr. M. K. C. Sridhar: The well under consideration is situated close to a sewage channel and the results of chemical and bacteriological analysis indicate the sewage pollution.

Shri C. J. Philip (Trivandrum): Did the author make any study to establish the pollution by adding a dye or other chemical?

Dr. M. K. C. Sridhar: No dye or other chemical was used. The high concentrations of chloride and of nitrate nitrogen in the well water indicate sewage pollution.

Shri N. G. Ashar (Bombay): Was malfunctioning of septic tanks not responsible for pollution?

Dr. M. K. C. Sridhar: It is known that septic tanks do not purify sewage.

Shri R. C. Dixit (Nagpur): In the presence of algae how was 5-day BOD determined? Whether oxygen demand for nitrification was considered or not? If not, then how the nitrification was suppressed during the test and carbonaceous BOD was estimated?

Dr. M. K. C. Sridhar: The BOD was determined by removing the algae by centrifugation. Oxygen demand for nitrification was considered.

Shri N. V. Ramamohana Rao: In the paper, authors mentioned that they have determined MPN of coliform/100 ml. I wish to know whether they have done differential tests for faecal coliforms to establish the contamination of water by sewage?

Have they examined for any other bacterial parameters of pollution such as faecal streptococci?

Dr. M. K. C. Sridhar: Differential tests were not done. Other bacterial parameters were not examined.

Shri N. W. Mirchandani (Bombay): The questioner had an opportunity last year to visit some of the swimming pools maintained by the Bangalore Municipal Corporation. It was found that the chlorination equipment was not working due to shortage of chlorine drums and bleaching powder was dumped into the swimming pool off and on. The sludge of the bleaching powder had accumulated and there was no regular programme of cleaning the same. Further, the pressure filters were not operated properly. Irrespective of the loss of head reaching its limits and break through occurring, the filters were washed once a fortnight or so. The filtrate was also not analysed. It is feared that somewhat similar operation and maintenance may have led to the present affairs of the swimming pool in the Institute.

Dr. M. K. C. Sridhar: The water in the swimming pool was polluted mainly at the source. The pool was also not maintained properly.

Dr. V. Chalapati Rao (Nagpur): Whenever sewage is used for irrigation, it may be necessary to tap sewage from a point 5-6 miles after the sewage travels a distance to give chance for self-purification, settling of pathogens with particulate matter and biological inactivation of viruses. In a short term study, we observed human enteric viruses in a concentration of 1000 PFU/l in sewage collected from all parts of Nagpur. But in Nag nalla, a sewage channel, the density of virus was reduced by more than 75% after the sewage travelled 5-6 miles and virus was not detected at a distance of 15 miles.

Dr. M. K. C. Sridhar: No studies on virus were made. The experience at Bangalore shows that, when the sewage flows down vigorously with turbulence in open gradient channels for about 5-6 miles, it is purified to a high degree due to the development and activity of ciliate protozoa such as the species of **Epistylis** and **Carchesium.**

Shri S. S. Rodgi (Dharwar): This report is extensive and very critical. Have the authors made studies on the stratification in these contaminated wells?

Dr. M. K. C. Sridhar: No.

Dr. N. U. Rao: The water in the swimming pool shows a large concentration of coliforms. Do they occur even in the presence of research? Did you try to isolate the enteric pathogens from vegetable washings besides TPC and coliforms?

Dr. M. K. C. Sridhar: The chlorine level was not maintained constant in the pool. The chlorine was injected only when the water was recirculated or during pumping. When there was sufficient chlorine, we could not detect any coliforms.

The washings of the vegetables showed some worms under the microscope. A detailed study was not done.

Shri V. P. Thergaonkar (Jaipur): Were any studies made to correlate soil permeability at Bangalore and the resulting pollution?

Dr. M. K. C. Sridhar: No. But it may be mentioned that the soil at Bangalore is mostly red loam.

Dr. T. J. Boman: Whether people working on the vegetable fields were examined for intestinal parasites?

Dr. M. K. C. Sridhar: Earlier studies from our laboratory showed that the people working on the sewage farm suffered from hookworm infection. Certain control measures were suggested.

Dr. G. B. Shende (Nagpur): Whether there was any ground water pollution due to irrigation of sewage effluents to vegetable crops?

Dr. M. K. C. Sridhar: Yes.

Dr. (Smt.) S. M. Vachha: Can you please inform what is the relation of the high pollutional load shown in swimming pool studies and the period of cleaning the swimming pool?

Dr. M. K. C. Sridhar: The swimming pool is cleaned at intervals of one to three months. The interval depends on the season and the number of people using the swimming pool and also on the availability of water for filling. When the cleaning was delayed, there was more pollution in the pool.

CHAPTER-II

INDUSTRIAL WASTE TREATMENT

PROC. SYMP. ON ENVIRONMENTAL POLLUTION (1973)

Effect of Iron in Anaerobic Lagooning of Molasses Distillery Wastes

R. SWAMINATHAN,* N. BASHEER AHMED* and A. RAMAN*

Long detention anaerobic lagoons have been tried recently in the country for the treatment of molasses distillery wastes which have low pH, and high sulphates not favourable to anaerobic fermentation. A study was, therefore, carried out to determine whether iron addition in reasonable quantities will speed up anaerobic digestion of distillery wastes in lagoons for a period of about 2 years. The studies showed that iron addition would be quite beneficial in the anaerobic lagooning of distillery wastes and the proposition would be economically feasible.

Introduction

In recent years in India, anaerobic lagoons have come into use for treating molasses distillery wastes. The detention capacity of these lagoons have been 60-90 days. Subba Rao (1) has reported a semi-full scale lagoon of this type at Sangli and a full scale lagoon at Golagokarnath. At Tiruchirapalli in Tamil Nadu, a field scale anaerobic lagoon treating about 30,000 gpd of distillery waste has been in operation for about 3 yr under the direction of the State Water and Sewage Purification Committee.

In anaerobic lagoons, the purification is brought about by methane fermentation. Some of the characteristics of molasses distillery wastes such as high acidity, low pH and high sulfate content are unfavourable for methane fermentation. Distillery wastes also have strong odours which could become a problem in open anaerobic lagooning.

Iron addition has been reported to be beneficial in methane fermentation. McCarty *et al.* (2, 3) has reported that addition of 20 to 50 mg/l of Fe in the form of Ferric or Ferrous salts or simply as iron filings is necessary for continuous methane fermentation, and that the reason for the iron requirement is not known. Jackson (4) has also reported that addition of iron had very pronounced effect on anaerobic digesters treating distillery wastes. In addition to reduction in detention time, the iron appeared to stabilize the process by preventing cyclic activity and decline. When iron addition was discontinued, the digesters deteriorated rapidly.

This paper presents the results of a laboratory study for a period of about 1½ yr on iron addition in the anaerobic lagooning of distillery wastes. The aim of the study was to determine whether iron addition in reasonable quantities would be beneficial in the anaerobic lagooning of distillery wastes.

Experimental Set-up

The studies were carried out on laboratory models of anaerobic lagoons with a detention time of 60 days and 1.7 m depth. In order to simulate conditions in field lagoons, temperature control or mixing was not adopted and the lagoons were kept open. The wastes were introduced at the bottom of the

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* Research Division, Tamil Nadu Water Supply and Drainage Board, Chepank, Madras-5.

lagoons and the effluents were withdrawn at the top. The raw waste dosings and effluent withdrawals were done only once in 24 hr. The dosings always succeeded the withdrawals. The conditions of field lagoons were simulated except in regard to the dosings and withdrawals. It was felt that, in view of the considerable detention time provided in the lagoons, the sludge withdrawals and dosings may not affect the performance of the lagoons significantly.

The wastes were obtained from the Trichy Distilleries and Chemicals factory at Tiruchirapalli, Tamil Nadu. In this distillery, the fermentation tank washings are segregated from the spent wash wastes. Only the spent wash was utilized in the studies. The characteristics of the wastes are shown in Table I.

Observations were also made on the degree of odour, and gas and sulphide evolution in the lagoons. Routine tests were made on the influent and the effluents for pH, COD (total and soluble) and sulphates. Occasional tests were also done for BOD ; sodium and potassium. Gas evolution was visually estimated by the degree of frothing at the liquid surface. Sulphide evolution was determined qualitatively by recording the degree of discolouration of lead acetate paper kept exposed over the laboratory lagoon surface for one hr immediately after the waste feed. Generally, all chemical analyses were made in accordance with the Standard Methods (5). Soluble COD was determined on samples centrifuged for 5 min. at 3500 rpm.

TABLE I—CHARACTERISTICS OF SPENT WASH FROM A MOLASSES DISTILLERY

Characteristics		Average Values*
Colour		Dark brown
Odour		Molasses
pH		3.5—3.65
COD (Dichromate Value)		
	Total	1,18,000
	Dissolved	1,06,000
BOD (5 day, 20°C)		41,380
Total solids		99,000
Suspended solids		350
Dissolved solids		98,650
Volatile solids		62,500
Total nitrogen (N)		1,135
Free Ammonia (N)		28
Chlorides (Cl)		5,500
Sulphates (SO_4)		4,200
Volatile acids as acetic acid		6000
Total Acidity ($CaCO_3$)		16,850
Mineral Acidity ($CaCO_3$)		2,000
Potassium (K)		5,070
Sodium (Na)		1,100
Calcium (Ca)		2,700
Magnesium (Mg)		2,400
Iron (Fe)		60

* All values except pH are in mg/l

Details of Study-I

In this study, the lagoons were seeded to 1/3rd their volumes (equal to 20 days' flow of wastes) with digested sludge taken from an anaerobic pond treating domestic sewage. The seed sludge had 96% moisture and 50% volatile solids. The lagoons were fed from the start itself with the distillery wastes without dilution. The dosage was maintained from the beginning at the full rate of 1/60th lagoon volume per day.

Three lagoons A, B and C were operated during the study. The lagoon A was operated as control and was dosed with raw wastes without neutralisation or iron addition. Lagoon B was dosed with raw wastes neutralised to pH 7.0 with lime. The lime dosage was 12,000 mg/l as $Ca(OH)_2$. Lagoon C was fed with raw wastes fortified with iron. The iron was added as $FeSO_4 .7H_2O$ in 0.5% solution of the salt. The iron dose was arbitrarily fixed at 50 mg/l of Fe. This rate was adopted so that the requirement of the chemical in field conditions may not be impracticably high. The BOD_5 loading of the lagoon was 0.55 kg/cu m/day and the volatile solids loading was 0.85 kg/ cu m/day.

The study was conducted for a period of eight months. The details of the lagoons and the characteristics of the effluent are shown in Table II. The reported characteristics are the averages obtained over a period of four months succeeding two displacements of lagoon volume during the 5th and the 8th month period.

TABLE II—PERFORMANCE OF LAGOONS IN STUDY I

Lagoon No.	Detention time (days)	Lime addition (mg/l)	Influent pH	Iron addition (mg/l)	Effluent pH	Effluent COD (soluble)		Sulphate (mg/l)	H_2S evolution	Degree of odours	Gas frothing
						(mg/l)	%Reduction				
A	60	—	3.5	—	5.2-5.8	45,500	55	387	Poor	High	Poor
B	60	12,000	7.0	—	8.1-8.5	21,100	80	0	High	Moderate	High
C	60	—	3.5	50	8.2-8.4	22,400	79	0	High	Low	High

Note—Average mid-day temperature of lagoons was 35°C.

Details of Study-II

It will be noted that in Study I, the lagoons were started with quite high volumes of seed sludge which might not be possible in field installations. In study II, the lagoons were started, using seed sludge equal only to one day's flow of wastes. The seed sludge was from the same source and had the same characteristics as in Study I.

Unlike in Study I, the lagoons were started up with diluted wastes in Study II. Initially, the lagoons were dosed with 1/5th the rated dosage of raw wastes made up with 4/5th tap water (dilution ratio of 1:4). During operation, the proportion of raw waste in the feed was increased progressively such that the lagoon did not turn sour i.e. the pH did not drop. In lagoons E and F, based on the criterion of pH, dilution with tap water was discontinued after two months. But in lagoon D, due to persistent sour conditions, dilution ratio could not be reduced beyond 3:2 (wastes: tap water) even after 5 months.

Lagoon D, the control, was dosed with raw wastes. Lagoon E was dosed with lime neutralised wastes, lime being added only to neutralise the mineral acidity *i e.* to raise the pH to 4.5. The lime dose required was 6000 mg/l as $Ca(OH)_2$. Lagoon F was fed with iron fortified wastes. The dosage of iron was the same as in lagoon C of Study I, i.e., 50 mg/l.

The lagoons started overflowing at the end of two months. The lagoons were kept under study for a period of 5 months from the start up. The details of the lagoons and the observations made on them during the 5 months operation are summarised in Table III.

Details of Study-III

Study III was made on the effect of discontinuing iron addition on the performance of the lagoons. In this study, two lagoons G and H which had been in operation for 3 months treating distillery wastes fortified with iron at 50 mg/l were taken. Their performances were checked up and found to be identical. Thereafter, in lagoon G, iron dosage was discontinued while in the lagoon H, iron dosage was continued as before. The lagoons were then run for 6 months. The performance of the lagoons is compared in Table IV.

Results and Discussion

The raw wastes were characterised by low pH (3.5), high acidity (including mineral acidity to an extent of 2000 mg/l), high sulphates and high dissolved salts as represented by fixed solids. These characteristics may be considered as unfavourable since methane fermentation is retarded at pH below 6 and at high concentrations of dissolved salts (3) and when sulfates are high (6). The raw wastes were also characterised by a high percentage of soluble COD equal to 90% of the total COD. A high percentage of soluble COD (95% of the total COD) persisted in the lagoon effluents also.

In Study I, the volumetric ratio of waste input to seed sludge was 1 in 20, whereas in Study II, the ratio was 1 in 5 initially because of dilution. Lagoon A and D of these studies were both dosed without neutralisation or iron addition. Lagoon A did not develop proper anaerobic activity inspite of the high amount of seed sludge provided. Similarly, lagoon D also did not show signs of proper anaerobic digestion inspite of the dilution. The pH remained much below 7.0 in both the lagoons. The percent COD removal was also unsatisfactory compared to the other experimental lagoons. In lagoon A, the average COD removal was only 60 percent. The percent COD removals in this case and in all the subsequent cases have been based on soluble COD in the influent as well as in the effluent in view of the fact that most of the COD in the wastes and in the effluent are in the soluble form.

Lagoon B of Study I was dosed with the wastes neutralised to pH 7.0, using lime. Lagoon E of Study II was fed with wastes neutralised to pH 4.5, also using lime. Both these lagoons gave successful performances. In lagoon B, the COD reduction was 80%. In lagoon E, at the end of the fifth month of operation the COD reduction was still higher (85%) but this apparent better performance might have been due to the continuing effects of the initial dilution. Sulphates were absent in both of the lagoons, unlike in lagoons A and D. H_2S evolution was quite marked in both of the lagoons. Gas evolution was also quite high compared to lagoons A and D which did not show any frothing. The pH of the lagoons remained well above 7.0. There was very little spent wash odour in the two lagoons and in spite of the greater

TABLE III—PERFORMANCE OF LAGOONS IN STUDY II

Characteristics	At Start	After 30 days	After 60 days	After 90 days	After 120 days	After 150 days	Remarks
LAGOON D (60 days' detention with raw wastes)							
Dilution ratio (Wastes: Water)	1:4	2:3	3:2	3:2	3:2	3:2	
pH	4.0	6.5	6.1	5.9	5.3	5.2	
COD, mg/l (soluble)	—	—	—	15,500	27,300	30,500	Overflow
SO_4, mg/l	800	—	—	—	250	275	commenced
Gas frothing	—	Low	Low	Low	Low	Low	after 60
H_2S evolution	—	Low	Low	Low	Low	Low	days.
Odour level	High	High	High	High	High	High	
Volatile acids, mg/l	2800	—	—	—	—	8350	
LAGOON E (60 days' detention with wastes neutralised to pH 4.5)							
Dilution ratio (Wastes: Water)	1:4	2:3	0	0	0	0	
pH	5.0	7.4	7.3	7.3	7.6	7.7	
COD, mg/l (soluble)	—	—	—	9,450	15,000	15,500	Overflow
SO_4, mg/l	750	25	--	0	0	0	commenced
Gas frothing	—	High	High	High	High	High	after 60
H_2S evolution	—	Low	High	High	High	High	days.
Odour level	High	Moderate	Low	Low	Low	Low	
Volatile acids, mg/l	1800	—	—	—	—	1250	
LAGOON F (60 days' detention with Fe-fortified wastes)							
Dilution ratio (Wastes: Water)	1:4	2:3	0	0	0	0	
pH	5.0	7.1	7.3	7.5	7.7	7.7	
COD, mg/l (soluble)	—	—	—	9,500	15,000	17,500	Overflow
SO_4, mg/l	700	25	—	0	0	0	commenced
Gas frothing	—	High	High	High	High	High	after 60
H_2S evolution	—	Low	High	High	High	High	days.
Odour level	High	Moderate	Low	Low	Low	Low	
Volatile acids, mg/l	2000	—	—	—	—	1200	

TABLE IV—PERFORMANCE OF LAGOONS IN STUDY III

Characteristics	At Start	After 30 days	After 60 days	After 90 days	After 120 days	After 150 days	After 180 days
LAGOON G (Iron addition discontinued)							
pH	7.6	7.6	8.0*	7.2	7.2	7.2	7.3
COD, mg/l (soluble)	26,000	28,000	34,000	40,000	42,000	43,000	43,000
SO_4 , mg/l	0	100	100	400	450	600	600
Gas frothing	High	Moderate	Low	Low	Low	Low	Low
H_2 S evolution	High	Moderate	Low	Low	Low	Low	Low
Odour level	Low	Moderate	High	High	High	High	High
Volatile acid, mg/l	1200	1700	1900	2000	2600	2900	2600
LAGOON H (iron addition continued)							
pH	7.6	7.6	8.2*	7.6	7.6	7.7	7.7
COD, mg/l (soluble)	26,000	26,000	26,000	26,000	26,000	26,000	26,000
SO_4 , mg/l	0	0	0	0	10	0	0
Gas frothing	High	High	High	High	High	High	High
H_2 S evolution	High	High	High	High	High	High	High
Odour level	Low	Low	Low	Low	Low	Low	Low
Volatile acid, mg/l	1200	1600	1600	1600	1700	1600	1600

* Average mid-day temperature of lagoons during this period was 38°C

amount of sulphide evolution, the lagoons presented lesser odour nuisance than lagoons A and D.

Lagoon C of Study I and F of Study II were dosed with the raw wastes fortified with iron. These lagoons functioned almost as efficiently in regard to COD removal as lagoons B and E treating lime neutralised wastes. The COD reduction was 79% in lagoon C and 82% at the end of fifth month in lagoon F. The pH in the two lagoons remained well in the alkaline range. Gas frothing and H_2 S evolution were present to the same extent as in lagoons B and E. The sulphate reduction was complete in both of the lagoons. The odour nuisance from the lagoons was much less than in the previous cases with almost complete elimination of spent wash smell.

Lagoon G and H had been treating iron fortified wastes for a period of five months and giving identical performance. When Study III was started, iron dosing was discontinued in one of these lagoons (lagoon G), there was slow deterioration in its performance. At the end of six months, the pH in the lagoon had fallen to 7.2 compared to 7.7 in the control lagoon H, receiving iron fortified waste. The COD reduction was only 60% as against 74% in lagoon H. The sulphate content of the effluent was 600 mg/l compared to nil in lagoon H. The odour level of lagoon G also increased significantly, whereas in lagoon H, it remained low.

The present studies have indicated that iron addition may be quite beneficial in the anaerobic lagooning of distillery wastes. The actual role played by the iron in stimulating the anaerobic digestion is under investigation. It has been found that the raw distillery wastes are not deficient in iron. These have an iron content of 60 mg/l. It has also been found that the effluent from all the lagoons had this same iron content whether iron was added to the wastes or not. Presumably, the added iron was being retained in the sludge in the lagoon.

Conclusions

The present studies show that :

1. It may be difficult to establish proper anaerobic activity in lagoons using raw distillery wastes as feed. When anaerobic fermentation is not properly established, the

lagoons may give off strong odours. Successful start-up of lagoons using raw wastes may probably require greater amounts of seed sludge or greater initial dilution of raw wastes and slower reduction of dilution ratio than employed in the present studies.

2. Neutralisation of distillery wastes with lime will help in quickly establishing the anaerobic activity in lagoons. When proper anaerobic activity is established using lime, the lagoon may not cause any odour nuisance. The amount of lime required for neutralisation may be quite large.

3. Iron addition may also help the quick and successful establishment of anaerobic fermentation in distillery wastes lagoons. Unlike the lime requirement, the iron requirement may be quite small. Iron addition appears to be capable of suppressing odours of the lagoons to the greater extent than lime neutralisation.

4. Continuous addition of iron appears to be necessary for maintaining the efficiency of distillery wastes lagoons.

5. Further studies are necessary to explain the actual role played by iron in stimulating the anaerobic digestion.

6. Both lime neutralisation and iron addition appear to be useful in the treatment of distillery wastes. Lime neutralisation may be quite costly because of higher requirements of the chemical. On the other hand, the cost of iron addition may not be much. The iron addition for fortifying 0.1 mgd distillery wastes for anaerobic lagoon treatment at a dose of 50 mg/l may be only 250 lb of $FeSO_4 .7H_2O$ and the cost may not exceed Rs. 50 per day. In view of the low cost involved, iron addition appears to be a practical proposition for field installations.

Summary

A laboraotry study was carried out on the anaerobic lagooning of distillery wastes with a detention period of 60 days. The lagoons were dosed with raw wastes, raw wastes neutralised with lime and raw wastes fortified with iron at a dosage of 50 mg/l of Fe. With the methods of seeding and starting up employed in the studies, the lagoons treating the raw wastes did not pick up anaerobic activity. However, the lagoons treating neutralised wastes and iron fortified wastes picked up anaerobic activity successfully. Odour nuisance was minimum in the iron dosed lagoons. In one of the iron dosed lagoons, discontinuance of iron addition resulted in the deterioration of the lagoon. The cost of iron addition in anaerobic lagoons treating distillery wastes may be quite small. Therefore, the method can be applied in the field

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DISCUSSION

Shri B. N. Patil: Iron is a transition element, possessing bacteriostatic property. How the addition of iron has helped in enhancing the growth of microbes thereby improving the quality of water in lagoon?

Shri A. Raman: In the present case of anaerobic fermentation, the added iron was not bacteriostatic as shown by the results. The specific need for iron in methane fermentation has been reported by McCarty, quoted in our paper. Presently, we have reported only the effects of iron addition. The mode of operation of the iron is under further investigation.

Shri V. Raman: The increase in the rate of fermentation process due to addition of iron salts is a new finding. Will the reason for this phenomenon be because of new types of bacteria being developed, which may enhance the process? Has the author examined the microorganisms present in the sludge?

Shri A. Raman: The beneficial effects of iron in methane fermentation and specifically in distillery wastes digestion have been reported by McCarty and Jackson (see the main paper) and cannot be considered a new finding. The digester flora have not been studied so far in an attempt to explain the phenomenon. The suggestion in this regard is welcome and will be tried out.

Shri K. R. Bulusu (Nagpur): Ferrous and ferric iron is non-existent in significant concentrations in alkaline aqueous solutions, such as the wastes under discussion. The pH is unfavourable and all iron will be precipitated as sulphide; the ions undergo de-protonisation resulting in the formation of several polyhydroxynuclear complexes before precipitation. In view of this transition, it is not clear as to how soluble iron species can exist as Fe^{++} as mentioned by the author and as to how the traces that can remain in solution help in the anaerobic lagooning process of molasses distillery wastes. The authors may kindly clarify.

Shri A. Raman: The anaerobic lagoon environment was near neutral pH and was not alkaline. The authors have also not stated in the paper that the iron remained in the lagoon as soluble iron. In spite of the possibility of its precipitating out as sulfide, the added iron was still useful in accelerating the anaerobic process. The exact reactions due to the added iron are under study.

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Wastewater Treatment of Union Carbide's Trombay Plant

D. CHOUDHURY* and A. K. AWASTHI*

Union Carbide's Sewage Treament Plant reclaims water from the Bombay Municipal Corporation's sewer, by activated sludge process with the BOD of the reclaimed water less than 1 mg/l. Exploratory work in the Laboratory, for utilising this process for treatment of the effluent, showed severe poisoning of the micro-organisms and hence this approach was abandoned. A project study was, therefore, initiated in the laboratory for development of micro-organisms resistent to chemical poisoning and capable of effective biodegradation of petrochemical wastewater.

The paper describes successful development of aerobic organisms from raw sewage. These were found to reduce influent BOD by 97 percent at variable organic loadings from 0.1 to 0.32 kg BOD/d/kg MLSS. At higher organic loadings, addition of nutrients was found necessary. This work has been extended further to pilot plant scale, with batch and continuous operation. Performance characteristics have been improved in pilot plant, which can successfully biodegrade 90 percent BOD at varying fluctuations of F/M ratio from 0.1 to 0.6.

Introduction

At Union Carbide's pertochemical complex, the refinery naphtha is steam cracked to ethylene, propylene, butanes and aromatics, etc. These are refined by fractional distillation. Fermentation alcohol-based chemicals, e.g. acetic acid, butanol, 2-ethyl hexanol, esters and plasticisers, etc., are also manufactured.

Petrochemical wastewater is more difficult to treat than any other wastes, because of its diverse organic and inorganic chemical constituents. The usual practice followed is to segregate the streams on the basis of pollutants and then follow primary, secondary and tertiary treatment. The degree and nature of the treatment is usually dictated by wastewater characteristics, local legislations and economics.

Wastewater Characteristics

Pollution abatement in a petrochemical industry starts from improving daily plant operation, either by elimination or reduction of finished and intermediate product losses from leaks, spills, high loadings and inefficient decanting, etc.

Hence, effluent sampling and monitoring for detection and identification of discharges in wastewater streams, are necessary in effective control. The pollution in a wastewater stream has always been measured as oxygen demand. However, it has two serious limitations: (i) it is time consuming to collect oxygen demand data, and (ii) it does not help to identify the source when many operating units are involved. Realising the problem, the Institute Plant of Union Carbide Corporation (1), as a part of their

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* Carbide Chemical Co., Union Carbide (India) Ltd., Bombay.

waste water control programme, had introduced total carbon analyser and gas chromatograph for continuous monitoring of effluents. Their experience was very revealing, in that, after six months of installation of these equipments, they were able to reduce organic loadings in the sewer by more than 50 percent.

The authors cite an example from their Institute Plant operations on total carbon and chromatographic analysers systems for detection and identification of an abnormal pollution load of effluent discharge: "One day, at about 1.00 PM, the total carbon loading started to increase from its normal level of less than 20 ppm. When it was detected, all production units discharging into the sewer were informed that a spill was in progress, but none of the units admitted any difficulties. At 1.05 P.M., the sample was injected in the gas chromatograph and within 35 minutes, the spill was identified as ketone. The concerned operating unit was notified of the identification. They were able to locate its source soon. A decanter level control had failed to function and, therefore, was causing discharge. The fault was corrected and within two hours of detection the effluent pollution load returned to normal."

In Trombay Plant, a survey was conducted to find out, (i) extent of pollution, and (ii) type of pollution, as part of the pollution abatement programme. All the wastewater streams were analysed. In total, sixtyone streams were subjected to investigation and representative samples were taken. Flow measurements were also done, using calibrated weirs of rectangular, triangular and trapezoidal shapes. Following measures were also taken: (i) Segregation of streams on the basis of pollution load; (ii) Cutting down on oil and organic discharges, spills and leaks; (iii) All process water was channalised and given primary treatment; (iv) Making operators aware of the necessity of keeping organics out of the process sewer. As a result, the nalla which carries the bulk of the wastewater is clean, having a BOD (5-days 20°C) between 15 to 25 mg/l.

Systematic investigations on wastewater effluent revealed that the process water contained contaminants, which necessitated institution of tighter controls at the operating unit level. Decanters, liquid level controllers and even stripping columns were provided for this purpose. It was noticed that in one of the chemical units, a small amount of crotonaldehyde was found in the refining unit tails. The amount was very small. However, because crotonaldehyde is a lachrymator and detectable at the 1 mg/l level, it was decided to provide suitable facilities for its removal. One additional stripping facility was installed, alongwith decanters and liquid level controllers. Besides these, facility for addition of caustic to condense any residual material was provided at the unit skimmer pit, so as to prevent the higher aldehydes from entering the plant process sewer. However, it must be borne in mind that in organic chemical industries, water is often a reaction product and many organics, specially the alcohol-based chemicals, are more or less water soluble and, therefore, usage of all the above mentioned devices do not prevent the presence of small amounts of organics in wastewater streams. Because of this, it was found that the plant effluents contain traces of acetic acid, formic acid, acetaldehyde, butyraldehyde, butanol, crotonaldehyde, aldehyde polymers, 2-ethyl propylacrolein, 2-ethyl hexanol, ethyl acetate, butyl acetate, D.O.P., benzene, xylene, toluene, mixed light and heavy hydrocarbons. The separable oils, after settling and decantation, were found to be negligible. The work revealed that primary treatment and effecting stringent controls at the operating units did reduce the organic loadings considerably and, in some cases, well over 50 percent. However, for further removal, it will be necessary to find a suitable biological process which can remove such diverse chemical pollutants.

Biological Treatment

Activated sludge treatment for industrial wastewater, bearing high organic content (2), acetone (3), aniline (4), benzene and xylene (5), phenols (6) and similar organic compounds from petroleum (7), and chemicals from organic chemical plant (8) have been found practical. American Petroleum Institute (9) has surveyed the treatment methods used for petrochemical wastes. Mostly, for secondary treatment, it is activated sludge plant, lagoons, oxidation ponds, trickling filters and anaerobic digestion in some combination with aerobic system that is used. The anaerobic treatment is generally suited for concentrated wastes, with B.O.D. (5 days, 20°C), in excess of 10,000 mg/l (10). The complete treatment of petrochemical waste conforming to near zero discharge is costly and is achieved by combination of methods.

Aerobic biological treatment process traditionally uses air and operates above a critical dissolved oxygen (DO) concentration in the mixed liquor of 0.2 to 0.5 mg/l (11). Below this level, the rate of bacterial respiration is dependent on dissolved oxygen concentration and the rate of waste assimilation decreases. Union Carbide Corporation's Linde Division has developed a very successful process for wastewater treatment, utilising pure oxygen contact with wastewater. The advantages of this process over aeration process are: (i) economic operation at high D.O. levels compared to conventional aeration; (ii) operation under high rate, high MLSS levels, speedy sludge settling and it compacts well; (iii) low net sludge production with low retention time, and (iv) higher rate of microbial metabolism.

Bench-scale Treatability Studies

Union Carbide reclaims water from the Bombay Municipal Sewer by an activated sludge process. This is a tertiary treatment plant, the only one of its kind in Asia, built at the cost of Rs. 50 lakhs. The plant effluent, after treatment, has the following characteristics: pH, 7.2 to 7.4; BOD (5 days, 20°C) $<$ 1 mg/l; COD 6 to 10 mg/l; TDS 350 mg/l. About 4 mil l/day are reclaimed and it has a designed capacity for 5 mil l/day. The treated water, after passing through a demineralisation unit, is also used as boiler feed water.

The initial efforts were to see if the industrial wastewater could be fed into the sewage reclamation plant. One part of wastewater was added to 99 parts of raw sewage to make a mixture of 2.5 l. It was then added to 2.5 l of activated sludge from the plant, having mixed liquor concentration of 3870 mg/l. Aeration was carried out by an aquarium aerator for 21 hr, which was nearly three times more than sewage plant aeration. After aeration, MLSS was allowed to settle and the top layer was siphoned off. A fresh mixture of industrial waste plus raw sewage was then added, to make the volume 5 l. The microorganisms were observed every day under a microscope for any possible change. It was found after five days that visible red stains have developed on them; moreover, MLSS also dropped to 3010 mg/l. Results obtained are given in Table I.

TABLE I—INDUSTRIAL WASTE FED INTO S.W.R.P. ACTIVATED SLUDGE PLANT

Experiment No.	COD of Influent Mixture; 2.5 l	COD of Effluent Mixture; 5 l	MLSS	Remarks
1	448	54.4	3870	
2	470	52.8	3490	
3	480	64.0	3340	
4	512	61.0	3250	
5	496	58.0	3010	Red stains developed after 5 days

Note— (1) All values are expressed in mg/l.

This approach was discontinued further because wastewater treatment in the sewage plant was not feasible for two reasons: (i) Due to severe poisoning of micro-organisms; and (ii) Inspite of higher aeration period, effluent COD was 52 to 64 mg/l, about three times higher than clarifier COD of sewage plant.

Similar poisoning was found when relatively low BOD and high ammonia bearing effluent of a fertilizer plant was tried. It was, therefore, clear that the organisms of a sewage plant are sensitive to industrial wastewater. The high COD water produced would be unsuitable for use in ion exchange beds for the production of boiler feed water.

It was decided to see if micro-organisms could be developed from raw sewage containing small amounts of industrial waste. Such microorganisms, it was thought, would have developed in a culture medium carrying industrial waste and would, therefore, be able to both survive and metabolise efficiently with higher dosage of petrochemical wastewater. For laboratory-scale experiments, a plastic carboy (height, 27.9 cm x diam 17.8 cm) was used as aeration tank. An aquarium aerator with 1 cu in. (16.4 cu cm) silica sparger was used. Raw sewage (5 l) containing 1 percent industrial waste, was placed in the container. The aeration rate was kept at 50 l/hr for 18 hr. After aeration, the mixture was allowed to settle and the supernatant liquid was siphoned off, leaving 2.5 l in the tank. To start the second experiment, 2.5 l of 1% industrial waste-bearing raw sewage was added and the total of 5 l volume was aerated for the required period. Evaporation losses were thus taken care of by this procedure. Effluent analysis was carried out on the supernatant liquid, using Standard Methods (12, 13).

The micro-organisms took about 7 weeks to develop and, in that period, MLSS was found to be 4000 mg/l. Then feeding of higher dosage of industrial waste was started, keeping aeration period and rate constant. After about 800 BOD feed to influent mixture, percent BOD removal was observed to be low. Therefore, addition of nitrogen and phosphorous as nutrients was started. This was to compensate for the lack of nitrogen and phosphorous supply from raw sewage. The waste does not have nitrogen and phosphorous compounds, which are essential for cell synthesis. For nitrogen supply, ammonium nitrate and for phosphorous, orthophosphoric acid were used. In 100 parts BOD 10 parts nitrogen and 1 part phosphorous were added in the influent mixture. The nutrient addition had marked influence on percent BOD removed. Progressively higher dosage of BOD was fed into aeration tank, keeping the aeration period and rate constant. The dissolved oxygen of the aerated mixture was also kept close to 2 mg/l. As higher dosage of BOD was fed, the requirement for air also went up.

The influent mixture pH was always adjusted and kept within 6 and 7.5. Initially, experiments were carried out maintaining MLSS range from 4000 to 6000 mg/l. Temperature of aeration mixture varied from 24°C to 30°C. Friedmann and Schroeder (14) have investigated the effect of temperature on growth and yield of activated sludge. It was found that maximum sludge yield occurred at 20°C. Apparently, carbon removal efficiency did not fluctuate very much with temperature and there was no appreciable difference from 12.4°C to 50°C.

Results obtained at different levels of organic loadings for 4000 to 6000 mg/l MLSS range are listed in Table II. The COD loading was given from 0.2 to 0.69 kg/d/kg MLSS and BOD loading was from 0.1 to 0.32 kg/d/kg MLSS. pH of the effluent was found to increase by 1 to 1.5 units. The percent BOD removal in the effluent was found to be 97+, whereas for COD it was low, 93+. The BOD : COD ratio of the influent was from 0.42 to 0.55 and seemingly it had no effect on efficiency of organic removal. The plot of BOD : COD ratio against percent BOD and COD reduction is given in Fig. 1. The lower BOD : COD ratio of the effluent indicated maximum treatability. For 97 + percent removal of BOD, the BOD : COD ratio of the effluent was usually around 0.15. MLSS was found to increase regularly with occasional

TABLE II—LABORATORY-SCALE DATA WITH 4000 TO 6000 mg/l MLSS

Expt. No.	Organic Loading (kg/d/kg MLSS)		pH		BOD/COD Ratio		COD (mg/l)			BOD (mg/l)			MLSS (mg/l)		Remarks
	COD	BOD	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	% Reduction	Inf.	Eff.	% Reduction	Initial	Final	
1	0.22	0.11	6.7	7.85	0.49	0.38	2205	411	81.36	1100	160	85.45	4860	6200	
2	0.24	0.09	7.2	7.60	0.51	0.37	2700	697.5	74.16	1400	200	81.42	5540	6180	
3	0.43	0.24	6.8	8.5	0.55	0.14	4325	339	92.16	2400	50	97.92	5020	5080	
4	0.61	0.31	7.1	8.5	0.50	0.15	7000	640	90.85	3500	100	97.14	5700	5830	
5	0.60	0.31	7.0	8.3	0.51	0.14	7040	680	90.32	3600	100	97.22	5830	6000	
6	0.69	0.33	7.3	8.45	0.47	0.29	8400	712	91.52	4000	210	94.75	6070	6200	
7	0.57	0.30	7.10	8.10	0.52	0.18	6300	640	89.84	3300	120	96.30	5500	5700	
8	0.25	0.11	7.0	7.65	0.42	0.28	3075	682.5	77.80	1300	192	85.23	6060	5900	Drop in MLSS
9	0.52	0.32	6.95	7.95	0.48	0.14	5350	336	93.72	2600	50	98.08	5080	5100	
10	0.53	0.28	6.7	8.2	0.52	0.15	5500	300	94.54	2900	46	98.41	5180	5200	
11	0.54	0.28	7.0	7.85	0.50	0.14	5800	350	93.96	3100	50	98.38	5280	5320	
12	0.27	0.12	7.0	7.45	0.46	0.14	2250	195	91.33	1050	28	97.33	4100	4640	
13	0.33	0.15	7.2	7.40	0.44	0.13	2700	240	91.11	1200	32	97.33	3980	4100	
14	0.58	0.35	7.0	7.35	0.60	0.51	4620	2625	43.54	2800	1360	51.42	3968	3980	Aeration has not been proper
15	0.53	0.25	6.40	8.35	0.47	0.28	4950	249	94.97	2300	52	97.7	4640	5000	
16	0.52	0.25	6.9	8.30	0.48	0.155	5350	387	92.76	2000	60	97.69	5100	5180	
17	0.53	0.23	7.1	7.75	0.53	0.175	5700	400	92.98	3000	70	97.66	5320	5500	
18	0.51	0.25	7.3	8.70	0.48	0.20	5200	267	94.86	2500	54	97.84	5040	5020	
19	0.21	0.12	6.25	7.60	0.47	0.42	2112	690	67.32	1200	288	42.50	4980	6060	
20	0.35	0.17	6.20	7.40	0.48	0.28	3975	1200	69.81	1900	335	82.36	5640	5480	Drop in MLSS
21	0.30	0.15	6.25	7.70	0.48	0.33	3375	945	72.00	1615	315	80.49	5480	6460	

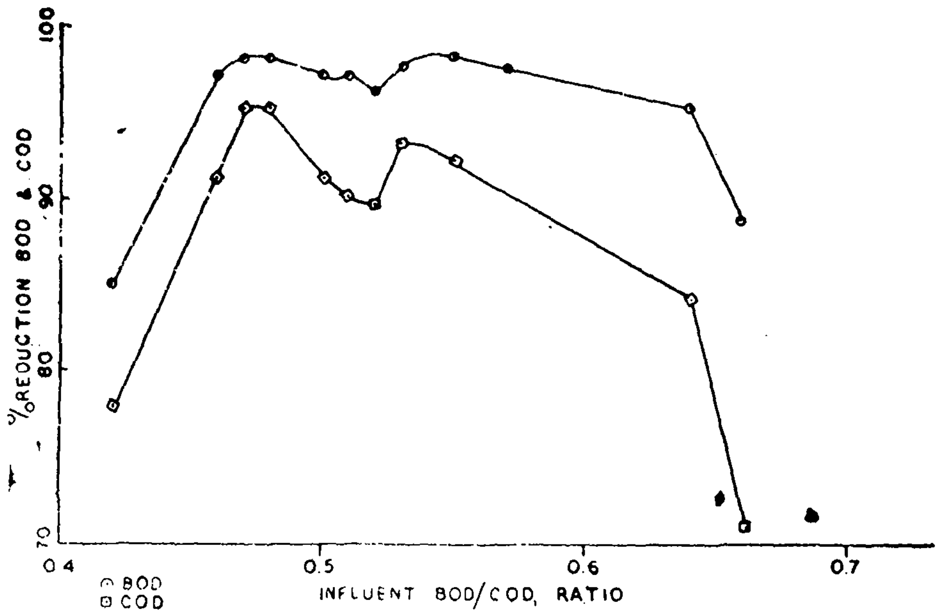

Fig. 1—BOD and COD Reductions in relation to Influent BOD/COD Ratio

drops which could be due to a variety of reasons.

It was decided to investigate treatment at higher concentration of mixed liquor suspended solids, to have comparison with effluent BOD. Table III and Table IV list the results obtained at MLSS concentration ranges of 6000 to 8000 mg/l and 8000 to 10000 mg/l respectively. It was observed that there was no appreciable difference in percent BOD and COD removed at higher concentration of mixed liquor. It will be observed from the Table that lower BOD and COD values have a higher effluent BOD : COD ratio. This indicates that the effluent was biodegradable and it needed further aeration. In this study, the authors also experienced problems of aquarium aerators getting choked at high MLSS concentration. Microscopic examination of organisms was regularly carried out and, on comparison to sewage plant organisms, they were found to be very different

The bench-scale results clearly indicated that the wastewater effluent was bio-degradable and the developed organisms were found to effectively remove soluble organics. These microorganisms were also at the same time remarkably resistant to poisoning, inspite of varied fluctuations of organic loadings.

Pilot Plant Treatability Studies

From success on bench-scale work, it was decided to extend the studies to pilot plant-scale. A tank of the following dimensions: 2.4 m x 1.05 m x 0.9 m, was utilised for the purpose. It was partitioned and in one compartment a 'Z' shape sparger was fixed at the bottom. Another compartment was used as a sedimentation tank. Initially, batch experiments were made, in which raw sewage and industrial wastewater were manually transferred to the tank, followed by aeration. After aeration, mixed liquor was allowed to settle and the supernatant liquid was siphoned off.

As in bench-scale experiments, the organisms were developed by aerating raw sewage with 1 percent dose of waste water. Mixture was aerated for a week, keeping records of BOD, COD and MLSS. After one week, MLSS was found to be 700 mg/l. Thereafter, raw sewage and wastewater were changed every day in proportion of 99:1 respectively. Supernatant was transferred to another compartment, after MLSS had settled in the aeration tank. In 23 days, MLSS concentration reached 3680 mg/l. It was then given 5 and 10 percent dose of wastewater. MLSS dropped to 1950 mg/l in the second dose of 10 percent, most probably due to shockloading, but it was temporary. When doses of 1, 5, 5, 10 and 10 percent were given again, rise in mixed liquor was fast and steady, and it reached 4130 mg/l. Table V lists the data collected in building up of MLSS. In pilot-plant-scale, the total period required was 31 days, whereas in bench-scale it was 7 weeks. Probably it was due to better mixing in pilot plant, which effected better dispersion of mixed liquor and waste, therefore resulting in increased mass transfer of oxygen and organics to organisms.

Since in bench-scale it did not seem very advantageous to operate at high mixed liquor concentration, experiments were carried out with MLSS around 4000 mg/l. Temperature of the aeration mixture also varied between 28 to 35°C. Aeration period was normally kept for eighteen hours. However, if dissolved oxygen was found to be lower than about 2 mg/l, mixture was aerated for longer periods. Experiments were run at different levels of Food: Microorganism ratio. For COD, loadings were from 0.2 to 1.16 and for BOD, from 0.16 to 0.58. Some loadings tried were higher than bench-scale experiments. Table VI lists the treatment data obtained on batch operation of pilot plant. It was found that pilot plant on batch operation can remove soluble organics. The BOD reduction was 90 + percent, however COD reduction was low, around 70 + percent. The cause for lower COD reduction is under investigation. Nutrient addition, adjustment of pH at the start of the experiment and wastewater of variable BOD : COD ratio from 0.3 to 0.7 was used, as in bench-scale experiments. Table VI also carries some TDS data on influent and effluent.

TABLE III—LABORATORY-SCALE DATA WITH 6000 TO 8000 mg/l MLSS

Expt. No.	Organic Loading (kg/d/kg MLSS)		pH		BOD/COD Ratio		COD (mg/l)			BOD (mg/l)			MLSS (mg/l)		Remarks
	COD	BOD	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	% Reduction	Inf.	Eff.	% Reduction	Initial	Final	
1	0.21	0.09	7.1	7.40	0.43	0.29	2625	622	76.30	1150	180	34.34	6200	6000	Drop in MLSS
2	0.24	0.09	6.9	7.65	0.36	0.34	3000	885	70.50	1100	300	72.7	6180	6840	
3	0.21	0.08	6.85	7.60	0.39	0.35	2925	885	69.74	1150	310	73.04	6840	6720	Drop in MLSS
4	0.32	0.20	7.3	7.55	0.64	0.18	3750	585	84.10	2400	110	95.5	5820	6680	
5	0.30	0.21	7.1	7.50	0.67	0.12	4125	465	88.73	2765	60	97.83	6680	6800	
6	0.23	0.10	7.0	7.7	0.44	0.31	3225	1260	60.93	1420	400	71.83	6800	6800	
7	0.29	0.13	6.20	7.75	0.45	0.14	4000	576	85.60	1800	80	95.56	6840	7840	
8	0.28	0.13	7.3	7.85	0.47	0.12	3840	249	93.52	1800	30	98.33	6720	8280	
9	0.67	0.31	7.3	8.45	0.46	0.22	8400	968	88.5	3900	220	94.5	6200	6400	
10	0.63	0.31	7.8	7.90	0.49	0.25	8200	760	90.73	4000	190	95.25	6500	6700	
11	0.31	0.09	6.9	7.60	0.31	0.42	4200	1680	60.00	1300	200	84.61	6700	6740	
12	0.41	0.24	6.3	7.45	0.58	0.42	5175	2175	57.37	3000	910	69.66	6240	7760	
13	0.34	0.19	6.9	7.50	0.57	0.42	5325	2212	58.46	3020	940	68.87	7760	6460	
14	0.52	0.25	6.25	7.90	0.47	0.23	6800	1800	75.29	3200	400	87.50	6480	7480	
15	0.32	0.13	6.20	7.85	0.41	0.39	4880	2240	54.09	2000	880	56.00	7480	7560	
16	0.32	0.21	6.15	7.45	0.645	0.41	4960	2480	50.00	3200	1040	67.50	7560	8000	
17	0.66	0.32	7.0	9.95	0.48	0.24	8480	760	91.03	4100	180	95.60	6400	6500	

TABLE IV—LABORATORY-SCALE DATA WITH 8000 TO 10000 mg/l MLSS

Expt. No.	Organic Loading (kg/d/kg MLSS)		pH		BOD/COD Ratio		COD (mg/l)			BOD (mg/l)			MLSS (mg/l)		Remarks
	COD	BOD	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	% Reduction	Inf.	Eff.	% Reduction	Initial	Final	
1	0.08	0.03	6.05	7.00	0.49	0.45	1722	300	82.67	850	136	84.00	10200	10400	
2	0.08	0.04	6.04	7.85	0.41	0.41	1680	261	84.46	700	108	84.57	10400	10080	Drop in MLSS
3	0.32	0.17	6.25	7.70	0.51	0.26	5040	684	86.42	2600	180	93.07	7800	10000	
4	0.20	0.09	6.35	7.75	0.45	0.23	4000	880	78.00	1800	200	89.00	10000	8860	
5	0.22	0.15	6.3	7.35	0.66	0.26	3920	1120	71.4	2600	300	88.5	8860	9200	
6	0.24	0.12	7.7	7.90	0.49	0.13	4050	315	92.22	2000	40	98.00	8280	8920	
7	0.29	0.12	7.3	8.15	0.42	0.12	5700	645	88.68	2400	80	96.66	9780	11620	
8	0.22	0.07	7.3	8.15	0.32	0.18	3750	240	93.6	1200	44	96.33	8420	8040	Drop in MLSS
9	0.29	0.12	7.35	8.20	0.42	0.27	4725	300	93.65	2000	80	96.00	8040	9140	
10	0.28	0.15	7.0	7.45	0.53	0.22	5250	1275	75.71	2800	280	90.00	9140	9480	
11	0.14	0.04	6.65	8.15	0.27	0.10	2925	270	90.76	800	28	96.50	10400	9780	Drop in MLSS
12	0.14	0.05	7.65	8.35	0.34	0.08	2925	330	88.71	990	28	97.17	10200	10400	

TABLE V—BUILDING OF MLSS FROM RAW SEWAGE IN PILOT PLANT

Sr. No.	Industrial Waste Used (%)	Influent Mix (mg/l)		Effluent (mg/l)		MLSS (mg/l)		Rise/Fall in MLSS
		BOD	COD	BOD	COD	Initial	Final	
1	1	200	488	—	—	Zero	—	MLSS reached 3680 mg/l with 1% dosage in a period of 23 days.
2	1	180	360	36	60.8	3120	3320	
3	1	180	416	36	96	3320	3680	
4	5	400	592	64	122	3680	3570	Drop in MLSS.
5	10	1040	1584	—	—	3570	2900	
6	10	610	880	300	—	2900	1950	
7	1	160	368	32	304	1950	2700	MLSS rises.
8	5	230	376	24	104	2700	2890	
9	5	260	360	30	120	2890	3570	
10	10	460	686	30	310	3570	3700	
11	10	400	544	24	227	3700	4150	

Note—Aeration rate was maintained to give 2 mg/l dissolved oxygen.
— not done

TABLE VI—PILOT PLANT BATCH OPERATION DATA

Expt. No.	F/M Ratio		pH		BOD/COD Ratio		COD (mg/l)			BOD (mg/l)			MLSS (mg/l)		TDS (mg/l)		Remarks
	COD	BOD	Inf.	Eff.	Inf.	Eff.	Inf.	Eff.	% Reduction	Inf.	Eff.	% Reduction	Inf.	Eff.	Inf.	Eff.	
1	0.36	0.31	6.7	8.4	0.85	0.10	1336	552	58.7	1140	60	94.7	3980	3060	—	—	Drop in MLSS
2	0.32	0.16	7.3	7.9	0.5	0.3	1280	389	70	640	120	81	3560	3280	—	—	Drop in MLSS
3	0.50	0.21	6.8	7.3	0.41	0.12	2272	720	69	940	90	90.5	3500	3760	—	—	
4	0.22	0.13	6.5	7.6	0.58	0.38	928	232	75	540	90	84	3080	3380	—	—	
5	0.33	0.15	6.75	7.5	0.47	0.22	1904	800	58	900	180	80	4740	4800	800	672	
6	0.46	0.21	6.5	7.4	0.39	0.07	2520	1500	41	1000	110	89	4840	4490	1280	1198	
7	0.42	0.26	6.8	7.5	0.58	0.09	2240	1000	56	1300	90	93	4220	4440	1020	800	
8	0.79	0.37	6.4	7.55	0.42	0.07	3640	2680	27	1550	200	87	4000	3800	1520	1440	Drop in MLSS
9	1.16	0.58	6.75	7.5	0.46	0.11	5720	3480	32	2700	400	86	3700	4100	1700	1200	
10	0.76	0.33	6.85	7.2	0.42	0.11	3880	2520	36	1640	300	82	4000	4240	2120	2000	
11	0.88	0.50	6.55	7.15	0.57	0.13	4720	2000	60	2700	310	89	3760	4420	3040	721	

— Not done

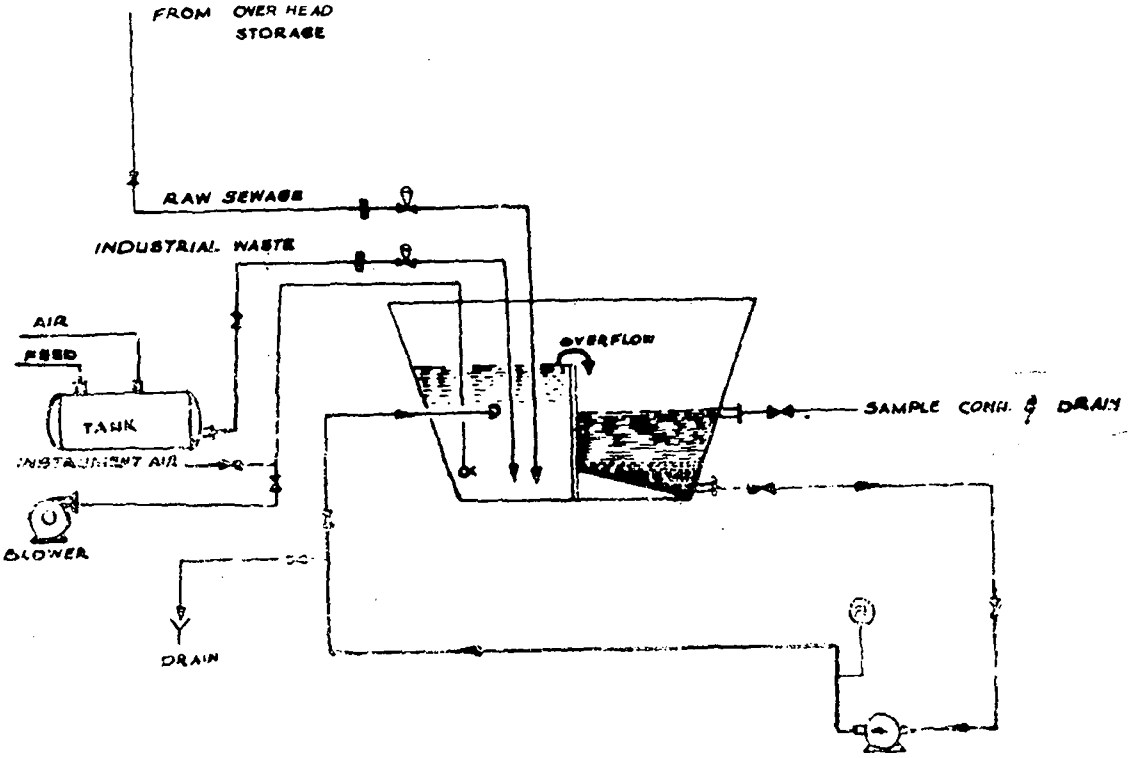

Fig. 2—Flow Diagram of Wastewater Treatment (Pilot) Plant

Further Work

Work is in progress to extend the batch operation of the pilot plant to continuous system. A flow diagram of the system is presented in Fig. 2. With aeration period of 18 hr, with regular feed of grit-free raw sewage and wastewater with overflow arrangement and recycling of settled sludge, the system will soon be under operation.

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DISCUSSION

Shri V. Raman: In Fig. 1, it is seen that percentage reduction of BOD and COD goes upto a certain extent as the ratio of BOD/COD increases. Then, it gradually drops. What is the reason?

Dr. D. Choudhury: The high BOD/COD ratio generally indicates good biodegradability and lower value, resistance to biodegradation. This was found to be true in the case of our wastewater also. However, it was noticed that even with higher BOD/COD ratio there was a levelling effect and also a slight fall in percentage reduction. This could be due to the presence of diverse chemicals, some of which may be extremely resistant. This point needs further study and we will look into it in our later experiments.

Dr. (Smt.) S. M. Vachha: What is the amount of residual oil in the effluent? Also, what is the concentration of oil at the point of discharge after mixture and 50 m downstream?

Dr. D. Choudhury: Within 50 to 100 mg/l. At 50 m downstream we are not able to take a sample, because it meets the industrial sewer.

Dr. T. R. Bhaskaran: Was soil used to develop the biological workshop for the treatment of the complex wastes?

Dr. D. Choudhury: There is an activated sludge process in our plant and we were successful in developing acclimatised bacteria for our wastewater pilot plant and, therefore, we do not find it necessary to look for another source of bacteria, e.g., soil, etc.

Shri G. C. Gupta (Jamshedpur): The authors have given analysis in terms of BOD and COD only. Have the authors made any study on the conversion of different chemicals by this method? Will it not help us in devising some chemical methods also?

Dr. D. Choudhury: Our wastewater contains diverse chemicals, some in ppm and others in ppb range, and to classify them would be an extremely difficult proposition. We have not made any efforts in this direction so far. We do not believe that the chemical methods for estimating them would be suitable, but a GLC method can be suitably developed for identifying these chemicals.

Shri R. C. Dixit (Nagpur): During discussions, oil has been reported to be 10 to 50 mg/l by the author. In this particular case, what method was used for estimation of oil?

Dr. D. Choudhury: The oil was estimated as per the standard method (**Ref.:** Standard Methods for the Examination of Water and Wastewater—APHA Publication).

Shri B. C. Gomes (Vasco, Goa): U.C. reclaimed water has a TDS of 350 mg/l as compared to 15-150 mg/l in Bombay Municipal Supply.

(a) What is the percentage contribution of the reclaimed water to the total water consumption in the factory?

(b) What is the percentage increase maintained in the blowdown of the cooling tower after the new reclaimed water having almost double the amount of TDS is supplemented?

(c) Has there been any side effect on the condensers/coolers, e.g., loss of efficiency due to scaling, etc?

(d) What has been the percentage decrease in the life of the resins in the demineralisation plant and what has been the percentage increase in the regeneration cycle of the anion/cation beds after reclaimed water usage came in force?

(e) There are conflicting figures given on TDS in force for the same plant, 400-600 mg/l by Shri N. D. Chhabria and 350 mg/l by the author. Please enlighten how this reduction was effected. Was a reverse osmosis or ion exchange unit added to the original plant?

(f) Please elaborate the following statement: "The high COD water produced would be unsuitable for use in ion exchange beds for production of boiler feed water".

Dr. D. Choudhury:

(a) Approximately 75% of our total consumption of water comes from reclaimed water from the sewage water treatment plant.

(b) There was a 100% rise in the blowdown.

(c) None has been reported so far.

(d) Use of reclaimed water as boiler feed water has started very recently and, therefore, we do not have any comparative data regarding % decrease in the life of the resins in the demineralisation plant. The regeneration cycle of our demineralisation plant is once per day.

(e) The earlier report of Mr. Chhabria of 400-600 mg/l TDS of our reclaimed water was presumably based on a grab sample analysis. The existing plant has never shown more than 350 mg/l solids throughout the year. We do not have any reverse osmosis unit, but there is a softener in the unit to reduce the hardness to the level of 40 mg/l.

(f) The higher values of COD of water will give correspondingly higher BOD values and water having high BOD/COD ratio will naturally coat the resin and foul up the bed.

PROC. SYMP. ON ENVIRONMENTAL POLLUTION (1973)

Treatment and Disposal of Effluents from Pharmaceutical and Dyestuff Industries in Baroda

S. RAJAGOPALAN, (Mrs.) I. S. JAYANGOUDER,
V. KOTHANDARAMAN and C. G. MEHTA

The manufacture of dyes, pharmaceuticals and antibiotics by the Sarabhai Group constitutes one of the foremost industrial development in the Baroda region. Their Baroda unit discharges about 0.6 mgd (2700 cu m/day) of combined wastes into the city's municipal sewers without adequate treatment. Similarly, the Suhrid Geigy's unit at Ranoli producing dyes, pigments, pharmaceutical active ingredients and textile auxiliary chemicals discharges an effluent volume of 0.4 mgd (1800 cu m/day) into the Mini river without any treatment.

On request from the management, CPHERI conducted studies on the problem in detail for a period of 2 years and suggested most suitable lines of treatment for respective wastes. The treatment proposed envisages equalization, neutralization and biological treatment by activated sludge and/or extended aeration in the oxidation ditch in both cases. For the effluent of Suhrid Geigys, it is suggested to give a further treatment in the oxidation pond at the final stage. On the basis of CPHERI's report, waste treatment plants have been installed both at Baroda and Ranoli where the first stage of the treatment process has been commissioned recently.

Introduction

Industrial effluents discharged by the pharmaceutical, antibiotic and dyestuff factories in Baroda contribute largely towards pollution of the receiving bodies of water. The problem of treatment and disposal of these wastes has been studied in the following two factories during 1969-70: (i) A factory located in Baroda, belonging to the Sarabhai Group of Industries; and (ii) A Unit of Suhrid Geigy Ltd., in Ranoli at a distance of 15 km north of the city along the Baroda-Ahmedabad rail line. The results of the study are presented in this paper.

Statement of the Problem

(1) In the Sarabhai Pharmaceutical complex in Baroda manufacturing pharmaceuticals, such as streptomycin, vitamin C etc., an effluent treatment plant has been in operation for some years for giving preliminary treatment to the wastes. The treatment consists of neutralization with lime for pH correction followed by sedimentation and digestion of the sludge. The effluent resulting from this treatment is discharged into the city sewers. However, BOD of this effluent has always been greater than the maximum permissible limit of 300 mg/l prescribed under the bye-laws of the municipality.

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[*] CPHERI Zonal Laboratory, Suburban Sub Pumping Station, Beyond Calico Mills, Sewage Farm Road, Ahmedabad.

(2) At the Ranoli plant of Suhrid Geigy Ltd., the combined effluent stream from manufacture of dyes, pigments, pharmaceutical active ingredients, textile auxiliary chemicals, optical whitening agents (Tinopals) and phthalic anhydride is discharged into the Mini river, which joins the Mahi river near Jaspur village. The State Public Health Authority was concerned about the pollutional hazards of the effluents and the factory management was required to provide suitable treatment for the wastewaters.

1. SARABHAI CHEMICALS LTD., BARODA

The problem was studied in detail on the following lines: (a) Characterisation of the wastes, and flow measurements; (b) To assess the performance of the waste treatment plant; and (c) To propose improvements and suitable modifications in the existing treatment practices and develop a new flowsheet in which the existing treatment plant will form an integral part.

(a) *Sources, Quantities & Characteristics of the Effluents*

The effluent streams are derived from the antibiotics, vitamin C, symbiotics and fine chemicals divisions. The quantities of some of the main effluent streams are given in Table I.

The total volume of the combined effluent streams by actual flow measurement was observed to vary in the range of 0.416 to 0.998 mgd with an average of 0.656 mgd (2950 cu m/day). The characteristics of the process wastewaters and the combined effluent showed that: (i) the effluents from the streptomycin & pharma divisions were either highly acidic or alkaline. The effluents from the pharmaceuticals and vitamin C plants were on the alkaline range; (ii) almost all waste streams showed high BOD, but the effluent streams from the streptomycin, vitamin C and pharma divisions were the main sources of BOD; (iii) the suspended solids content of all effluent streams was generally low; and (iv) the combined factory effluent showed a BOD in the range of 665-1380 mg/l with wide variation in various characteristics.

The relative distribution of BOD and suspended solids derived from the different unit processes are shown in Table II.

TABLE I—CHARACTERISTICS OF PROCESS WASTEWATER AT SARABHAI COMPLEX AT BARODA

Sr. No.	Characteristics	Streptomycin Plant	Vit. C Plant	Fine Chemicals	Pharma Division	Suhrid Geigy Unit	Combined Factory Effluent* (24 hr composite sample)
1	Flow (mgd)	0.20-0.25	0.08-0.10	0.05-0.07	0.13-0.14	0.03-0.05	0.660
2	pH	2.7-10.3	7.9-8.5	8.0-9.2	3.4-7.0	7.5-7.6	3.0-7.2 (4.7)
3	TDS	4300-5800	2600-2650	360-880	1570-1860	960-1080	1660-7980 (4840)
4	Suspended solids	300-700	120-240	120-160	240-540	140-440	40-980 (500)
5	Alkalinity	2500	630	490	350	—	—
6	Acidity	1700	—	—	980	490-560	700
7	BOD	680-950	720-1080	410-425	690-1080	165-425	665-1380 (1010)
8	COD	1695-2940	2650-3250	700-2000	1060-5000	435-1570	1179-6867 (3615)
9	Total N	77-114	5.6-22	18-22	11-24	1.7-40	(7.5)
10	PO_4	1-2	0.5-6.8	0.5	$<$ 0.5	0.5	(0.5)

Note: All the figures, except flow and pH, are expressed in mg/l.

* This does not include the wastes from water softening plant and other miscellaneous units which amount to 0.065-0.080 mgd (292-350 cu m/day).

Thus, it will be seen that the BOD and suspended solids resulting from combined effluent streams of 0.656 mgd is 6340 and 3137 lb/day (2875 and 1422 kg/day) the population equivalent being 63400 and 15600 persons respectively.

(b) *Performance of Waste Treatment Plant*

(i) PRIMARY TREATMENT

The primary treatment consists of neutralization with lime and sedimentation in a clarifier and anaerobic digestion of the sludge in a digester. The efficiency of this treatment is shown in Table III.

(ii) SECONDARY TREATMENT

About 0.1 mgd of the effluent from primary treatment process was further given biological treatment in an oxidation ditch on a pilot plant scale.

The biological treatment process was capable of bringing down the BOD of the combined effluent from 700-1000 mg/l to less than maximum permissible limit of 300 mg/l, prescribed under the municipal bye-laws for disposal into the city sewers. Alternatively, BOD reduction to the extent required could also be achieved by conventional activated sludge process. From analysis of data available from the pilot plant oxidation ditch and laboratory data on activated sludge process, the following parameters were arrived at (Table IV).

The flowsheet developed on the basis of the aforesaid results for complete treatment

TABLE II—DISTRIBUTION OF BOD AND SUSPENDED SOLIDS

Sr. No.	Source	BOD		Suspended Solids	
		(lb/day)	(kg/day)	(lb/day)	(kg/day)
1	Streptomycin Plant	170-2360	770-3445	700-1500	317-680
2	Vitamin C Plant	575-870	261-395	108-216	49-78
3	Fine Chemicals	200-300	90-136	70-100	32-45
4	Pharma	900-1460	405-682	325-230	147-330
5	Suhrid Geigy Unit	90-215	40-98	56-175	25-79
6	Misc. including Sanitary Wastes	1000-1300	—	—	—
7	Combined Wastes	4100-8600 6340*	1860-3900 2875*	1260-3785 3187*	572-1717 1422*

* Average values

TABLE III—PERFORMANCE OF PRIMARY TREATMENT

Characteristics	Influent	Effluent	Reduction (%)
pH	4.7-6.1	5.1-6.9	—
Suspended Solids (mg/l)	500-1120	280-800	30-41
BOD (mg/l)	700-1010	310-730	28-57

TABLE IV—PARAMETERS OF BIOLOGICAL TREATMENT METHODS

Sr. No.	Parameters	Extended Aeration (Oxidation ditch)	Conventional Method (Activated sludge process)
1	Loading : (lb BOD/lb MLSS/day)	0.1-0.5	0.3-0.7
2	MLSS Concentration (mg/l)	3000-4000	1500-2500
3	Aeration time (hr)	22	6-8
4	Final effluent BOD (mg/l)	80-200	80-200
5	BOD reduction (%)	70-80	70-80

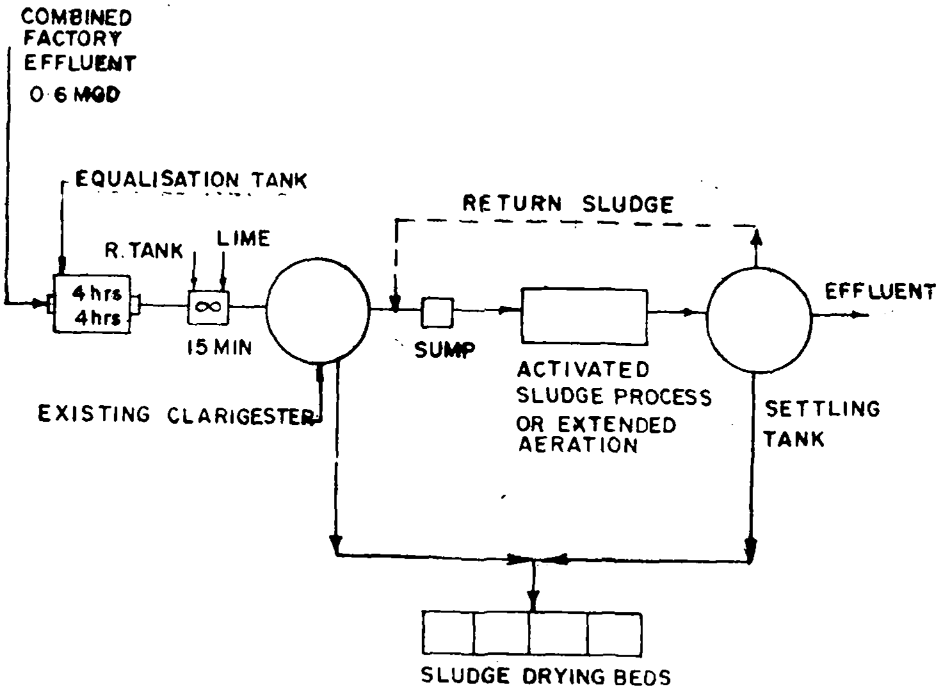

Fig. 1—Flowsheet for Treatment of Combined Effluent from Sarabhai Pharmaceutical Complex at Baroda.

of the wastes consisting of chemical and biological treatment, is shown in Fig. 1.

2. M/S SUHRID GEIGY LTD., RANOLI

In this case, the studies consisted of: (a) characterisation and flow measurements, (b) laboratory studies on chemical and biological treatment, and (c) development of a flowsheet for treatment of the wastes.

(a) *Sources, Quantities and Characteristics of the Wastes*

The principal effluent streams of the factory and their relative volumes are shown below (Table V) :

The variations in the volume of the combined effluent as determined by actual flow measurements were as follows :

Minimum	0.2500 mgd	1125 cu m/day
Maximum	0.4996 mgd	2250 cu m/day
Average	0.3400 mgd	1530 cu m/day

The characteristics of the process waste-water showed the following salient features: (i) The waste streams from the various sections were generally acidic and had a high TDS; (ii) The suspended solids content of the waste streams was in the range of 500-900 mg/l; (iii) The BOD was mostly contributed

TABLE V—VOLUME OF WASTES

Sr. No.	Source	Quantity (gal/day)	Quantity (cu m/day)
1	Dyes, pigment and dyes intermediates	100000	450
2	Textile auxiliary chemicals and pharma intermediates	60000	270
3	Phthalic anhydrate plant	50000	225
4	Tinopal unit	50000	225
5	Cyanuric acid plant	15000	67.5
6	Misc. wastes including sanitary wastes	25000	125
7	Combined waste	300000	1300

by the effluent streams from the phthalic anhydride and pharma divisions (1300-1500 mg/l). The combined waste showed BOD in the range of 130-700 mg/l, with an average value of 380 mg/l; (iv) The COD of the waste was generally high. The COD/BOD ratio was in the range of 1.2 to 13.0; (v) Cyanide was present in the combined waste to the extent of 0.1 mg/l; and (vi) The 24 hr composite sample of the combined factory effluent showed the following average composition :

pH	2.6—8.0	BOD	380 mg/l
TDS	4400 mg/l	COD	1775 mg/l
Acidity	1080 mg/l	Total N	104 mg/l
Suspended solids	595 mg/l	PO_4	2.0 mg/l

(b) *Laboratory Studies*

(i) CHEMICAL TREATMENT

Ferrous sulphate in combination with lime was found to be the most suitable preliminary treatment of the wastes and the effective dose was 500 mg/l. The addition of lime was in 2 stages: first, to neutralise the waste to pH 7.0—7.5 and then a further addition of lime, after chemical dosing, was made to raise the pH to 10.0. An appreciable reduction in BOD and COD was observed as shown below (Table VI) :

(ii) BIOLOGICAL TREATMENT

The biodegradability of the combined effluent after chemical treatment with $FeSO_4$ and lime, was studied on a laboratory scale activated sludge unit on batch system using a sludge well acclimated to a mixture of soil extract, domestic sewage and the waste. The proportion of the waste volume was kept at a maximum of 60 percent (after a series of trial runs with varying concentration of the wastes in the mixture). The mixed liquor was aerated for 12 hr and the MLSS was maintained in the range of 1500-3000 mg/l. Air rate was maintained constant at 25 l/min. for the waste volume of 3 l (i.e., 1.5 to 2 cfm of air/gal. of waste). The results of the study are shown in Table VII.

The study revealed the following points :

(i) By proper acclimatization of the activated sludge organisms developed from a soil, sewage and waste mixture, it was possible to treat the wastes in an aerobic biological system either by the conventional activated sludge or by extended aeration;

(ii) The maximum reduction in BOD and COD occurred during an aeration period of 12 hr and the overall reduc-

TABLE VI—EFFICIENCY OF CHEMICAL TREATMENT METHOD

Characteristics	Raw Waste (mg/l)	Effluent* (mg/l)	Reduction (%)
BOD	210	77.5	63
COD	2215-2410	240-686	71.5-90

* after chemical treatment

TABLE VII—EFFICIENCY OF BIOLOGICAL TREATMENT METHOD

Sr. No.	COD				BOD			
	Aeration Period (hr)	Raw waste (mg/l)	Effluent (mg/l)	Reduction (%)	Aeration Period (hr)	Raw waste (mg/l)	Effluent (mg/l)	Reduction (%)
1	12	2355	428	82	6	200	30	85
2	12	2355	357	85	12	240	20	91
3	12	2676	410	85	12	300	60	80
4	12	2611	765	71	12	240	56	77
5	12	1899	499	74	12	205	28	86

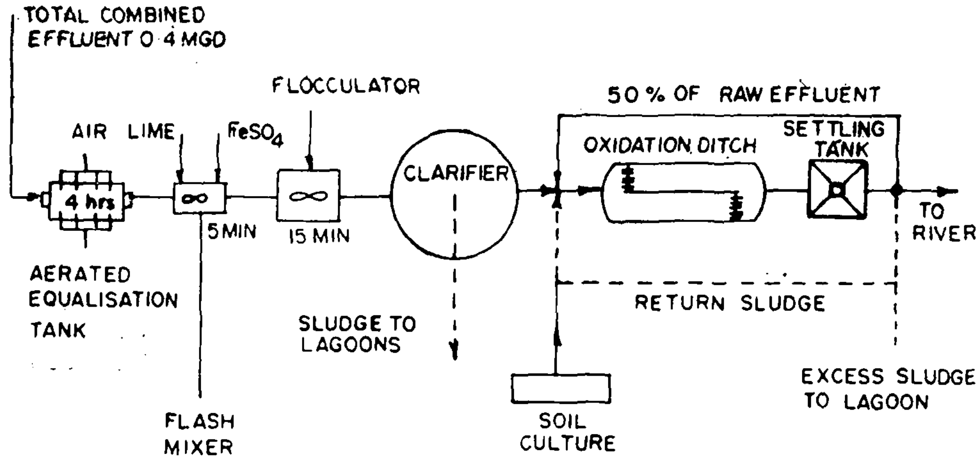

Fig. 2—Flowsheet for Treatment of Combined Effluent from Suhrid Geigy Ltd., Ranoli.

tion in BOD & COD was in the range of 77-91 and 71-85 percent respectively;

(iii) The final effluent had a BOD in the range of 20-60 mg/l and COD in the range of 357-765 mg/l. The high COD of the effluent indicated the presence of an appreciable proportion of organic constituents which are persistant to biodegradation;

(iv) The system 'k' value was 0.172/day; and

(v) The most feasible method of treatment of the wastes would be a two-stage treatment consisting of chemical treatment with $FeSO_4$ and lime in the first stage and biological treatment in the second stage either by conventional activated sludge process or extended aeration.

A flowsheet was developed on the basis of the above results (Fig. 2).

Conclusions

Based on the process flowsheets developed in the aforesaid studies for treatment of the effluents. feasibility reports were submitted to the respective authorities. The recommendations contained therein were accepted and steps were taken to instal effluent treatment systems. The biological treatment plant employing conventional activated sludge system and the first stage chemical treatment plant are in operation at Baroda and Ranoli respectively.

DISCUSSION

Dr. T. J. Boman: Authors have stated that by treatment BOD was reduced by 80 percent. What was BOD of influent and what BOD was found after treatment?

Shri S. Rajagopalan: The BOD of the influent and effluent from treatment are as follows :

	BOD (mg/l)		
	Inf.	Eff.	% Red.
Sarabhai Chemicals	710-1010	90-270	74-87
Suhrid Geigy	138-700	20-80	76.7-86.7

Shri P. T. Shah (Ahmedabad) : Can authors tell whether any studies have been made for the disposal of solid waste, e.g., 'mycin' from antibiotic products like Penecillin? If so, what is considered as the best method. The present system followed is burying the waste in trenches in the ground but in monsoon the fields are flooded with water and trenches can not be dug. How far this waste creates pollution?

Shri S. Rajagopalan: No studies were undertaken on the disposal of the solid wastes "mycin" from the antibiotic factory. The solid wastes are the mycelia from the fermenters. At present, this material is segregated from the liquid wastes. This solid waste could be treated hygienically by the composting method practised for treatment of municipal refuse. The site chosen for trenching in composting pits should be relatively free from water logging even during monsoon.

Shri P. R. N. Rau (Bombay) : What monitoring programme is followed to check the effluent before discharge? Have you established any relationship between COD and BOD?

Shri S. Rajagopalan: The effluent resulting from treatment plants installed by the factories have been analysed by us and are also being monitored regularly by the laboratory attached to the waste treatment plant.

The COD/BOD ratios are as follows:

	COD/BOD Ratio		
	Max.	Min.	Average
Sarabhai Chemicals	4.98	1.71	3.12
Suhrid Geigy	9.92	1.15	5.49

Shri V. V. Joshi (Bombay) : What are the various constituents of soil used for culture? Whether any study has been made since it will have a significant effect on the performance?

Shri S. Rajagopalan: No detailed studies were undertaken on the constituents of the soil used for culture. The soil culture technique was employed for developing an activated sludge well acclimatized to the chemical constituents present in the wastes which were not readily amenable to biodegradation by normal microorganisms present in domestic sewage. It is well known that soil microorganisms are relatively more efficient to degrade various types of organic substances.

Shri Subodh Mukherjee: It is stated that ratio of COD and BOD is as high as 15 and still biological method of treatment alone has been suggested. But, for such high ratio of COD and BOD biological treatment should be carried along with chemical treatment.

Shri S. Rajagopalan: Yes, I agree. The treatment process developed during our studies includes chemical treatment in the first stage.

Shri B. I. Bhatt (Ahmedabad): What type of dyes were present in the dye waste obtained from the factory? Can all the dyes including disperse dyes be treated by the method suggested by you?

Shri S. Rajagopalan: The dyes and pigment present in the wastes are water soluble substances. It may be feasible to treat even disperse dyes since by chemical treatment an appreciable fraction of the coloured substances are removed easily with lime and ferrous sulphate.

Shri N. Sriramulu (Kanpur) : It is reported by the authors that the plant effluents were let into the municipal sewers. May I know what is the treatment given to municipal sewage and what are the effects of your plant discharges on the treatment of municipal sewage?

Shri S. Rajagopalan: The municipal sewage of Baroda city into which the industrial wastewaters are discharged is treated at the Atladra sewage disposal plant by conventional high rate trickling filters and anaerobic digestion of the sludge. This municipal plant is receiving all the effluents discharged from all the different pharmacutical and antibiotic factories located in the city and hence the plant is subjected to a severe overloading. With a view to reduce the BOD load on the municipal plant, the Sarabhai's factory has installed the treatment plant reported in this paper.

PROC. SYMP. ON ENVIRONMENTAL POLLUTION (1973)

Vermiculite Decontamination of Atomic Power Station Effluents

T. A. SEBASTIAN,* I. S. BHAT* and P. R. KAMATH*

Environmental monitoring of sea silt and sea food at Tarapur Atomic Power Station site has shown the presence of radiocesium and radiocobalt as most predominant long lived radionuclides. Analyses of liquid radioactive wastes discharged from the plant has confirmed these contaminants.

Experiments were carried out for decontamination of these effluents using vermiculite and sand columns. The paper presents the results of these investigations discussing the different chemical species in which state the contaminants can be present.

Introduction

Nuclear Power Stations produce low level radioactive wastes which are usually dispersed by dilution in the environment. The radionuclides so dispersed can get accumulated in the environmental produces and reach man through foodstuffs.

The Tarapur Atomic Power Station (TAPS) has been operating with twin boiling water reactors from February, 1969. The Station discharges low activity liquid radioactive wastes after dilution with condenser coolant sea water (1000 cusecs of flow) to coastal sea water. The environmental surveillance (1-3) for the TAPS has shown that radiocesium and radiocobalt are the predominant long lived radionuclides along with the short lived radioiodine released from the plant, reaching public through sea food. During 1971, the radiation dose from radiocobalt and radiocesium coming through sea food to the fisherman population in the plant vicinity has been estimated as 5.45 mrem/yr. This dose is about 100 times less than the maximum permissible dose to the general public.

In order to prevent even this small fraction of exposure to public, economic decontamination of plant radwaste effluents before discharge or discharge to offshore sea water with adequate dilution have been thought of This paper presents the preliminary findings from the investigation on decontamination of TAPS effluents with vermiculite which is available easily in our country.

Composition of Radwaste

The analysis of the Tarapur plant waste had shown that it contained mainly 30 to 40% 134 Cs+137 Cs, 10-15% 60 Co and about 25% 131 I of the total activity. The remaining part consisted of small amounts of 50 Co, 54 Mn, 51 Cr, 89 Sr, 90 Sr, 99 Mo etc. 131 I is short lived and its decay can be taken advantage to reduce exposure through food stuffs. 134 Cs, 137 Cs and 60 Co are the long lived major components and removal of these radionuclides from liquid radwaste discharges can reduce significantly the dose to public through the sea food pathway.

The pH of the radwaste effluent is about 8 and in this condition, radiocesium is com-

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*Environmental Survey Laboratory, TAPS Colony, Thana, Maharashtra.

pletely in ionic state and radiocobalt is partly ionic and partly in colloidal hydrous oxide state. A substance efficiently picking up these ionic and colloidal portions can serve as a decontaminating medium.

Properties of Vermiculite and its use as Radwaste Decontaminant

Vermiculite is a hydrated aluminosilicate of Ca and Mg formed by the weathering of mica. It appears very much like mica and has layer-lattice with Mg ions and water molecules occuring between the layers. Inter layer K^+ or Mg^{+2} are the exchangeable ions in vermiculite. The cation exchange capacity varies from 50 to 130 meq/100g depending on the mica content.

Use of vermiculite clay mineral for decontamination of 137 Cs and 90 Sr from low level aqueous radioactive waste has been studied by quite a few people (4-6). Mg form of vermiculite has been found to give about 74% removal of activity from low level radwaste containing 137 Cs+90 Sr from Canda India Reactor (4). Decontamination of power reactor effluents, with 60 Co activity, using vermiculite has not been reported.

Experiment and Results

Vermiculite mineral was powdered and sieved to get 40-60 mesh particles. This material (2g) was made into 1 cm diam. column in a burette using glass wool pluggs. The radioactive waste from TAPS effluent sampling tank was passed through this column at a flow rate of 2 to 5 ml/min. A fraction of 5 ml of the effluent was collected after passing each 100 ml aliquot. The 60 Co and 137 Cs+134 Cs activity in the 5 ml column effluent was determined by gamma spectrometry.

The radwaste originally containing 960 cpm 60 Co and 2590 cpm of 134 Cs+137 Cs per ml gave only 2 cpm 60 Co and 11 cpm 134 Cs+137 Cs per ml after passing through the vermiculite column. The 60 Co and 137 Cs removal is nearly 99.5 percent. The decontamination factor for 60 Co is 480 and for radiocesium is 235. The effluent from the vermiculite column did not show any increase in the activity that is breakthrough even after passing 15 l of radwaste through the 2 g column.

Since 60 Co was mostly in colloidal state, absorption of the radioactivity on a sand column was also tested. A 50 ml column of fine sand from Tarapur beach area was prepared in a burette and the radwaste is passed through this column. 5 ml portion for each 100 ml was tested for 60 Co and 134 Cs+137 Cs.

Initially, the sand column also gave results very similar to vermiculite column that is 99.5% removal of 134 Cs+137 Cs and 60 Co. But, after passing 1.5 l of radwaste through the column, the radiocesium in the effluent started increasing and passing about 2.5 l gave complete breakthrough of radiocesium. 60 Co in the sand column effluent started increasing after passing 2.0 l of radwaste and showed the breakthrough after passing 5 l of radwaste through the column.

131 I in radwaste did not show any decrease either in passing through vermiculite or sand column.

The 2 g vermiculite column on which radiocesium and radiocobalt were absorbed was washed with water and dilute (4N) ammonia. Passing about 200 ml of each through the column did not show any leaching of absorbed activity.

Conclusion

Passing through vermiculite mineral column showed significant decontamination of radioactivity from TAPS effluents. This clay mineral has shown high capacity for absorption of major activity from TAPS liquid radwaste. The liquid effluent presently discharged by dilution, if decontaminated by passing through a vermiculite column before dilution, can give appreciable decrease in the dose received through sea food consumption.

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PROC. SYMP. ON ENVIRONMENTAL POLLUTION (1973)

Removal of Low Concentrations of Tannin

T. H. VENKITACHALAM* and A. V. S. PRABHAKARA RAO*

The paper reports results of laboratory investigations of the removal characteristics of tannins from dilute solutions by chlorination and adsorption on activated charcoal. The effects of the presence of tannins in the influent on an ion exchange resin column were also studied.

In spite of the high resistence of the ion exchange resin to organic fouling agents, tannins were found to cause clogging of the resin beds besides permanently damaging the resin material. Although chlorine could oxidize tannins, the doses required were quite high.

Preliminary investigations showed that adsorption on high surface solids such as activated charcoal could substantially remove tannins from dilute solutions. The positions of adsorption equilibria and utilizable capacities of several indigenous activated carbons are investigated and the results are reported.

Introduction

Inferior raw water quality, caused by the pollution of natural waters is today a major problem faced by many industrial and other users of the natural water supplies, especially the surface sources. The problem is no less acute in India than in the more advanced countries of the World.

Tannins from vegetable tanning operations in the manufacture of leather are discharged into natural waters in large quantities. In spite of the biochemical oxidizability of tannins, appreciable residual concentrations are often encountered in the downstream waters, if the time of flow between the point of introduction of tannins and the point of draw-off of water for further use is relatively small. Presence of tannins in the water supply can have definite deleterious effects on specific water uses such as discoloration of paper and textile stock in the textile and paper industries etc. In Kanpur, for example, a rayon industry, situated downstream of a tanneries complex on the banks of the Ganga, seems to be experiencing difficulties due to the presence of vegetable tannin in the waters at their intake (1, 2). In spite of having a small water treatment plant of the conventional type within the factory, the problem of discoloring the transparent colorless rayon is not solved. A short survey of the river Ganga near Kanpur did indicate, as reported later in this paper, the presence of tannin near the intake of the rayon factory.

The present study is a part of an experimental investigation on the feasibility of using ion exchange resin, chlorination and active carbon for removing the low concentrations of tannins that may normally be encountered in waters polluted by vegetable tanning effluents. Ion exchange is a water conditioning process used generally in industries where ultrapure water is required for specific purposes. It was expected that an anion exchange resin column could remove

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* Department of Civil Engineering, Indian Institute of Technology, Kanpur-16.

that part of the tannins (tannic acid) which exists in the dissociated form. Use of activated carbon, even though widespread in other countries for treatment of water and tertiary treatment in wastewater reclamation, specific information on adsorptive removal of tannin is not available in literature. In India, use of activated carbon for water or waste treatment has been adopted hitherto on a limited scale, because of the difficulty in obtaining sufficient quantities of active carbon economically. However, several grades of activated charcoal are now being manufactured indigenously, for example, by Patco Chemical Industries, Gujarat; Arcoy Industries, Ahmedabad; Laxmi Carbons, Najibabad, U.P., etc. Chlorination has been practised on a wide scale for purposes of disinfection as well as for oxidizing organic matter present in water as also in wastewater. But data on tannin removal by chlorination is again sparse.

Previous Work

Although significant amount of research has been carried out on the treatment and disposal of tannery effluents, studies stressing on the specific removal of tannin are few. This probably is due to the fact that very few people have worked on the deleterious effects of tannin, physiological or otherwise.

A few persons have investigated the effects of tannin on plants and animals (3, 4, 5, 6). These studies indicate that tannin can inhibit certain enzymes like catalase, glucosidase, peroxidase, etc. Other effects include damage to the liver cells, inhibition of response to acetyl choline, etc. But the concentrations of tannin employed in these studies are much higher than normally encountered in natural waters and hence these results are not of great significance to a sanitary engineer.

On the other hand, it is known that tannin imparts color in combination with certain metallic ions like iron. Dasnurkar and Rao (7), therefore, have reasonably stated that "Presence of tannin in waters even in small amounts has a deleterious effect on its beneficial use in industries like rayon, textile, paper, etc., where it discolors the otherwise white product and consequently reduces its value." Therefore, tannin removal from waters to be used in such industries may have to be effected in order to combat the color problem. Published data on the maximum permissible concentration of tannin, however, is not available at present. Hence, the extent of removal of tannin has to be decided by the water user in relation to his requirements.

Dasnurkar (8) has worked on removal of tannin in conventional waste treatment operations such as coagulation and flocculation, sedimentation, activated sludge, etc., where significant removal of tannin, comparable to removal of chemical oxygen demand (COD), were observed. A maximum of 90% tannin removal was observed in activated sludge while other methods could remove only less than 50 percent. Barkley and Tomlinson (9. 10), have worked on color removal from tannery wastes by coagulation using polyelectrolytes and could achieve removal orders of above 90 percent.

Dasnurkar and Rao (7) have reported a study on tannin removal from natural waters. However, in that study they employed pure tannin rather than the waste derived from a tannery. Their results, therefore, may not be applicable to field situations where the source of tannin in the water is, in most cases, the tanning effluents, which will contain many other organic matter besides tannin.

The present study was conducted using tannery effluent diluted suitably with water in order to obtain the desired concentration of tannin in the raw water. The aim of the study was to compare the tannin removal efficiencies of ion exchange, adsorption and chlorination.

Experiments, Results and Discussion

1. Sampling and Analysis for Tannin in the Ganga near Kanpur.

Sampling was carried out in the Ganga for two days for obtaining information on the tannin concentrations encountered in the river water. The sampling points were selected as shown in the map in Fig. 1. Three samples were collected from each station at thirty minutes intervals on each day of sampling. These samples were analyzed for tannin and the results are shown in Table I.

Tannin concentration near the J.K. Rayons water intake was observed to be maximum among the five sampling points. This could be reasonably expected since a majority of the tanneries in Kanpur are located at a place called Jajmau, about a mile upstream of the rayon factory.

The first day's samples were collected in the afternoon while on the second day the sampling was done in the morning. Chakrabarty *et al.* (11) have reported that in the case of the Kanpur tanneries most of the wastes were discharged in the morning time

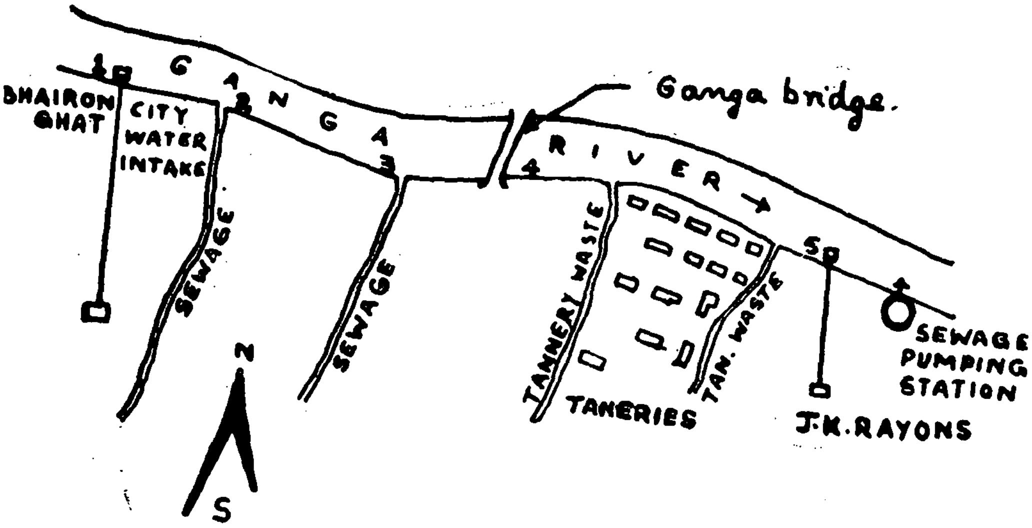


Fig. 1—Location of Sampling Points

TABLE I—TANNIN CONCENTRATIONS IN THE GANGA NEAR KANPUR

A. First day of sampling :

Stn. No.	Sampling Station	Tannin Concn. in sample No. 1	2	3	Average tannin concn.
1	Bhairon Ghat	0	0	0	0
2	Parmat Ghat	0	0.2	0.1	0.1
3	Ganga Ghat	0.5	0.7	0.6	0.6
4	Ganga Bridge	0.9	1.0	0.8	0.8
5	JK Water Intake	1.3	2.0	1.8	1.7

B. Second day of sampling :

Stn. No.	Sampling Station	Tannin Concn. in sample No. 1	2	3	Average tannin concn.
1	Parmat Ghat	0	0	0	0
2	Ganga Ghat	0	0	0.1	0.033
3	Ganga Bridge	0.3	0.8	0.2	0.433
4	JK Water Intake	0.6	1.0	0.3	0.667
5	Bhairon Ghat	4.3	5.2	6.0	5.2

All values are given in mg/l.

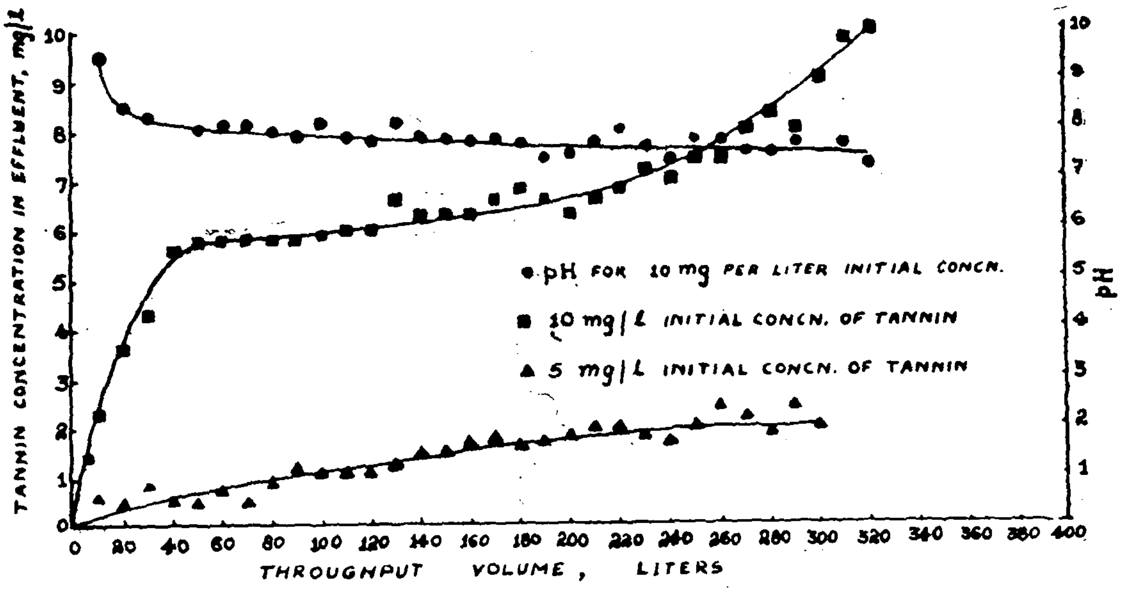
and hence it seems logical to expect higher concentrations of tannin in these samples, as was observed in the present study.

The observed maximum tannin concentration of about 5 mg/l is for the high flow season in the river since the samples were colleced in the month of October. The summer flow in the Ganga is many times less than the flow in rainy season and hence during the dry months the concentrations of tannin to be expected on the basis of the present study is correspondingly higher. In fact, Dasnurkar and Rao (7) have given values of about 20 mg/l tannin to be expected in the river water.

2. Ion Exchange for Tannin Removal

An ion exchange column experiment using the strong anion exchange resin DE ACEDITE FF-IP was conducted with influent tannin concentrations of 10 mg/l and 5 mg/l. The influent was made up by diluting suitably a tanning waste collected from a vegetable tannery in Kanpur. Before being fed into the ion exchange column the influent was pretreated by filtering through a sand bed 18 in. deep in order to remove the suspended materials from the feed. The resin column consisted of 3 g (about 10 ml) of the resin in chloride form which was regenerated by 10 bed-volumes of 5% sodium hydroxide solution. The influent flow rate through the resin bed was maintained at 3 to 4 ml per min. The effluent was collected in five liter lots and analyzed for tannin, as per the Standard Methods (12). The exhaustion curve for tannin is presented in Fig. 2.

An examination of the exhaustion curve reveals a deviation from the normal breakthrough curves for ion exchange. For most of the part, the removal of tannin does not seem to be due entirely to an ion exchange reaction. It appears that in the present case the ion exchange phenomenon is also accompanied by adsorption of the tannic acid on the resin. The initial stage on the exhaustion curve where, the tannin in the influent rises progressively from 0 to 6 mg/l, ion exchange seems to be predominating, because of the sharp decrease observed in the pH of the effluent. The breakthrough aparently had started from the beginning of the run itself However, the effluent tannin concentration, instead of equalling that of the influent, levels off at 6 mg/l thereby indicating that a removal of 40% is still accorded in the



INFLUENT : TANNERY EFFLUENT ADDED TO TAP WATER

Fig. 2—Tannin Removal in Ion Exchange

column. This situation continues till towards the end, the concentration of tannin in the effluent gradually rises and more or less equals that of the raw water. The removal is probably due to adsorption of tannin on the ion exchange resin. This is also supported by the fact that the pH does not change appreciably during this period, when adsorption is presumed to be dominating. The flat portion of the curve when the effluent concentration was more or less constant as 6 mg/l may perhaps be thought of as representing a steady state performance. This could have been brought about probably by the diffusion of the tannin molecules into the microporous matrix structure of the resin (13) where they might get adsorbed. Once this diffusion process stops (when all the active sites on the resin has attained equilibrium with the effluent), the effluent concentration increases till it equals the influent concentration. Detailed experimentation to confirm this hypothesis or to further elucidate the mechanism of tannin removal in the ion exchange beds was not undertaken in this study because of certain other factors limiting the feasibility of employing ion exchange for tannin removal. These factors are discussed below.

During exhaustion of the column, the resin bed was observed to be clogged after about one week of continuous operation. Since the suspended matter would have been removed in the pretreatment step, it seems that either some microorganisms capable of utilizing tannin and growing on the bed or certain insoluble end products of the biodegradation of tannin may be cause for the clogging. It is in fact, known that some microorganisms produce mucopolysaccharides from tannin (14) which could clog the ion exchange bed.

Another interesting fact noted during the experiment was that the resin changed color from light brown to black while being exhausted. Further attempts to bring back the exhausted resin to its original form by regeneration were futile. Irrespective of the extent of regeneration, all the tannin retained on the resin bed could not be eluted out Similar effects were noted by Ward and Edgerley (15) on another strong anion exchange resin, Dowex 1, with an influent containing tannin. They reported that the capacity of the Dowex 1 resin reduced approximately by 3% per regeneration-exhaustion cycle, while removing tannin. In a batch study, the reduction in capacity of the DE ACEDITE FF-IP resin was determined for five regeneration-exhaustion cycles using an exhaustant consisting of a 5 g/l solution of tannin. The results are reported in Table II. The reduction ranged from 2.5% to 3.6% comparing well with the other reported study by Ward and Edgerley (15).

The fact that all tannin retained on the bed could not be eluted out suggests the possibility of some sort of chemical bonding between the resin and tannin.

3. Chlorination for Tannin Removal

The raw water used for chlorination experiments was prepared by adding sufficient

TABLE II—REDUCTION IN CAPACITY OF DE ACEDITE FF-IP RESIN DUE TO TANNIN IN SUCCESSIVE REGENERATION-EXHAUSTION CYCLES

Reg.—Exhaus. cycle no.	Anion exchange capacity* of resin meq/g	Reduction in capacity (%)
1	3.5	—
2	3.41	2.57
3	3.30	3.23
4	3.18	3.64
5	3.08	3.14

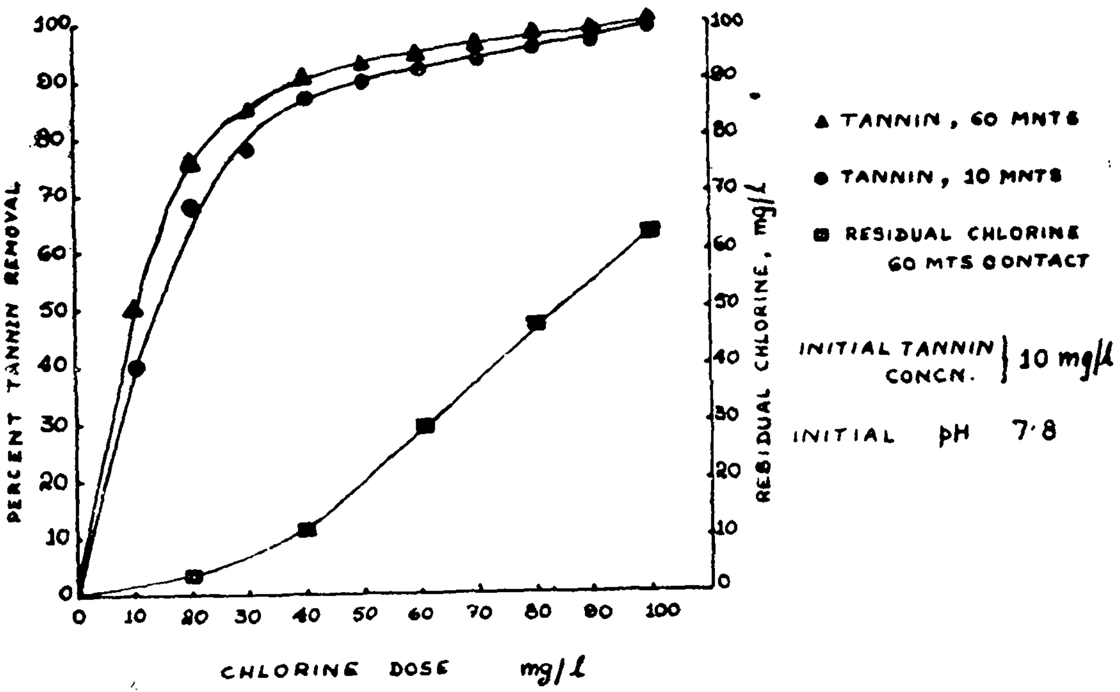
* Capacity of the resin is expressed in milliequivalents per gram of the resin in chloride form.

amounts of a tannery waste to the water from the Ganga. Waters with initial tannin concentrations of 5, 10 and 20 mg/l were used in the experiments. The chlorine doses employed in this study ranged from 0 to 120 mg/l. To one liter of the raw water an appropriate quantity of chlorine water was added and system kept well mixed. Samples were withdrawn after 10, 20, 30 and 60 min. contact and analyzed for tannin. The 10 min samples were also analyzed for total residual chlorine.

Fig. 3 and 4 present the results of experiments on tannin removal by chlorination. It is apparent that contact time beyond 10 min does not result in considerable increase in the removal of tannin, as can be seen from Fig. 3. Initially the removal rate with increased dose improves rapidly, but at higher doses of chlorine the rate of increase in efficiency of removal is considerably lower and hence operation in this range becomes uneconomical. A dose of 20 mg/l chlorine removes about 68% of tannin when the initial tannin concentration of the raw water is 10 mg/l, while the corresponding efficiencies are 40% and 85% for initial concentrations of 20 and 5 mg/l, respectively. Above this dose, the residual chlorine concentration rises sharply with dose and the increase is more or less directly proportional to the dose added as can be seen from the linear curve for residual chlorine versus chlorine dose. It may be noted that higher orders of removal of tannin necessitate the use of relatively high doses of chlorine and residual chlorine concentrations then become much higher than can be tolerated for most water uses. It is probable that the high chlorine dosage requirement is due to the presence of plenty of other organic matter in the tanning effluents.

4. Tannin Removal by Adsorption on Animal Charcoal.

Synthetic raw water was prepared for the experiments as in the case of chlorination. Powdered animal charcoal doses ranging



RAW WATER: TANNERY EFFLUENT IN GANGES WATER

Fig. 3—Residual Chlorine and Tannin Removal with Chlorine

from 0 to 1000 mg/l were employed for the study. The appropriate charcoal dose was added to one liter of the raw water and well stirred. Analyses for residual tannin were carried out after 5, 15, 30 and 60 min contact; the equilibrium for the system was observed to be established after 60 min contact time.

The data from these experiments was found to fit, reasonably well, a Langmuir type of isotherm which is depicted in Fig. 5.

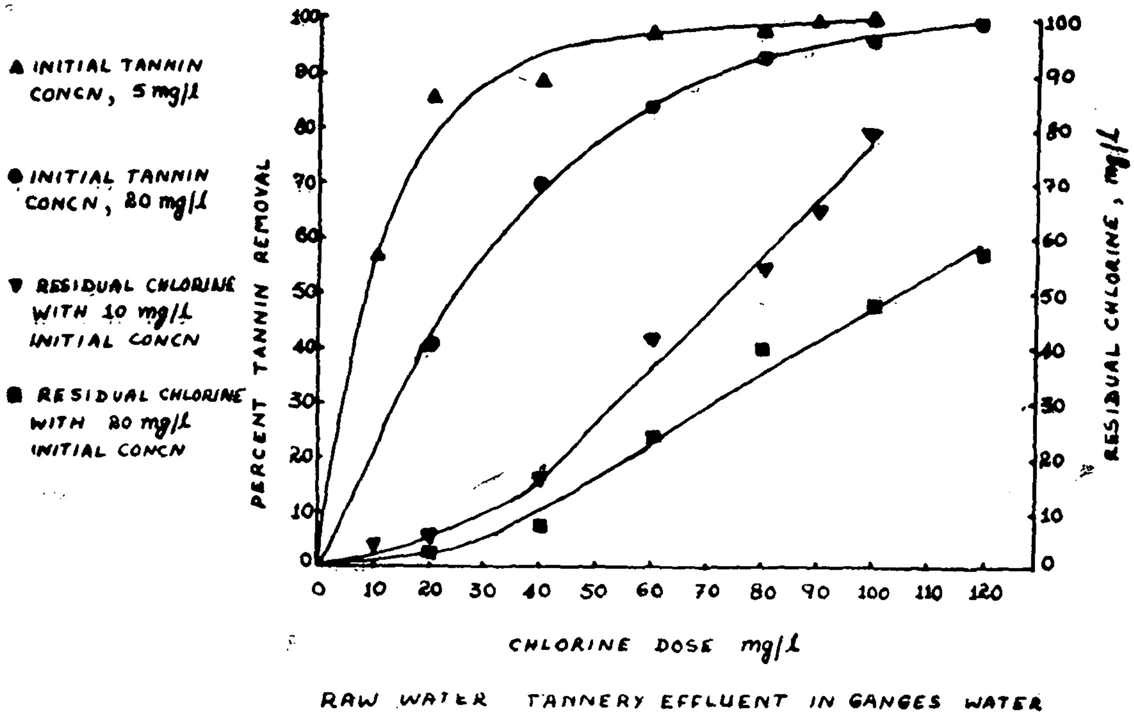


Fig. 4—Tannin Removal and Residual Chlorine with varying Chlorine Doses

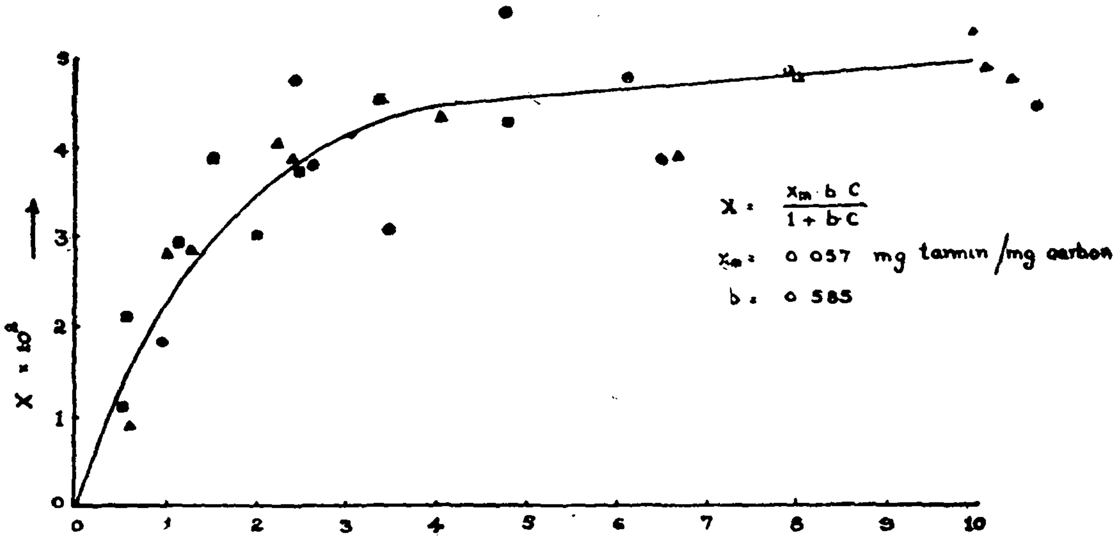


Fig. 5—Langmuir Isotherm for Adsorption of Tannin on Animal Charcoal

The Langmuir isotherm may be expressed by the relationship:

$$X = \frac{X_m . b . C}{1 + b . C}$$

where X =-observed capacity of the charcoal, mg tannin/mg carbon

X_m = the ultimate capacity

b = reciprocal of the equilibrium concentration at which half-coverage of the available surface is attained.

C = Concentration of solute in solution at equilibrium.

The relationship may also be expressed as:

$$\frac{1}{X} = \frac{1}{X_m . b . C} + \frac{1}{X_m}$$

Plotting 1/X vs. 1/C, the values of the constants X_m and b for the system of animal charcoal and tannin studied were found to be 0.057 mg tannin per mg of charcoal, and 0.585 respectively. It is however, to be noted that these constants may vary with different sources of tannin or water.

The closeness of the experimental points to the theoretical curve in Fig. 5 indicates the good fit which Langmuir isotherm provides for adsorption of tannin on animal charcoal in the concentration range employed in this study. The constants X_m and b may have higher values in systems with pure tannin because the competing influence on adsorption of other organic matter would be absent in such cases. Although animal charcoal gives efficient removal of tannin from dilute concentrations, it is a rather expensive material. It is, therefore, proposed to investigate the adsorption of tannin on several grades of indigenous carbons, both powdered and granular. These investigations are expected to yield results providing a basis for comparison of the performance and cost of using the different carbons for practical purposes.

Conclusions

From the study reported herein the following conclusions may be drawn :

1. Ion exchange using the strong anion exchange resin DE ACEDITE FF-IP cannot successfully be employed for removal of tannin, firstly because of the low orders of removal and secondly because of the fouling of the resin by tannins.

2. Tannins in waters being treated using the resin DE ACEDITE FF-IP results in a reduction in the anion exchange capacity of the resin ranging from 2.5 to 3.6% per regeneration-exhaustion cycle.

3. Although chlorine could oxidize the tannins, very high doses of chlorine are required for this purpose which results in an undesirably high residual chlorine in the treated water.

4. Adsorption on active charcoal appears to be an effective method for removal of low concentrations of tannins from waters. The adsorption equilibrium is aparently well described by the Langmuir type of isotherm.

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DISCUSSION

Shri B. I. Bhatt: Regarding the removal of tanning with the help of activated carbon it looks alright to experiment with powdered activated carbon in order to select the type of activated (from the adsorption isotherm) carbon and the temperature of adsorption operation. However, for large scale operation, a test column containing granular or pelletized activated carbon may be tried out. Considerable literature exists on the purification of dye liquors with the help of activated carbon. In this case, the research workers have used biological culture for regenerating the bed. Do you believe that such experiments will help you in bringing down the cost of purification?

Dr. T. R. Bhaskaran: It may be worthwhile trying filtration through granular activated carbon and regenerate it for reuse.

Shri T. H. Venkitachalam: It is generally true that from the operational point of view filtration through a bed of granular activated carbon is more convenient than the use of powdered carbon in dispersions for adsorptive removal of dissolved constituents. The experimental work outlined here was intended to be a comparative basis between ion exchange, chlorine-oxidation and adsorption on carbon. Powdered carbon was used in order to facilitate equilibrium studies within a reasonable time limit. Considering the high cost of activated carbon, it does seem that regeneration and reuse of the carbon will many a times prove to be economical. Further, in the case of tannins which are easily biodegradable, biological regeneration of the granular carbon might prove to be a feasible proposition. Investigations on this aspect are, however, yet to be carried out.

Prof. J. J. Ghosh: By following the basic principles of chemistry, whether the tannins, which are polyphenolic in nature, can be converted to polyphenolic acids by using oxidizing agents like Cl_2 or potassium permanganate? The oxidized product being mainly polyphenolic acids, whether could be converted to insoluble salts with iron or other metals?

Shri T. H. Venkitachalam: Chlorine and other oxidizing agents can, of course, be used for removal of tannins from water. However, as is seen from the present study, the dosage of chlorine for high removal efficiency is very much above the normal chlorine doses used in water treatment practice. Moreover, at such high doses of chlorine, the residual chlorine in the water was also substantial which could mean further processing of the water to bring down the chlorine residuals. As for precipitating the tannins out of the water as insoluble compounds, it does not seem to be a desirable method from the point of view of feasibility. The concentrations of tannins normally encountered in surface waters are small and hence economic removal of precipitated tannins may not be possible.

PROC. SYMP. ON ENVIRONMENTAL POLLUTION (1973)

Water Pollution Control in Steel Industries in India—A Plan for Action

S. K. CHAKRABARTI*

The importance of a fool-proof pollution control program in integrated steel plants in India has been highlighted in this paper. Some of the important considerations in planning an effective waste control program in integrated steel plants are discussed.

It is pointed out that cost associated with operating pollution control programs is not insignificant but it should be *judiciously* related to the effectiveness in removing and controlling the pollutants by thoughtful and well engineered planning. It is suggested as an economical proposition to reduce the waste volume at the source by necessary process changes, material recovery and water reuse wherever it is economically feasible.

Introduction

Steel industry in India, as it stands now, is the biggest industrial complex with its subsidiaries and supporting industries. It has a definite impact on a locality in so far as social, economical, political and environmental aspects are concerned. So, in fixing steel industry's production goals for the future, its tremendous responsibility towards welfare of the society in respect of giving a better and livable environment cannot be ignored.

Effective and economic control of pollutional discharges in integrated steel plants is essential. Steel plant management in India are gradually becoming aware of this. But, there is a huge information gap and derth of knowledge for precise, accurate and reliable data which can be utilised for specifying system design, performance and management. It is the responsibility of the industrial management, pollution control engineers and plant operators to work in a team to establish treatment processes which will remove and dispose of pollutants with minimum hazard and damage to environment. Management's concern should be expressed in the form of interest and stimulation of planned programmes to control and resolve each individual situation.

Design of industrial waste treatment systems for integrated steel plants requires knowledge of the manufacturing processes involved and an understanding of inplant control of wastes. It is very important that designers become familiar with the wastes to be treated and their expected variations. Because of the diversity in manufacturing processes in integrated steel plants, each waste stream need to be systematically studied. Treatment requirements and abatement plans should be determined after studying the available receiving waters, the water quality requirements and the waste loads. Some of the important considerations in preparing an effective pollution control programme in steel plants in India are discussed in this paper.

Study of the Manufacturing Processes and Pollution Parameters

Pollutants that are of main concern in integrated steel plants, are suspended solids, cyanides, acids, ammonium compounds, phosphates, phenols, oils etc. Oxygen con-

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* Central Engineering & Design Bureau, Hindustan Steel Ltd., Ranchi.

suming wastes, temperature etc. also have serious effect on stream. Principal waste streams generated from different processes are discussed here plantwise with their pollutant potentials.

1. Cokeoven and Byproduct Plant

Ammoniacal liquor alongwith wastewaters from Byproduct plant pose a serious problem for effective treatment. Various chemical and biological means are adopted for breaking down ammonia, phenols and cyanides to reduce their toxicity and high biochemical oxygen demand. Tar and oil contents of the waste stream also create nuisance condition.

Plants practising coke quenching with this waste also experience problem of air pollution, corrosion of exposed metals induced by oxides of sulphur, nitrogen and by the chlorides released during quenching. Chlorides deposited on the coke also attack the lining of blast furnaces and contaminate the gas washer water.

2. Blast Furnace Gas Cleaning

Dust in the furnace flue gas is removed by dust collectors, wet gas scrubbers and electrostatic precipitators. Usually, finer dust particles accumulate in the gas washer water which may amount to 1000-2000 gal/ton of hot metal. Most of this waste water is recycled after removing the dust by settling and other means. However, because of heavy sludge content, there is a constant maintenance problem in this area.

3. Basic Oxygen Furnace Gas Cleaning

This process involves jetting of pure oxygen onto the surface of a bath of molten pig iron resulting in burning out impurities with the production of tremendous heat. This heat is carried by the gas and finally taken out by water from the gas. Water is also used for cooling the gas ducts or hoods, for scrubbing the dust from the gas and for cooling the oxygen lance. Most of this cooling water is uncontaminated, except for the temperature increase. However, the scrubber water is contaminated with dust containing iron oxides, lime etc. with particles ranging from 5-6mm to 2 μ in size. Because of wide distribution of particle size, density abrasiveness and intermittency of flow, the treatment of this waste causes serious problems such as clogging of sludge lines, break down of thickener mechanism, wearing of sludge pumps etc., resulting in poor quality of effluent. Because of high alkalinity and pH of this water, it is often not recommended for recirculation.

4. Rolling Mills

Usually, very high volume of waste water is generated in hot rolling mills which may range upto several thousand gpm. Part of this water is uncontaminated, part contains coarse scale and part fine scale which might make it necessary for secondary treatment. Oil is also present. Cold rolling mill waste contains variety of floating and emulsified oils, detergent, mill scale, cleaning chemicals and dirt. In one of the processes, water and oil are applied from separate systems directly to the strip and are completely discharged. In recirculating system, the rolling solution is occasionally discharged which usually contains significant quality oil. Wastes from cleaning lines contain detergents etc. and are occasionally discharged.

5. Pickling Waste

Both sulphuric and hydrochloric acids are used to remove mill scale, dirt and grease. Usually, the waste amounts to about 55 gal/ton of steel produced. The acids used in pickling eventually become weak and contaminated with dissolved iron. This must be treated before disposal. The rinse water produced here is weaker in acid content but higher in volume.

6. Metallizing Lines

Several processes are involved here like tinning, plating, galvanizing, wire drawing etc. Wastes generated may be contaminated with chromate, cyanide, fluoride, zinc, tin, copper, acids and alkalis, Because of presence of very toxic materials, these wastes have high pollution potential.

Other than the main plant units, there may be several other sources from the supporting plants as commonly noticed in integrated steel plants. These wastes may be of considerable quantity and may have high degree of pollution potential. A typical waste analysis of an integrated Steel plant in India is given in Table I. This, however, does not include all the waste streams generated in the steel plant. Information on types and quantities of raw materials is important and helps in calculating the characteristics of the waste generated from a process. Other than finished products manufactured, some of the raw materials are catalysts and do not enter into reactions or the products. A material balance of the raw materials should account for the losses that may end up in the industrial effluents. After studying the manufacturing operation, its inputs and outputs, a process flow diagram should be prepared showing the sources, quantities and qualities of the liquid waste from each area. It often becomes necessary to reduce waste load by some inplant changes. After analysing a waste stream, a review may be made of a process contributing a particular contaminant to determine whether certain amount of the contaminant can be reduced or recovered economically for reuse. Process wastewater use practices may also be reviewed to determine if use of fresh water can be reduced.

Study of Water Quality Standards

Water pollution can be defined as discharge in sufficient amounts of such materials into a natural water course that will affect the quality of the water for its legitimate uses. These uses may include drinking, agricultural, industrial, navigation, aesthetic, etc. The words "sufficient amounts" are important here and these amounts may vary with regard to country, State and river. These amounts will be given in the applicable water quality standards which should be thoroughly studied before taking up a pollution control programme. In some cases, the local State agencies may guide in this respect. From the effluent quality criteria, it is necessary to decide the degree of treatment required for the wastewater. If a particular standard is so stringent that the waste will necessitate very expensive treatment, then, in some cases, total reuse of the particular waste stream may be more economical.

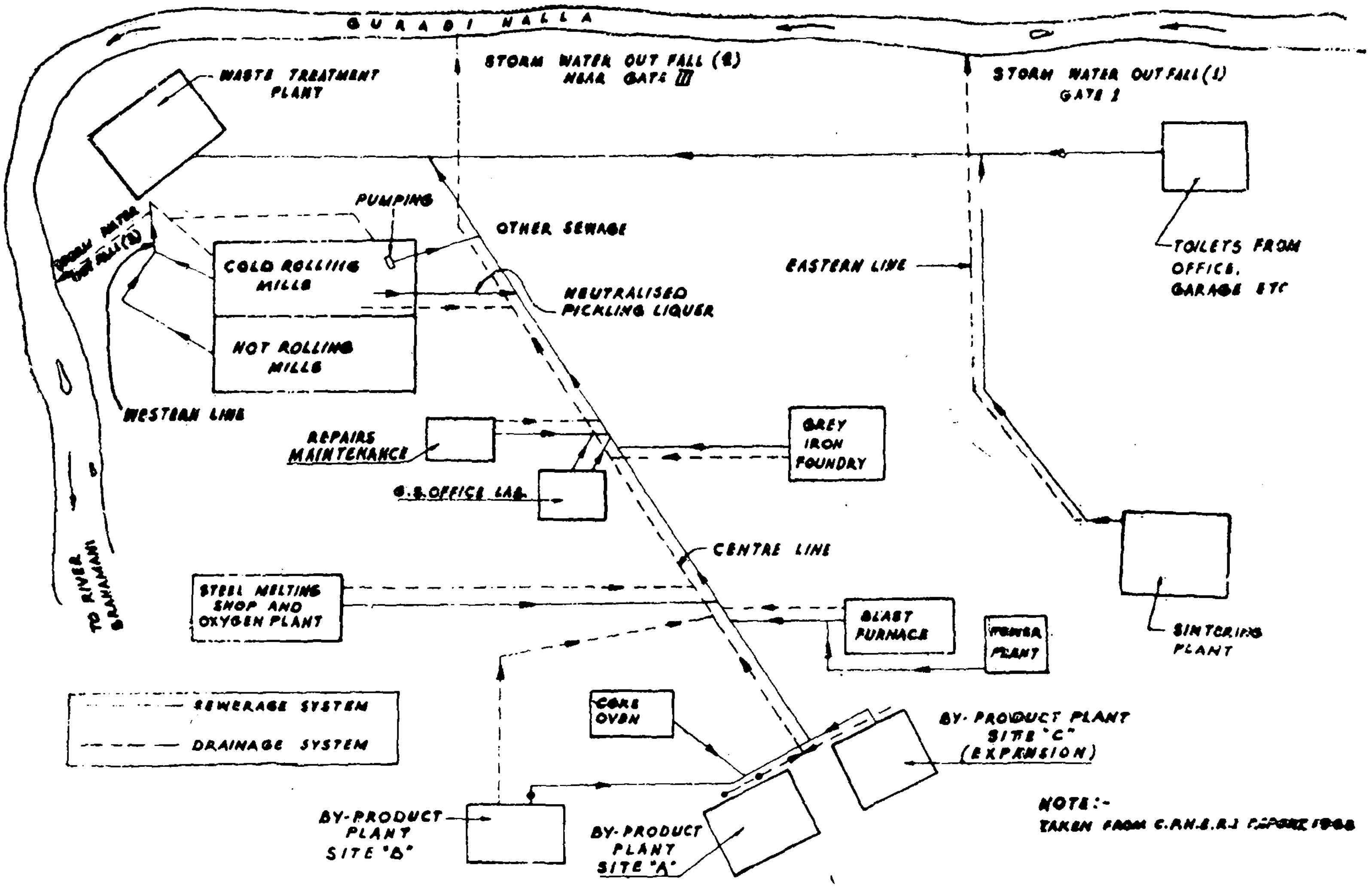
Study of Waste Conveyance System

It is very important to prepare a complete sewer map showing underground sewer systems and connections from different manufacturing plants. This is also essential for wastes sampling programmes and for establishment of meaningful sampling points. Some existing steel plants may have combined sewer system for all the wastewater including surface waters and sanitary sewage. It is also possible to have separate conveyance system with interconnections at places. A typical sewer layout of an integrated steel plant in India is shown in Fig. 1. It is also necessary to have an area map showing location of the treatment facilities, receiving waters, outfall sewers and outfalls for other wastewater contributors.

TABLE I—TYPICAL CHARACTERISTICS OF WASTE STREAMS FROM DURGAPUR STEEL PLANT

Coke oven & Byproducts		Blast Furnace	Hot Rolling Mills	Power Plant	Coal Washery
Ammonia	300—500				
Sulphide	10—20	SS	SS	Phosphate	
Cyanide	10—50	1000-10500	320-600	40-60	SS
Phenol	900—1000		Oil & Grease		800-24700
Chloride	4000—4200		60-80		
BOD (5 days, 20°C)	3800				

Note— (1) Values are expressed in mg/l.
(2) Analyses are taken from routine laboratory test results of R & C Laboratory, Durgapur Steel Plant.



NOTE:-
TAKEN FROM C.P.H.E.R.I REPORT 1968

Fig. 1—Sewerage and Drainage System of Rourkela Steel Plant (Schematic)

Treatment of Industrial Wastewater

Industrial wastewaters may be treated individually or in combination with sewage, depending on the quantity and quality of the wastewaters. Other than treatment methods employed at the manufacturing sites for technological requirements, there are numerous methods employed for treatment of steel mill wastewaters. These may include screening, sedimentation, neutralisation, chemical precipitation, absorption, filtration, biological treatment etc. Cooling towers or ponds are also considered as waste treatment facilities for heated discharges. Vacuum filtration, burial, lagooning, incineration etc. are employed for ultimate disposal of sludge solids and toxic materials. The details of these methods are, however, beyond the scope of this paper.

Operation and Maintenance of Waste Control Facilities

Industrial waste treatment plants of steel complexes in India are usually operated without due regard for plant efficiencies and proper consideration for variations in wastewater flows and characteristics. It is very important that proper attention is given to maintenance and operation of the plant and equipment used for waste treatment purposes. It is also essential that waste treatment facilities are operated by adequately trained personnel to detect symptoms and irregularities of a treatment system before it fails. For this, routine laboratory analyses of samples collected at the right places and at right times must be run. Samples should be representative and properly collected and preserved before the analyses are made. Procedures for proper collection and preservation of samples are given in standard texts and are not discussed here. The laboratory test results should be systematically recorded for future guidance, operational controls, research and for evaluating effluent compliance with applicable water quality standards. Proper operation of waste treatment facilities in integrated steel plants largely depends on adequate work planning and good personnel management without which it is impossible to have a foolproof pollution control programme.

Conclusions

The importance of organising a well planned waste control programme in integrated steel plants in India and the steps involved in such a programme are discussed in this paper. As such, it contains very little information on actual waste treatment plant performances. As a matter of fact, what is basically missing in the steel plants in India today, is sufficient scientific and usable data for systematic study and research in this area of waste water control. In industrially developed countries, most of the important industrial complexes have established well engineered industrial waste control programmes. These programmes have been successful following long range study and research at the plant level. In our country, at this stage of rapid industrialisation, we have to make enough efforts to develop treatment processes through research and pilot plant studies to suit our own requirements and economy. The responsibility for efficient design and control of waste treatment processes lies with every one involved in this programme, starting from the top management down to individual plant operators. It is only an organised team work which can help in making a programme like this successful.

Acknowledgement

The author is grateful to Shri S. K. Sanyal, Superintendent, and Shri S. N. Chanda, Asst. Superintendent, both of Central Engg. & Design Bureau, Hindustan Steel Ltd. Ranchi, for their continued interest and guidance.

DISCUSSION

Shri M. L. Shah (Bombay): (i) Have the cost studies on the treatment plant as compared to cost of the plant been made? (ii) Reuse of wastewater has been done by Kaiser Steel Plant at Fomtana (California). Tremendous literature is available about reuse of wastewaters and such information can be used in the design of waste treatment plant.

Shri S. K. Chakrabarti: (i) There are various waste treatment units provided in an Integrated Steel Plant. Some of them serve both technological and pollution control purposes; some are for pollution control only. The treatment cost exclusively for pollution control has not been worked out. (ii) Agreed.

Shri V. D. Kothiwale (Bhavnagar): With the suitable system of water recovery from waste, what proportion of water do you think can be reused as compared to fresh water?

Shri S. K. Chakrabarti: The quantity of wastewater, that can be reused, depends on a particular technological process. Whether the wastewater can be economically treated to produce water of such quality as can be fed to the recirculation system needs further study. On an average, about 10% fresh water of total water requirement can be augmented.

Shri A. R. Tiwari (Bhilai): In Bhilai Steel Plant the wastes arising in various processes are re-used. Major quantity of water is required for cooling in any steel plant. At Bhilai, we have recirculation system for cooling water. The phenolic wastes and the liquid wastes from blast furnace gas cleaning system are re-cycled, after due treatment. Even the solid waste (blast furnace slag) is a saleable product. The ACC purchase this slag for manufacture of cement.

Shri S. K. Chakrabarti: Agreed.

Shri N. Sriramulu: It is suggested that, by treating the effluents you can: (i) meet ISI effluent standards, and (ii) reuse your waters for a number of units in the steel plants. Costs do not matter.

Shri S. K. Chakrabarti: (i) We always endeavour to provide adequate treatment to all wastewaters of Steel Plants. However, due to variation in the processes and due to plant operational troubles, it is very difficult to meet the standards. Even in technologically advanced countries, it has not yet been possible to provide 100% control of wastewaters for large industrial complexes. (ii) We always try to reuse waters in different units of the Steel Plants and even for large plants cost is always taken into consideration.

PROC. SYMP. ON ENVIRONMENTAL POLLUTION (1973)

Cost of Industrial Waste Treatment

B. B. BHALERAO* and S. R. ALAGARSAMY*

Treatment problems of a variety of industrial wastes have been studied in detail and treatment alternatives have been suggested to the Industries by CPHERI. In evolving these treatment flow sheets and cost data, the emphasis was on the Low Cost Waste Treatment methods namely anaerobic lagoon, oxidation pond, aerated lagoon and oxidation ditch.

In this paper cost data have been presented for some of the industries viz. starch, brewery and distillery, instant coffee, dairy and milk bottling, fertilizer, pulp and paper, and tannery. It is hoped that the data presented in this paper will be found useful by various industries to obtain approximate costs involved in putting up the treatment system. This will also help the new industries to make adequate provision for waste treatment in the budget estimates in the planning stage itself.

Introduction

Industrial wastes like domestic sewage contain suspended, colloidal and dissolved solids of mineral and organic origin. Industrial wastes are treated either by themselves or in admixture with domestic sewage before disposal. For many industrial wastes the polluting constituents are capable of being removed by physical and biological action and the methods are similar to those for domestic sewage. Conventional treatment methods employing activated sludge or trickling filter and the newly developed low cost waste treatment methods, namely, anaerobic lagoon, waste stabilisation pond, mechanically aerated lagoon and oxidation ditch are employed for treatment of some industrial wastes.

CPHERI has surveyed several industries for determining their wastewater characteristics. The Institute has also advised many industries on economic method(s) of waste treatment on the basis of waste characterisation, laboratory or pilot plant studies, as the case may be, and cost estimates for various possible alternative treatment methods. In this paper, a brief account of waste characteristics, possible treatment methods and costs involved, is presented for the following industries :

1. Starch Factory
2. Brewery & Distillery Complex
3. Instant Coffee Plant
4. Dairy and Milk Bottling Plant
5. Nitrogenous and Complex Fertilizer Plant
6. Pulp & Paper Mill
7. Tannery

It would be pertinent to give here briefly the relevent information for each of the above industries, such as manufacturing process involved, raw materials employed and characteristics of the emanating wastewaters, before the costs involved in the economics and efficiency of the proposed treatment methods are discussed.

1. Starch Factory

The manufacture of starch from maize consists of: (i) steeping of maize in water containing sulphuric acid till the grain be-

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* Scientists, Central Public Health Engineering Research Institute, Nagpur-20

comes softened; (ii) shredding in disintegraters and resuspension in water when germ floats on the surface.

The germ is within oil which is extracted by steam. The hull, starch and gluten remain in suspension from which starch is screened out, washed, settled and dried at low temperature.

CPHERI has recently conducted wastewater survey in a starch factory and the waste characteristics are shown in Table I, from which it will be seen that the starch wastes are rich in BOD and suspended solids (1). The quantity of wastewater expected from a starch factory utilising the above process will be about 500-1000 gal/ton of starch produced.

CPHERI has prepared various flowsheets for treatment for one starch factory on the basis of information on effluent characteristics supplied by the factory. The cost of treatment of starch factory wastes for these flowsheets is summarised in Table II.

TABLE I—CHARACTERISTICS OF A STARCH FACTORY WASTE

pH	...	5.5-6.0
Total solids (mg/l)	...	4000
Suspended solids (mg/l)	...	1000-2000
BOD (mg/l)	...	800-1000

2. A Brewery and Distillery Complex

CPHERI has recently completed the study of waste characterisation and developed treatment flowsheets for a large complex having brewery, distillery and fruit canning plants under one management (2).

Amongst all the production plants in this complex, the effluent from distillery is the worst polluting waste with an average BOD of 19000 mg/l. It was found more economical to treat such a high BOD waste separately in anaerobic system before admixture with other less polluted streams.

The quantity of flow and BOD concentration of the wastes from different sections of the complex are given in Table III and the characteristics of combined effluent in Table IV.

On the basis of the characteristics of wastes and the requirements of local regulatory authorities, 3 different flowsheets were suggested for treatment of combined effluent of this brewery and distillery complex. These

TABLE II—COST OF TREATMENT OF STARCH FACTORY WASTES*

Wastewater volume = 60,000 gpd; BOD = 100 mg/l

Sr. No.	Process	Capital cost (including land) (Rs.)	Running Expenditure (Rs.)	Land Requirement (acres)
1.	Anaerobic lagoon followed by oxidation pond	80,000	6,000	1.25
2.	Anaerobic lagoon followed by oxidation ditch	120,000	8,000	0.55
3.	Oxidation ditch	200,000	10,000	8,000 sq ft
4.	Dilution and disposal by irrigation	30,000 + land cost for 40 acres	4,000	40 acres for irrigation

* Note : Cost of neutralisation, if found necessary, will be additional.

flowsheets are shown in Fig. 1, 2 and 3. Costs have been worked out for these 3 flowsheets which are presented in Table V.

3. Instant Coffee Plant

The manufacture of instant coffee incorporates the following two steps: (i) extracting the decoction coffee—chicory mixture; and (ii) ultimate spray drying of the liquid into powder.

The important characteristics of the wastewater consisting of spent coffee wastes alongwith percolator discharge carried out by the Institute for an Instant Coffee Plant are given in Table VI (3).

CPHERI has developed 5 different treatment alternatives and costs have been worked out as shown in Table VII.

4. Dairy and Milk Bottling Plant

Dairies and milk bottling plants discharge wastewater 2 to 8 times the volume of milk processed. The source of organics in the wastes are derived from spills, leaks and washings in various operations of the dairy industry. A dairy in India processing 1000 l of milk adds a BOD equivalent to that from 110 people. The principal wastewater characteristics in a large product-oriented dairy are shown in Table VIII.

Dairy wastes can be treated by almost any of the biological treatment methods. Provision of grease trap is necessary as a pretreatment to remove fat globules and greasy matter from milk wastes. The treatment methods for dairy wastes have been designed on the basis of the wastewater characteristics given in Table VIII.

TABLE III—CHARACTERISTICS OF COMBINED EFFLUENT FROM DISTILLERY COMPLEX

Characteristic	mg/l
COD	2840
BOD	1500
Total nitrogen as N	49.7
Ammoniacal nitrogen as N	3.5
Total phosphate as PO_4	9.7
Ortho phosphate as PO_4	1.09
Total solids	2540
Dissolved solids	2550
Suspended solids	240
Total volatile solids	1430
Dissolved volatile solids	1230
Suspended volatile solids	200
Potassium as K_2O	138

Cost estimates were prepared for various flowsheets for treatment of milk wastes. The extent of treatment required and, therefore, the cost of treatment will be different for the effluent to be discharged into inland surface water and on to land for irrigation. These estimated costs for a large product-oriented dairy having wastewater BOD of 1250 mg/l are shown in Table IX (4).

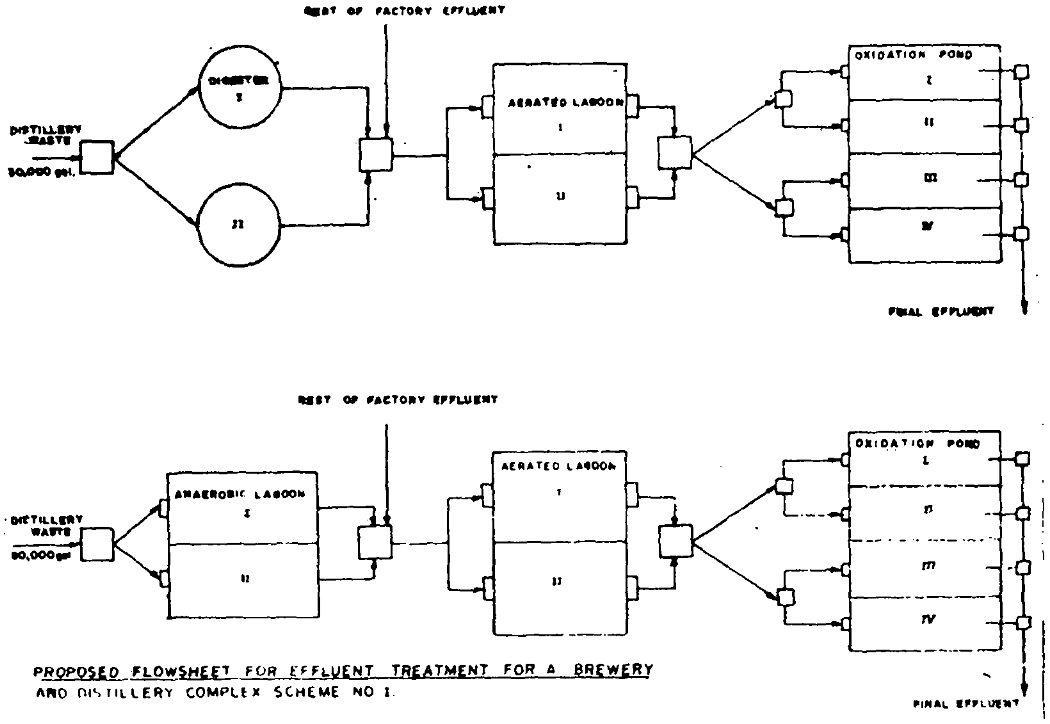
5. Fertilizer Plant

The fertilizer factories can be classified into two broad categories, **viz.**, nitrogenous

TABLE IV—VOLUME AND BOD OF WASTES FROM DIFFERENT SECTIONS OF THE DISTILLERY COMPLEX

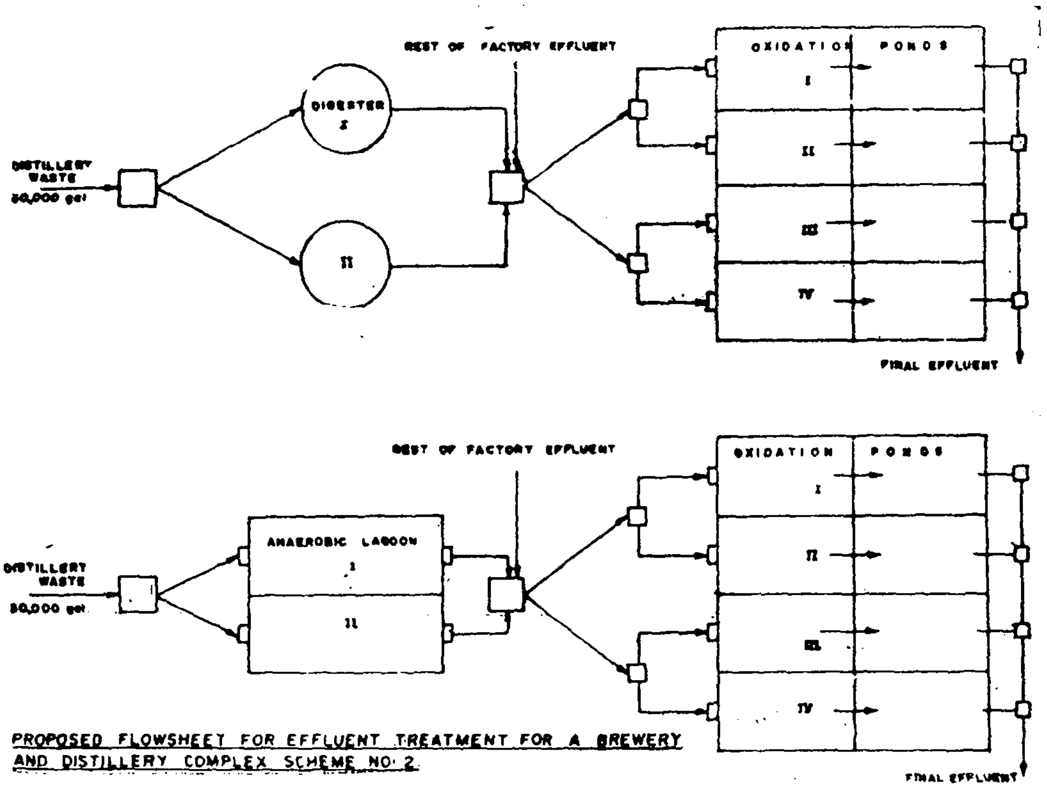
Total flow = 0.56 mgd; BOD load = 8690 lb/day

Sr. No.	Source of wastes	Flow (gpd)	BOD (mg/l)	BOD (lb/day)
1.	Brew house	50,000	2600	1300
2.	Distillery	30,000	19000	5700
3.	Malt house	50,000	800	400
4.	Storage bottling & floor washing	10,000	4200	420
5.	Bottle washing	1,80,000	35	63
6.	Food products division	1,00,000	750	750
7.	Domestic wastes	1,00,000	40	56



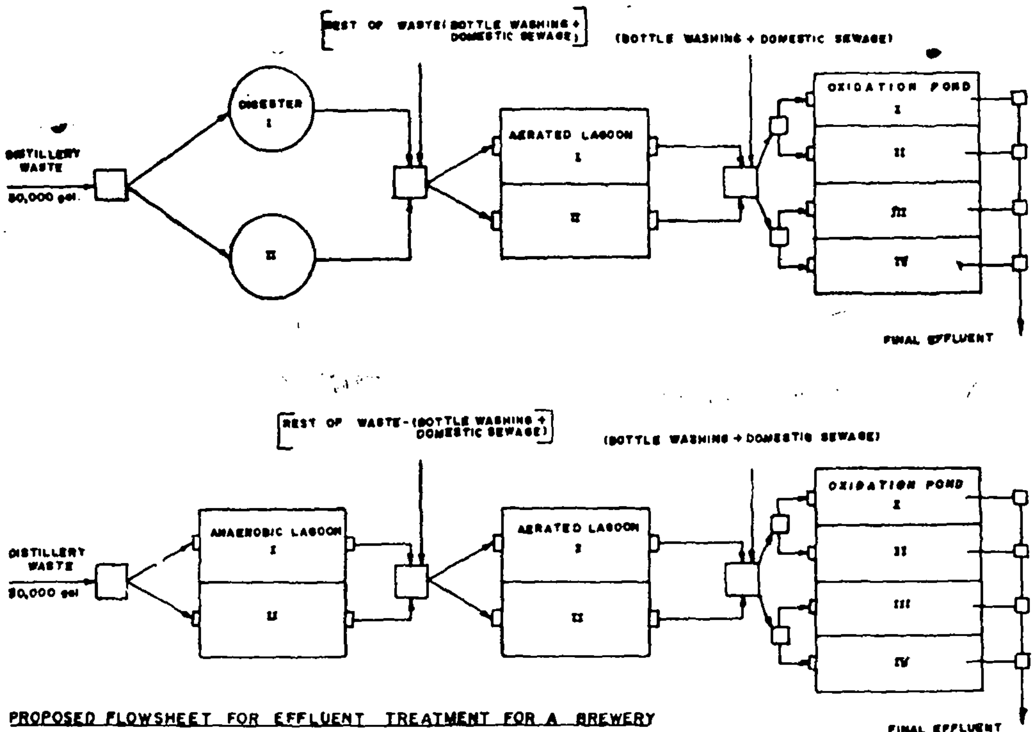
PROPOSED FLOWSHEET FOR EFFLUENT TREATMENT FOR A BREWERY AND DISTILLERY COMPLEX SCHEME NO 1.

Fig. 1



PROPOSED FLOWSHEET FOR EFFLUENT TREATMENT FOR A BREWERY AND DISTILLERY COMPLEX SCHEME NO. 2.

Fig. 2



PROPOSED FLOWSHEET FOR EFFLUENT TREATMENT FOR A BREWERY AND DISTILLERY COMPLEX SCHEME NO. 3

Fig. 3

TABLE V—COST OF WASTES TREATMENT OF A DISTILLERY COMPLEX

Flow = 0.56 mgd; BOD load = 8690 lb/day

Sr. No.	Scheme	Capital cost for construction of plant (Rs.)	Running cost for operation & maintenance of plant per annum (Rs.)	Land requirement (acres)
1.	Employing digesters for anaerobic treatment followed by aerated lagoon and oxidation pond	10,62,000	1,00,000	14
	Employing lagoons for anaerobic treatment followed by aerated lagoon and oxidation pond	7,62,000	82,000	15
2.	Employing digesters for anaerobic treatment followed by oxidation ponds	9,20,000	40,000	24
	Employing lagoons for anaerobic treatment followed by oxidation ponds	6.20,000	25,000	25
3.	Employing digesters for anaerobic treatment followed by aerated lagoon and oxidation pond	11,15,000	1,10,000	11
	Employing lagoons for anaerobic treatment followed by aerated lagoon and oxidation pond	8,15,000	95,000	12

TABLE VI—CHARACTERISTICS OF INSTANT COFFEE WASTES

BOD (mg/l)	1300-1600
COD (mg/l)	2700-3400
pH	6.0
Colour	Dark brown

TABLE VIII—PRINCIPAL WASTES CHARACTERISTICS OF A LARGE PRODUCT ORIENTED DAIRY

pH	7.8-10.0
Total solids (mg/l)	770-2730
Total volatile solids (mg/l)	320-2205
BOD (mg/l)	78-1810
COD (mg/l)	100-4500

TABLE VII—COST OF TREATMENT OF INSTANT COFFEE WASTES

Waste Flow = 8,000 gpd; BOD = 1,500 mg/l

Sr. No.	Mode of treatment	Minimum gross area requirement (sq ft)	Cost (Rs.)	
			Capital excluding land cost & initial pumping	Power requirement @ Re. 0.15/(kwh)
1	Anaerobic lagoon followed by oxidation ditch	5000	30,000	2700
2	Anaerobic lagoon followed by aerated lagoon	6000	27,000	2000
3	Aerated lagoon followed by oxidation ditch	5000	35,000	6000
4	Aerated lagoon followed by irrigation	3500 plus land for irrigation at 4-5 acres	17,000	4000
5	Oxidation ditch followed by irrigation	2000 plus land for irrigation at 4-5 acres	20,000	4800

TABLE IX—COSTS OF WASTE TREATMENT FOR A LARGE PRODUCT ORIENTED DAIRY

Flow = 0.65 mgd; BOD = 1250 mg/l

Sr. No.	Treatment method	BOD reduction (%)	Gross area reqd. (acres)	Horse Power (HP) reqd.	Cost (Rs.)	
					Capital cost excluding land cost	Running cost (only for power at the rate of Re. 0.15/kwh/annum
1	Aerated Lagoon	90	2.2	153	8,00,000	1,65,000
2	Oxidation ditch	95-98	1.8	198	11,00,000	2,21,000
3	Aerated Lagoon (Partial Treatment)	66	0.97	75	3,00,000	80,000

TABLE X—CHARACTERISTICS OF WASTES FROM A NITROGENOUS FERTILIZER FACTORY

Source	AMMONIA PLANT			UREA PLANT				B.F. water treatment plant	Steam Generation slurry 180 cu m/day	
	Hydro Refining	Reforming	CO_2 removal	Compressor house	Storage and recovery	Compressor house	Vacuum		Boiler blow down	Ash slurry
Quantity	0.4	2.1	3.0	2.4	0.3	10.2	25.50	80	10	180 850,400 220.32
Nature of waste	Condensate	Boiler blow down	Condensate	Condensate	Purge	Condensate	Condensate	Purge	Boiler blow down	—
Constituents (tonnes/day)										
Ammonia	tr	tr	—	—	0.072	—	14.6	—	—	—
Urea	—	—	—	—	—	—	6.12	—	—	—
CO_2	tr	tr	Saturated	—	—	—	7.95	—	—	—
$Mg\ SO_4$	—	—	—	—	—	—	0.545	0.545	—	—
H_2SO_4	—	—	—	—	—	—	—	0.565	—	—
$CaSO_4$	—	—	—	—	—	—	—	0.137	—	—
Na_2SO_4	tr	—	—	—	—	—	—	0.037	—	—
NaCl	tr	—	—	—	—	—	—	0.141	—	—
NaOH	—	—	—	—	—	—	—	0.118	—	—
HCl	—	—	—	—	—	—	—	0.018	—	—

tr=traces

fertilizer and phosphatic fertilizer. Treatment and disposal of a variety of highly polluting and toxic wastes from this industry has posed great problems in recent years. CPHERI has collected data on the loss of important chemicals in the waste and its flow variations in a number of fertilizer factories in India (5).

Tables X and XI give the important characteristics from nitrogenous and phosphatic fertilizer plants. It will be seen that the major pollutants from nitrogenous fertilizer plant include ammonia, urea, oil and traces of arsenic; while phosphate and fluoride are the additional pollutants in a complex fertilizer plant. The wastewater BOD is not really significant as compared to high concentration of ammonia. CPHERI has worked both in laboratory and field on some processes for ammonia removal.

TABLE XI—CHARACTERISTICS OF WASTES FROM A PHOSPHATIC FERTILISER PLANT

Characteristics	Phosphoric acid plant	D.A.P. plant
pH	4.9	7.4
Dissolved Solids	16040	3340
Alkalinity ($CaCO_3$)	—	275
Acidity ($CaCO_3$)	760	—
Free Ammonia	—	12
Fixed Ammonia	—	26
Phosphates (PO_4)	1800	—
Fluorides (F)	200	—

Note—All values except pH are expressed as mg/l

The Institute has developed the following flowsheets (Figs. 4, 5, 6) for treatment of waste from a complex fertilizer plant for ultimate discharge into inland waters to satisfy IS: 2490 (1963). The treatment includes ammonia removal by: (i) air strippers, (ii) simple lagooning, (iii) nitrification, and (iv) nitrification and denitrification. Costs for these treatment alternatives are presented in Table XII (6).

6. Pulp and Paper Mill

Pulp and Paper is one of the largest water consuming industries in India. Most of the

TABLE XII—COST OF VARIOUS WASTE TREATMENT METHODS FOR A COMPLEX FERTILIZER PLANT

Method	General Treatment for Arsenic, Oil, Phosphate and Fluorides removal	Ammonia and Urea Plant Effluents (3 mgd)				
		Alternative Treatment for Ammonia Removal				Disposal method
		Air Stripping after pH adjustment	Simple lagooning after pH adjustment	Nitrification in stone media reactors	Nitrification and denitrification	Storage for 9 months and disposal during monsoon
	(Rs.)	(Rs.)	(Rs.)	(Rs.)	(Rs.)	(Rs.)
1. **Using lime for pH increase**						
(i) Capital cost	2,00,000	44,00,000	21,00,000	30,13,000	44,00,000 (Initial costs for pumping distillery wastes/domestic sewage extra)	65,00,000
(ii) Running cost per annum for power and chemicals only	68,000	23,00,000	20,76,000	4,60,000	4,75,000 (Running cost for power for pumping distillery wastes/domestic sewage extra)	1,50,000
2. **Using Caustic Soda**						
(i) Capital cost	—	33,00,000	—	—	—	—
(ii) Running cost power and chemicals only	—	43,00,000	—	—	—	—

water used in this industry is discharged as wastewater. The objectionable constituents present in the effluent are colour, high suspended solids (375-2490 mg/l), BOD (160-1370 mg/l) and COD (470-2940 mg/l) (7).

CPHERI has carried out waste characterisation and pilot plant studies using anaerobic and aerobic lagoons for treatment of pulp and paper mill waste from a number of industries. Based on this work, treatment flowsheets have been formulated and cost estimates prepared for a few pulp and paper mills. Table XIII presents wastewater characteristics from a paper and board mill in South India for which CPHERI has worked out cost estimates for various possible treatment methods.

The cost of treatment for the wastewaters from this mill based on flow sheets as given in Fig. 7 are presented in Table XIV (8). It may be mentioned here that none of the biological methods studied will remove colour from effluents. For colour removal massive lime treatment and activated carbon treatment may have to be used. The above costs do not include colour removal for which the economics has to be worked out under Indian conditions.

7. Tannery

Tannery industry is also a major consumer of water and most of the water used is discharged as a waste. Liquid wastes are produced in large quantities in leather industry during soaking, liming, and tanning operations. Usually soak wastes, liming wastes and spent vegetable tan liquor are discharged intermittently, while spent deliming and bating liquors are discharged once a day. In addition to the wastes from different processes washings after different operations

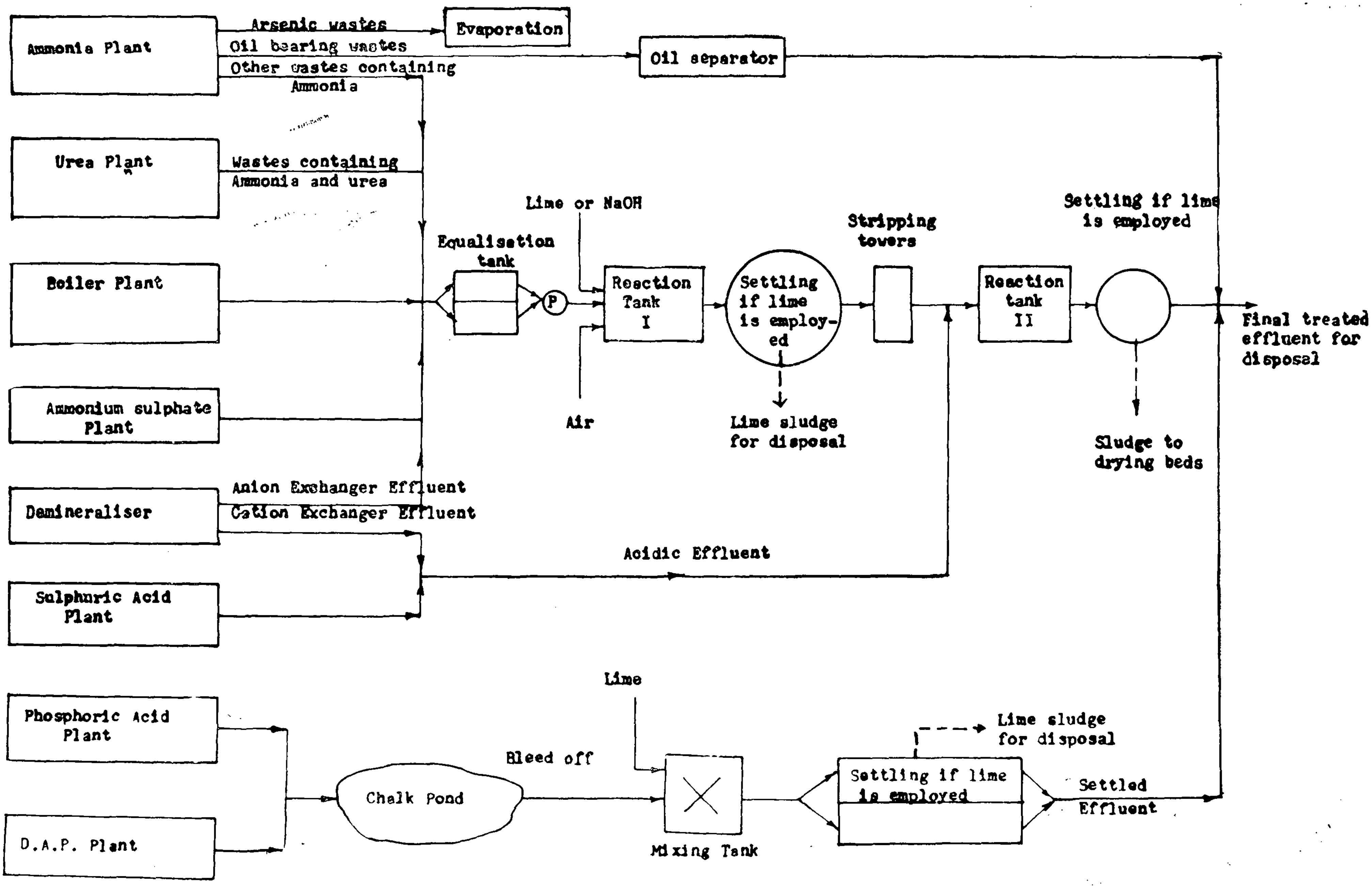


Fig. 4—Flowsheet for Effluent Treatment for a Complex Fertiliser Plant—Scheme No. 1

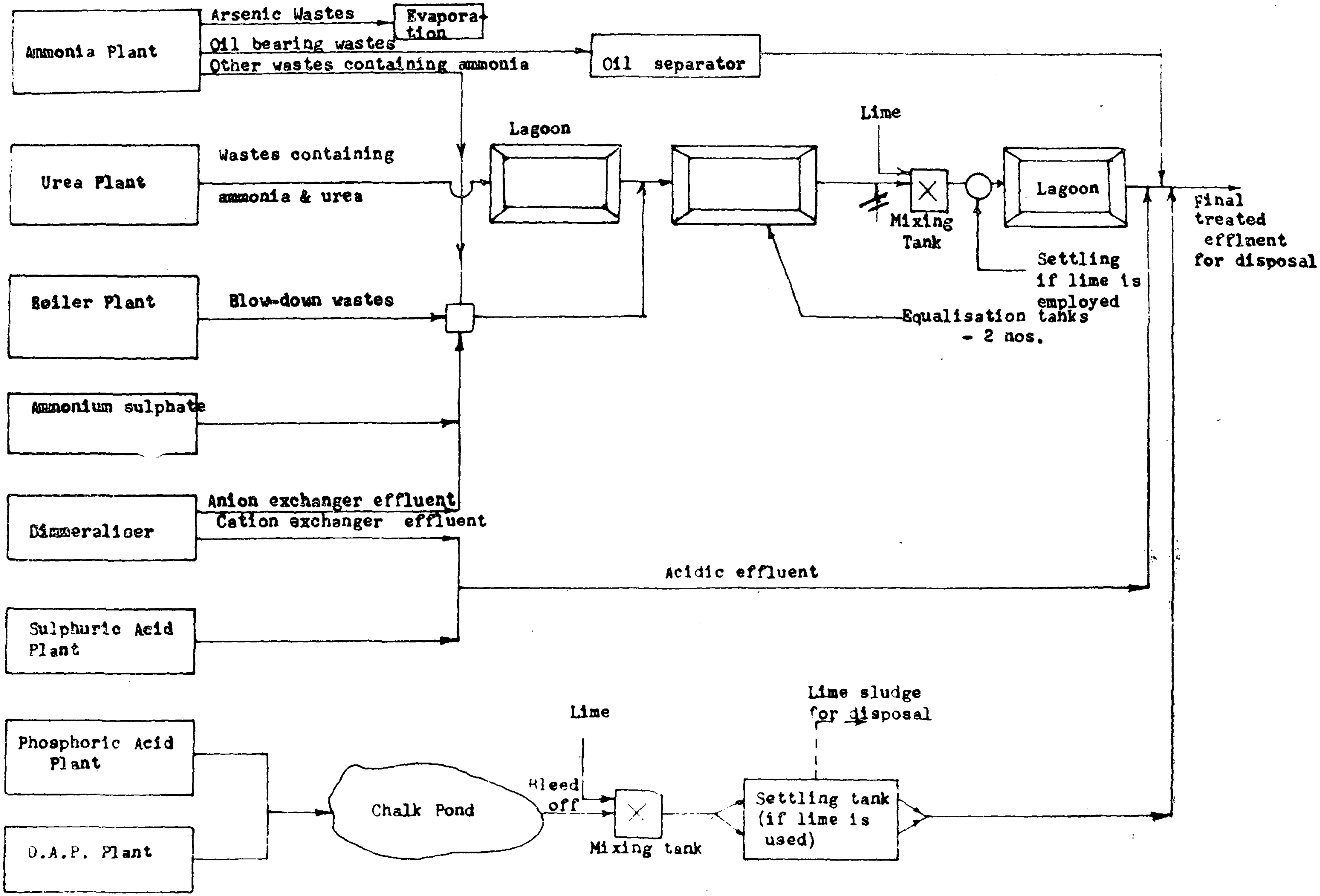


Fig. 5—Flowsheet for Effluent Treatment for a Complex Fertiliser Plant—Scheme No. 2

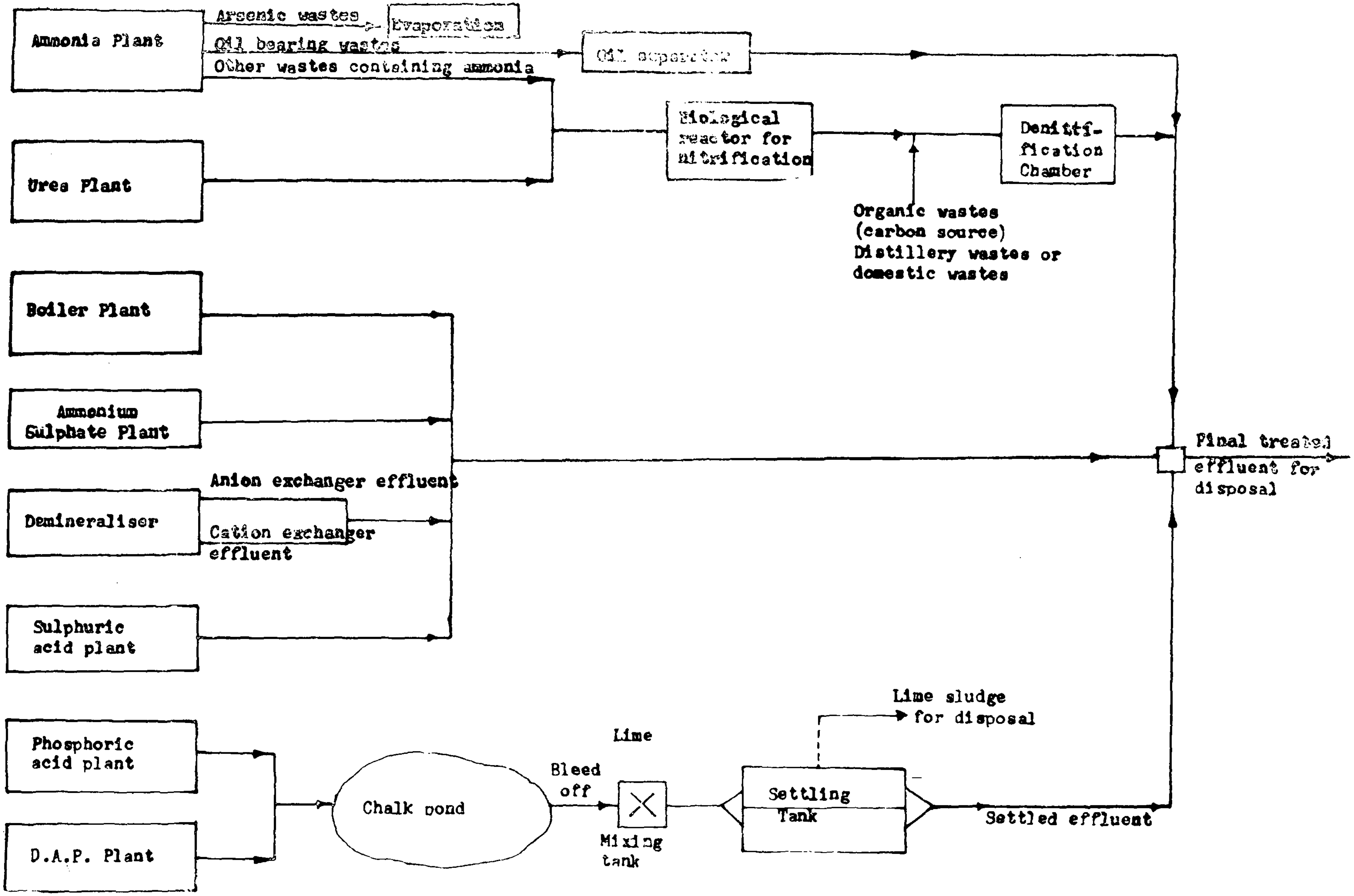


Fig. 6—Flowsheet for Effluent Treatment for a Complex Fertiliser Plant—Scheme No. 3

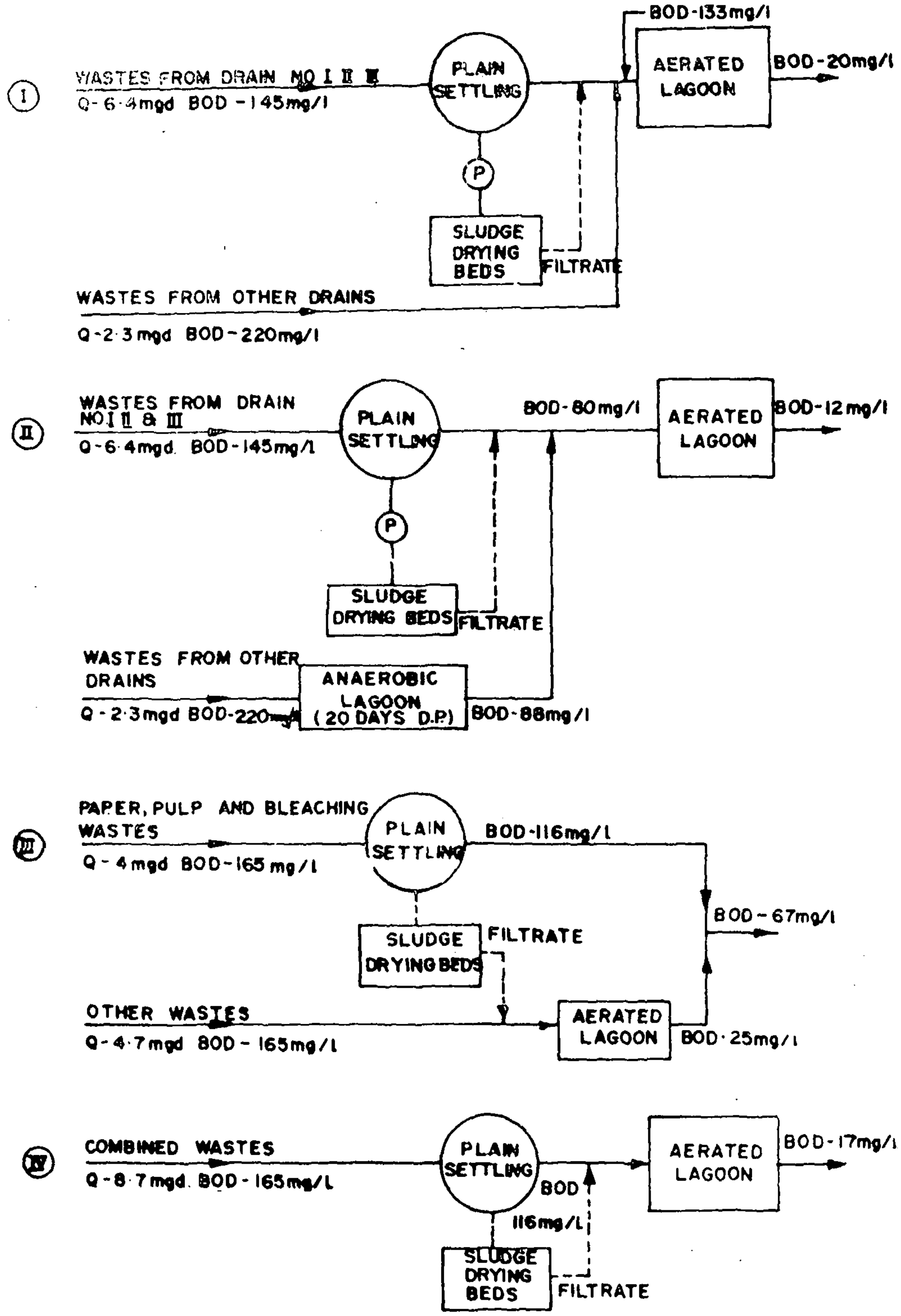


Fig. 7—Treatment Alternatives for a Pulp and Board Mill Wastes.

TABLE XIII—CHARACTERISTICS OF WASTES FROM VARIOUS SECTIONS AND COMPOSITE WASTES FROM A PAPER AND BOARD MILL

Sr. No.	Tests	Soda recovery, boiler, turbine etc.	Paper machine	Floatation saveall	Screening & washing	New Digester knots etc.	Pulp, paper & bleaching (Includes paper machine waste)	Combined Effluent (24 hrs. composite)
1.	Flow (mgd)	1.2	2.9	2.1	0.8	0.15	4.0	8.3
2.	Temp. (°C)	35	34	34	34	34	39	—
3.	pH	7.1	7.1	6.8	7.8	8.3	6.9	8.0
4.	Colour	Brown	White	Yellow	Yellow	White	Yellow	Brown
5.	Total solids	2800	1920	9200	1200	1560	1900	1720
6.	Dissolved solids	2040	800	7500	1080	1080	1300	1060
7.	Suspended solids	760	1120	1700	120	480	600	660
8.	Volatile solids	—	—	—	—	—	—	940
9.	BOD	180	130	160	180	150	160	165
10.	COD	610	298	510	770	340	650	630

All results except 1, 2, 3 & 4 are expressed as mg/l

TABLE XIV—COSTS OF WASTE TREATMENT OF A PAPER AND BOARD MILL

Treatment Alternative	Expected final effluent BOD (mg/l)	Construction cost of				Annual running cost (only for power at Re. 0.15/unit) (Rs. in lakhs)
		First stage treatment		Second Stage treatment aerated or aerated-anaerobic lagoon (Rs. in lakhs)	Complete treatment (Rs. in lakhs)	
		Settling tank (Rs. in lakhs)	Sludge drying bed (Rs. in lakhs)			
I	20	5.25	8.5	22.50	36.25	3.5
II	12	5.25	8.5	28.75	42.00	2.1
III	67	3.75	5.3	14.75	23.80	2.4
IV	17	6.75	11.5	18.80	37.05	3.0

add to the total volume of the factory effluent to an appreciable extent.

Liming liquor and vegetable tanning liquors are the two worst polluting wastes from a tannery. The objectionable constituents present in the effluent are colour, high suspended solids, BOD, COD, chlorides and chromium (in chrome tanneries). One of the worst pollutants in the tannery wastes from the point of view of treatment cost is the simple innocuous chemical, sodium chloride.

Typical analysis of tannery effluent as reported by ISI is given in Table XV (9).

All the sewage treatment processes can be successfully employed for tannery waste treatment. Screening (for coarse impurities and hair) and settling for at least 4 hr in settling tanks form essential primary treatment. Based on the work carried out so far, CPHERI developed 5 flow sheets as described in Table XVI (10).

Cost estimates are prepared for treatment of vegetable tannery wastes on the basis of assumption given in Table XVII where BOD load is taken at 37 lb/100 lb of raw hides. The costs are summarised in Table XVI (11).

It may be noted here that the BOD values obtained in some tanneries may be as high as 5000 mg/l against the value of about 2000 mg/l, assumed here. The cost of treatment for such high BOD wastes will exceed twice the above costs.

Plant Design Assumptions

On the basis of the wastewater characteristics and effluent standards required (depending upon the mode of final disposal),

TABLE XV—TYPICAL ANALYSIS OF TANNERY EFFLUENT (ISI—1969)

Sr. No.	Characteristics	Sources of Effluents					
		Soaking	Liming	Deliming	Vegetable tanning	Chrome tanning	Composite (including washing)
1.	Volume, l/100 kg hide skin tanned	480	470	320	360	430	3430
2.	pH min	7.7	9.9	2.4	5.1	2.6	7.6
	max	13.2	13.2	10.1	6.7	3.2	12.2
	ave	9.3	12.7	8.0	5.8	2.9	9.5
3.	Total solids, mg/l						
	min	11250	16200	1410	8250	8300	11920
	max	54800	79660	15550	55560	74800	31000
	ave	21200	48400	5870	31800	11550	20000
4.	Suspended solids, mg/l						
	min	145	1235	220	585	260	1280
	max	5080	23290	4450	9960	705	6080
	ave	2590	10380	1390	3510	480	3170
5.	BOD (5 days, 37°C), mg/l						
	min	260	4400	500	6000	—	2800
	max	7500	24000	3500	31200	—	14800
	ave	1610	10000	1520	19290	1000	7000

TABLE XVI—COST OF WASTE TREATMENT FOR A VEGETABLE TANNERY

Flow = 20,000 gpd; BOD = 1750 mg/l

Sr. No.	Flow sheet	Capital cost (Rs.)	Running cost/year (Rs.)
1.	Settling and sludge drying	30,000	7,000
2.	Settling + anaerobic lagoon for settled effluent + sludge drying	44,000	9,000
3.	Settling + anaerobic lagooning of settled effluent followed by treatment in aerated lagoon	70,000	15,500
4.	Settling + anaerobic lagooning of settled effluent followed by treatment in oxidation ditch	80,000	16,000
5.	Settling + anaerobic lagooning of settled effluent followed by treatment in oxidation ditch	60,000	11,000

laboratory experiments were conducted to assess amenability of the wastes to biological treatment. Designs of waste treatment plant have been prepared on the basis proposed by Arceivala *et al.* (12) for sewage treatment processes.

For design of any biological treatment process, the most important parameter is the BOD load per unit of final product. Table XVII gives the BOD load per unit of production for the industries under study (1-11).

Cost Estimates

It is obvious that both the capital and running costs should be taken into account before a choice is made from any of the conventional or low cost waste treatment systems which are suitable for treating a particular industrial waste.

The various items of capital and running costs that essentially need to be taken into account are as follows:

(i) Capital Costs

(a) Plant construction costs including equipment, electrification, etc.

(b) Land cost

(ii) Annual Expenditure

(a) Plant running costs consisting of:

- (i) Power or fuel
- (ii) Chemicals
- (iii) Staff
- (iv) Maintenance and repairs

(b) Repayment of loan.

For the purpose of the present study, capital costs have been taken in this paper for all the items of construction work from inlet chamber to final effluent chamber. However, this does not include the costs due to: (i) any initial and final pumping of the effluent to the disposal point; (ii) rising main upto the inlet chamber and the outfall pipeline after the effluent chamber; (iii) special site conditions such as water logging, rock cutting, etc., and (iv) cost of any pretreatment like neutralisation, sedimentation, oil & grease removal, etc.

Construction Cost

Construction costs have been worked out on the basis of market prices prevalent during the year 1972.

TABLE XVII—POLLUTION LOAD OF VARIOUS INDUSTRIES

Sl. No.	Industry	Volume of wastewater per unit of product or raw material used.	Average BOD of wastewater (mg/l)	BOD load per unit of product
1	Starch	500-1000 gal/ton of Starch	800-1000	7.5 lb/ton starch
2	Brewery & Distillery Complex	0.42 mgd For (i) Beer, 40000 l/day, (ii) Alcohol, 15000 l/day and (iii) Fruit juices, 15 tons/day	2040	8650 lb BOD load
3	Instant Coffee	8000 gal/ton of Instant Coffee	1500	120 lb/ton of Instant Coffee
4	Dairy & Milk Bottling	2.2 gal/gal of Milk processed in a product-oriented Dairy	1750	120 lb/1000 gal of Milk processed
5	Fertilizer	Urea Plant 650 gal/ton of Urea	Major pollutant is Ammonia	—
6	Pulp & Paper	80000 gal/ton of Paper	165 (suspended solids 660 mg/l)	135 lb/ton of paper and (530 lb S.S/ton of paper)
7	Tannery	7550 gal/ton of Raw Hides	5000	37 lb/100 lb of Raw Hides

TABLE XVIII—CAPITAL COST FOR TREATMENT OF SOME INDUSTRIAL WASTES

Sl. No.	Industry	Capital Costs	
		For discharge into inland surface water (IS: 2490-1963)	For discharge on to land for irrigation
1	Starch	Rs. 2000/- per ton of Starch	—
2	Brewery & Distillery Complex	Rs. 760000 to Rs. 815000 for 15000 l of Alcohol/day, 40000 l of Beer/day, and 15 ton/day of canned food	Rs. 620000
3	Instant Coffee	Rs. 20000/- per ton of Instant Coffee	Rs. 10000/- per ton of Instant Coffee
4	Dairy & Milk Bottling	Rs. 3700/- per 1000 l of Milk processed	Rs. 1000/- per 1000 l of Milk processed
5	Fertilizer	Rs. 2600/- per ton of Urea production	—
6	Pulp & Paper	Rs. 40000/- per ton of Paper	Rs. 23000/- per ton of Paper
7	Tannery	Rs. 40/- per kg of raw hide	Rs. 20/- per kg of raw hide

Note: The costs mentioned above are for the cheapest amongst the various possible alternatives.

Land Cost

Since land cost varies considerably from place to place, the requirement of land for each method of treatment has been shown separately. Wherever these have been included in the cost of treatment, these are estimated at Rs. 10000/acre.

Plant Running Cost

(a) *Power* : Power costs have been taken at the rate of Re. 0.15 per kwh. This is both for equipment as well as general lighting for the plant area at night.

(b) *Staff* : The staff requirement taken into account is the operational staff only, such as operators, mechanics, helpers, malis, etc. Administrative staff and higher supervisory staff have not been taken into account, since these are presumed to be already available with the industrial undertakings and can be diverted for supervising treatment plant installations.

(c) *Maintenance and Repairs* : Provision for annual maintenance and repairs has been made in accordance with the usual basis, **viz.**, one and two percent per annum of civil and mechanical and electrical costs respectively.

Arceivala *et al.* (12) have reported capital costs and running expenditures for various treatment methods for domestic sewage. The costs worked out in this paper are generally based on this work.

The capital costs for construction of effluent treatment plant for the industries studied are presented in Table XVIII.

Conclusion

The type of treatment for any industrial wastewater will depend upon the type of process adopted, extent of reuse of water and housekeeping. The cost estimates presented in the paper are, therefore, not directly applicable to other cases of the same industrial wastes. Nonetheless, these will provide valuable guidelines to choose an appropriate mode of treatment.

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DISCUSSION

Shri M. Miakhan (Madras): A passing mention has been made in the paper regarding operation and maintenance costs. Have these costs been capitalised and added to the capital cost to arrive at the total cost?

Shri B. B. Bhalerao: No. It can, however, be easily arrived at depending on the condition of repayment and rate of interest. In this paper, the following terms have been assumed for the repayment of loan.

"Government loan at the rate of 6 percent per annum repayable in 20 annual equated instalments of principal and interest commencing from the sixth anniversary of its drawal, interest alone being recovered during the first five years". This gives a factor of 0.0871 in calculating the instalment to be repaid for each year for 20 years. Thus, we can obtain the equated instalment for repayment of loan. The same formula can be applied for finding out the capitalised running cost and the multiplying factor in this case will be 1/0.0871 or 11.48.

Shri O. P. Gupta (Rourkela): (i) How old are the costs of plants indicated? (ii) At what intervals the costs are proposed to be revised depending on the rise in the cost of materials and wage structure of labours?

Shri B. B. Bhalerao: As stated in the paper, market prices of 1972 have been taken for arriving at the estimated costs. The question of revision of costs can be best decided by the user agency depending upon the rise in costs.

Shri R. Rajagopalan (Hyderabad): The speakers' data do not show any correlation between the capital cost and the capacity for the various treatment plants discussed for several industries. All the data are based on capital cost given in Rupees/Ton of the product produced. It needs clarification as to how the waste treatment plant capacity on product capacity is related to the capacity/ton of finished product.

Shri B. B. Bhalerao: Normally, larger the capacity lesser the cost of treatment per unit of production. Here, costs have been worked out for particular plants where production capacities have been given.

Shri V. D. Kothiwale: (i) The authors deserve congratulations for doing such a commendable work in costing of the treatment plants. It would have been still better if the following information were incorporated in the paper: (a) Percentage of reuse water to that of net effluent, (b) The initial and final water composition in each case along with the capacity, and (c) Foreign exchange components involved, if any? (ii) Has reverse osmosis been considered for treatment of Dairy Waste? This work has been done by CSMCRI, Bhavnagar. (iii) Time schedule should be given for completion of these plants.

Shri B. B. Bhalerao: (i) It is difficult to give precise information on items (a) and (b) since the practice varies from plant to plant. Moreover, the paper is intended to give only the costs involved for the treatment of wastewater. (c) No foreign exchange is involved. (ii) We have not considered reverse osmosis for treatment of dairy wastes. (iii) Any plant suggested in this paper can be constructed in a period of one year.

CHAPTER-III

SEWAGE TREATMENT

PROC. SYMP. ON ENVIRONMENTAL POLLUTION (1973)

Air Drying and Incineration of Sewage Screenings

V. HANUMANULU* and V. RAMAN+

Studies on air drying and incineration of sewage screenings from Dadar Sewage Purification Plant showed that the moisture content of the raw screenings was about 80 percent which decreased to about 66 percent and 46 percent with 24 and 48 hr air drying respectively at a relative humidity of 80-88 percent and temperature of 25-29°C. The studies further brought out that the screenings supported their combusion below 20 percent moisture content, while with the help of auxiliary fuel, the screenings could be incinerated at a higher moisture content.

Introduction

Screen chamber, normaly, is the first unit of sewage treatment plants. The function of screen chamber is to remove larger floatable materials present in sewage which otherwise would impair the proper functioning of pumps, grit chamber and piping by clogging the units. The floating material being mostly organic in nature creates unsightly conditions in treatment units and receiving body of water.

Screens are installed before raw sewage pumping stations, as a first unit in the treatment plant, in the bypass channels and sometimes before auxiliary pumping stations on the sewerage system.

The screens are classified as (i) bar screens with 3 to 6 in. (7.5 to 15.0 cm) openings, (ii) coarse screens with ½ to 3 in. (1.2-7.5 cm) openings and (iii) fine screens with openings of 3/16 in. (0.6 cm) or less (1). Coarse and bar screens are adopted in sewage treatment while fine screens find their use in industrial processes.

The screens can be cleaned manually or mechanically. The mechanical cleaning could be automatic type or of manual start-stop operation.

The raw sewage screenings have high moisture content and should be disposed of carefully. Improper disposal of sewage screenings fouls the atmosphere due to the bad odours given out by them. The dumps of sewage screenings will also serve as breeding places for flies, mosquitoes and rodents, thus posing health hazard to the community.

The study reported herein was carried out (i) to assess the quantity of sewage screenings collected at the treatment plants, (ii) to know the air drying characteristics of the screenings and (iii) to evaluate optimum air drying period at which the sewage screenings could be incinerated.

Quantity of Screenings

The quantity of screenings collected at the treatment plant varies from place to place and depends on the status of the city, population of the city, season and habits of the people and type of sewerage system (separate, combined or partially separate). For screens with 1 in. (2.5 cm) openings the

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* Scientist, Central Public Health Engineering Research Institute, Nagpur-20

+ Scientist-Incharge, CPHERI Zonal Laboratory, 89-B, Dr. Annie Besant Rd., Worli, Bombay.

quantity of screenings (1) collected at various places were reported to be 0.25-5 cu ft/mgd of sewage flow, in sanitary sewerage system.

Disposal of Screenings

The sewage screenings can be disposed of by (i) dumping, (ii) sanitary landfill, (iii) comminuting and digestion, and (iv) incineration.

Dumping of the screenings in open areas creates unhyigenic condition. If organised properly and adequate land is available, disposal of screenings by sanitary landfilling can be adopted, but it may not be practicable due to limitation of land availability in case of metropolitan cities. If the screenings are comminuted and put in digesters, they may cause operational problems. Incineration of screenings is well suited for hygienic disposal of screenings.

Incineration of Sewage Screenings

Screenings can be incinerated alone or by mixing with sewage sludge, greases and scums and municipal solid wastes. Some cities in the United States are using solid waste-sewage sludge incineration methods (2, 3).

Auxiliary Fuel

For incineration, it is desirable to have auxiliary fuel (4) available for (i) furnace warm up; (ii) promotion of primary combustion when the solid waste is wet or does not contain adequate heating value for good combustion; (iii) completion of secondary combustion to ensure odour and smoke control; and (iv) supplementation of heat for heat recovery units when the supply of heat value of the solid waste is not sufficient.

Some of the auxiliary fuels that can be used for incineration of screenings are presented in Table I alongwith their heating values.

TABLE I—HEATING VALUE OF AUXILIARY FUELS

Fuel	Heating value
Coal (5) BTU/lb	8610-14550
Green wood (5) BTU/lb	2380-4660
Wood (5) (air dried) BTU/lb	5240-6000
Bagasse (5) (dry) BTU/lb	8000-9000
City refuse (3) (dry) BTU/lb	7000-8000
City refuse (3) (as received) BTU/lb	3000-6000
Calcutta city refuse (7) (as received, M.C. 41.1%) BTU/lb	2708
Fuel oil (5) BTU/gal	162000-183000
Kerosene (5) BTU/lb	20000-21000
Natural gas (5) BTU/cu ft at NTP	1000-1100
Coke oven gas (5) BTU/cu ft at NTP	588
Producer gas (5) BTU/cu ft at NTP	134-150
Sludge gas (6) BTU/cu ft at NTP	650-700
Paraffin wax (5) BTU/lb	20000-21000

Experimental Details

Two sets of experiments were conducted on air drying and incineration of screenings. The first experiment was conducted to know the quantity of screenings collected at the treatment plant and the second experiment to find the decrease in moisture content with increase in period of air drying and the amount of auxiliary fuel required to start combustion of screenings.

Experiment 1

Screenings were collected from Extension plant of Dadar (Bombay) Sewage Purification Works. The screen chamber, with screenings of 1-in (2.5 cm) spacing is before the detritus tank. The screens are mechanically cleaned with manual start-stop operation. The volume of screenings obtained while a known flow of sewage passes through the screens was noted and recorded in Table II along with corresponding density of screenings.

The quantity of screenings collected varied between 0.2-1.45 cu ft/mil gal of sewage flow with an average value of 0.5 cu ft/mil gal. The density of raw sewage screenings was 14.0-33.6 lb/cu ft with an average value of 19.7 lb/cu ft. The moisture content of the raw screenings was 79.4-93.2 percent with an average value of 81.6 percent.

TABLE II—QUANTITY OF SCREENINGS COLLECTED

Batch	Date	Volume of Screenings (cu ft/mil gal)	Density of Screenings (lb/cu ft)	Moisture content of raw screenings (%)
I	18.6.71	0.44	33.6	81.8
	19.6.71	0.64	22.5	73.3
	21.6.71	0.46	17.0	83.4
	22.6.71	0.49	16.4	73.5
	25.6.71	0.53	17.6	78.2
	26.6.71	0.73	18.7	85.3
	28.6.71	0.60	21.1	85.6
II	29.6.71	0.35	14.0	79.5
	30.6.71	0.33	16.9	82.5
	1.7.71	0.32	16.9	83.9
	2.7.71	0.25	20.6	82.6
	3.7.71	0.20	18.3	79.4
	5.7.71	0.34	19.7	93.2
	6.7.71	1.45	24.3	79.7
Average Value		0.5	19.7	81.6

To arrive at a suitable auxiliary fuel for incineration, the screenings were burnt with paraffin wax and kerosene oil in batches I and II respectively. Kerosene oil was found to be unsuitable as the wet screenings were not able to absort it.

Experiment 2

The screenings from Extension plant of Dadar Sewage Purification Works were collected and spread on an impervious floor in a covered, open varandah. The moisture content of the screenings was determined at various periods of air drying and presented in Table III.

The screenings were burnt in a drum, which has a grating to support the screenings. The screenings were ignited from below the grating by means of Bunsen burner flame. Since the wet screenings were not burning without auxiliary fuel, incineration was carried out using peraffin wax as auxiliary fuel.

The screenings were incinerated using different ratios of paraffin wax to screenings, by weight, and the optimum ratio at which the screenings and wax mixture support their combustion was noted and recorded in Table III. Air drying and incineration of screenings was continued till the screenings supported their combustion without addition of auxiliary fuel.

The hourly relative humidity and temperature figures for the duration of the experiment were obtained from the Colaba Observatory, Bombay, and the average relative humidity and temperature for the test period were calculated and recorded in Table III.

Moisture content removal with period of air drying was plotted in Fig. 1. Ratio of weight of wax required for burning known weight of wet screenings is plotted against the corresponding moisture content of the wet screenings in Fig. 2.

Discussion

The quantity of screenings collected at the treatment plant varied from 0.2-1.45 cu ft/mil gal of sewage which compared favourably with the results reported in literature (1).

The air drying of sewage screenings was carried out for four batches of screenings as shown in Table III. There was no control on relative humidity and temperature of the atmosphere surrounding the screenings. These values were varying from day to day and within a day also. However, the average relative humidity during air drying of screenings for four batches was within a narrow range of 80-88 percent and average temperature in the range of 25.6-28.8°C. Hence, no attempt was made to find out the effect of relative humidity and temperature on air drying of the screenings. When the moisture content removal was plotted against period of air drying for the four batches, a straight line was found to be the best fit (Fig. 1).

The ratio of wax (auxiliary fuel) required for incincerating the screenings decreased with decrease in moisture content as represented in Fig. 2. Below a moisture content of 20 percent, the screenings supported their combustion without auxiliary fuel, which means a reduction of about 75 percent in the moisture content of the raw screenings. It can be seen from Fig. 1 that it takes about

TABLE III—RATE OF AIR DRYING OF SCREENINGS

Batch	Period of air drying (hr)	Average relative humidity (%)	Average Temperature (°C)	Moisture content (%)	Ratio of wax added to screenings, by weight, for supporting combustion
I					
20.9.71	0	—	—	83.8	—
(Dry period)	4	77	29.9	81.8	—
	22	88	28.1	61.3	0.54
	28	86	28.7	55.4	0.32
	46	86	28.7	37.4	0.11
	52	85	28.9	34.1	0.08
	72	85	28.8	15.2	0
II					
22.9.71	0	—	—	84.2	—
(Dry period)	4	79	30.9	80.6	—
	24	84	28.9	70.6	0.36
	28	83	29.2	66.5	0.23
	46	85	28.7	50.2	0.10
	52	83	28.9	47.6	0.085
	70	84	28.8	30.5	0.035
	76	83	28.6	21.8	0
III					
27.9.71	0	—	—	79.5	—
(Rainy period)	4	88	26.7	77.0	—
	22	90	25.8	72.6	0.41
	28	90	25.7	71.2	0.33
	46	90	24.1	58.8	0.17
	52	90	24.5	52.7	0.134
	72	89	25.1	34.8	0.081
	76	88	25.3	33.9	0.078
	94	88	25.6	9.7	0
IV					
4.10.71	0	—	—	82.7	—
(Dry period)	6	72	28.8	80.2	—
	24	82	26.8	61.4	0.265
	30	80	27.3	56.5	0.11
	48	80	27.2	38.3	0.096
	54	N.A.	27.4	35.8	0.081
	72	N.A.	27.2	23.9	0

N.A.: Data not available.

80 hr to decrease the moisture content of the screenings from 80 to 20 percent. Such a long air drying period becomes uneconomical. By using auxiliary fuel the screenings can be incinerated at higher moisture content. From Fig. 2, it can be seen that the optimum moisture content for incineration of screenings using auxiliary fuel is about 50 percent beyond which the fuel requirement increases at a faster rate. At a moisture content of 50 percent, the ratio of wax required (by weight) to screenings for incineration is 0.125. Fifty percent moisture content of screenings corresponds to about 40 percent decrease in the moisture content by air drying. It takes about 42 hr for decreasing the moisture content by air drying to 50 percent under these conditions.

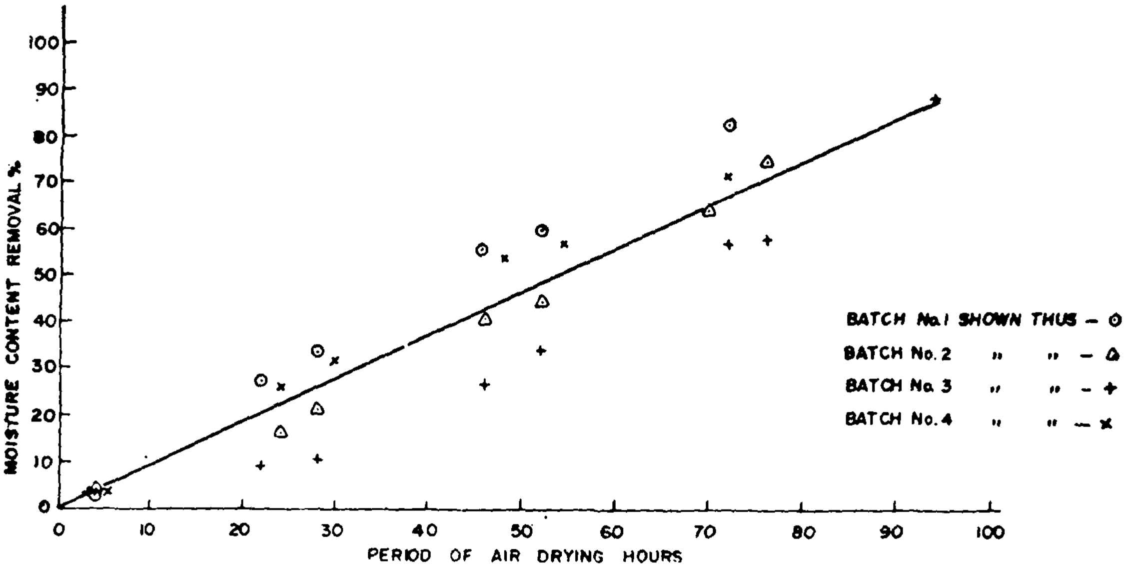

Fig. 1—Decrease in Moisture Content of Screenings due to Air Drying

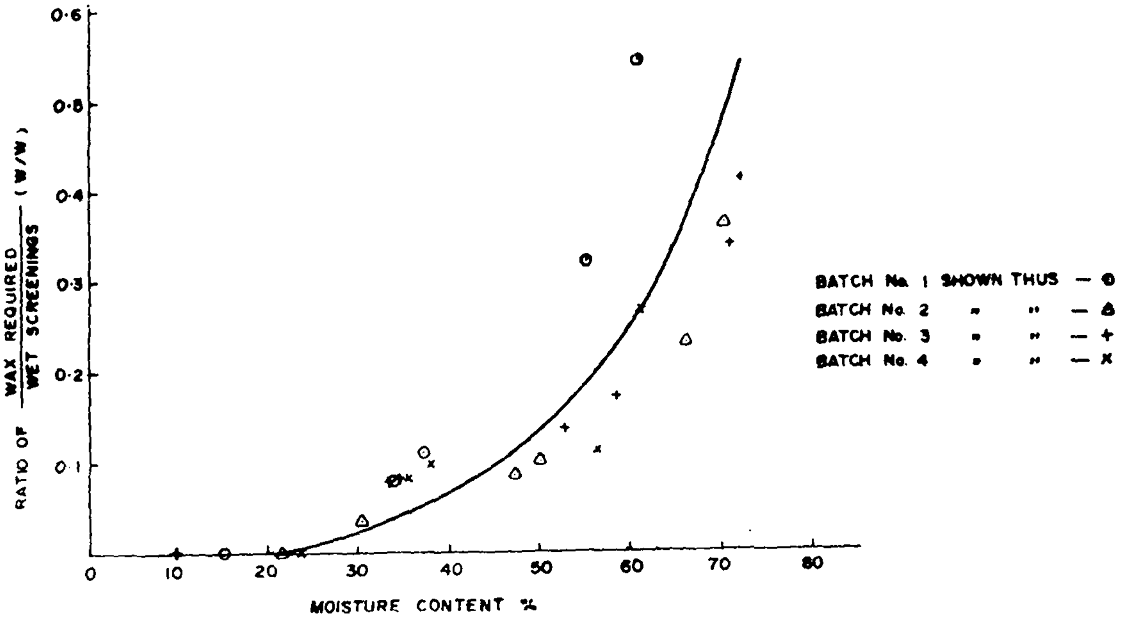

Fig. 2—Wax required for Incineration of Screenings

Conclusions

1. The average quantity of sewage screenings collected was 0.5 cu ft/mil gal of sewage at the Extension plant of the Dadar Sewage Purification Works.

2. The moisture content of raw screenings was 80-85% and decreased to about 65% in 24 hr of air drying and to about 40% in 48 hr of air drying during normal dry period (Batches I, II and IV) with average relative humidity of 80-85% and average temperature of about 28°C. It took long period of drying during rainy days (Batch III) with average relative humidity of 88-90% and average temperature of 25.6°C.

3. Paraffin wax was found to be advantageous over kerosene oil as an auxiliary fuel during the experiment, since wax form-

ed a coat over wet screenings while kerosene oil was not absorbed.

4. The screenings support their combustion without additional fuel at or below 20 percent moisture content.

5. It seems to be economical to incinerate the screenings, by using auxiliary fuel, at a moisture content of about 50 percent.

6. Instead of paraffin wax, other fuels like refuse, sludge gas, fuel oil, wood, coal, coke etc. can be used as auxiliary fuels.

7. The moisture content decreases to 50 percent in about 42 hours of air drying. However by circulating the hot flue gases of the incinerator through the screenings the drying period can be decressed considerably.

Acknowledgement

Facility given by Bombay Municipal Corporation for sampling the sewage screenings at their Dadar Sewage Purification Works is gratefully acknowledged.

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DISCUSSION

Prof. M. S. Shetty (Poona) : (i) The authors did not mention the size of screen. The number of screenings will depend upon the size and type of screen. (ii) The authors have given the relation between moisture content, drying period and paraffin wax required. In my opinion, the drying period has got a much significant effect upon the ingradient. If higher organic and excremental matters are sticking to the solid waste, drying period will be more and consequently higher quantity of paraffin wax will be required.

Shri V. Hanumanulu : (i) The size of screen has been mentioned in the paper. The screens were bar screens (1 in spacing) with push button start-stop raking arrangement. The authors agree that the amount of screenings depends upon the size and type of screens. (ii) The screenings were collected from screen chamber without any attempt to alter the character of the screenings. The authors feel that the sample of screenings collected were representative of the sewage screenings.

Shri S. Mukherjee : Type of incinerator for this material, best suited to our environment and economy may please be stated.

Shri V. Hanumanulu : The study was conducted on air drying and incineration characteristics of sewage screenings and not for designing an incinerator.

PROC. SYMP. ON ENVIRONMENTAL POLLUTION (1973)

Study of Extended Aeration Systems in Tropical Climatic Conditions

S. S. MUDRI* (Mrs.) M. V. VAIDYA,+ M. H. ANSARI + and G. J. MOHANRAO+

The paper presents a study undertaken on laboratory model activated sludge units with a view to evaluate the operation of extended aeration systems at tropical climatic conditions as in India.

The relationship between SVI and volatile solids content in the sludge, sludge age and organic loading, the BOD due to suspended solids and sludge age and net sludge yield and the organic loading are discussed. The results indicated that it would be possible to load extended aeration plants without any sludge bulking upto 0.25 kg BOD/kg MLVSS/day when the average temperature of the mixed liquor was above 21°C.

Introduction

In the extended aeration activated sludge plants, there is no need for primary sedimentation and sludge digestion units which are essential in the conventional treatment plants (1). A high mixed liquor suspended solids (MLSS) concentration and extended periods of aeration are utilised in the process to effect a reduction of BOD over 98 percent by converting the organic matter partly into biological sludge and partly into carbon dioxide and water. During the long period of aeration provided, the biological sludge undergoes further mineralisation by endogenous respiration and hence, this sludge does not need further treatment.

In European countries which are in temperate zone, the extended aeration activated sludge plant loadings are not more than 20 to 40 lb BOD/d/1000 cu ft of aeration tank volume and they have a BOD removal efficiency of 80 to 95 percent (2).

Pasveer (3) has recommended a BOD loading of 12.5 lb/d/1000 cu ft for oxidation ditches with MLSS concentration in the range of 3000-5000 mg/l. He (4) observed that during summer, when the mixed liquor temperature was upto 20°C, the volatile matter in the sludge in an oxidation ditch amounted to 65 percent whereas during winter months when the temperature of mixed liquor was 0-1°C, the volatile matter was raised to an extent of 75 percent or more. However, the performance was not affected.

Downing *et al.* (5) observed that, while in USA BOD loading for extended aeration plants generally were 15 lb BOD/d/1000 cu ft (or 0.05 lb BOD/d/lb MLSS) with a 24 hr detention period, in Great Britain where sewage was stronger, the second criterion corresponds to an aeration time of about 48 to 72 hr and seemed to be normally recommended.

The design criteria as given by Lesperance (6) for extended aeration systems were

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* Scientist, CPHERI Zonal Laboratory, 4th Floor, Premises No. 23, R. N. Mukherjee Rd., Calcutta-1.
+ Scientists, Central Public Health Engineering Research Institute, Nagpur-20

0.03 lb BOD/d/lb MLSS at an ambient temperature of around 21°C with a minimum detention time of 12 hr. The BOD removal efficiency should be over 98 percent.

While studying the operational stability of extended aeration systems on laboratory models, Guady *et al.* (7) used an organic loading of 50 lb COD/d/1000 cu ft of aeration capacity (32 lb BOD/d/1000 cu ft) during continuous flow operations at mixed liquor temperature of 23° ± 2°C.

During the bench-scale studies on extended aeration systems, Ludzack (8) used a volumetric loading of 15 to 20 lb BOD/d/1000 cu ft of aerator capacity (i.e. about 35 lb COD/d/1000 cu ft). He observed good performance with a load ratio between 0.10 to 0.15 lb COD/d/lb MLVSS. The sludge characteristics were studied at different temperature ranges from 5° to 25°C. The sludge from the operation at 5°C was highly gelatinous and the sludge from the operation at 10°C drained more slowly than the sludge produced at higher temperatures (21-25°C).

Operating a laboratory model oxidation ditch at a constant temperature of 20°C with a wide range of volumetric loadings of 20-100 lb COD/d/1000 cu ft, Rakshit and Chaudhari (9) obtained removal performance of over 95 percent. Glucose was used as a substrate.

Aim of the Study

On account of the enhanced bacterial activity at high temperatures, it is expected that the extended aeration activated sludge systems at tropical climatic conditions like in India should be able to take up higher loadings. This study was undertaken to arrive at an optimum organic loading that could possibly be used at tropical climatic conditions.

Materials and Methods

Laboratory model activated sludge units similar to the unit developed by Ludzack(10) were used. The aeration and settling compartments were 8 and 2 l in capacity respectively. Air was introduced through a diffuser at the bottom of the aeration compartment by an air-compressor. A constant and continuous dosing device (11) was used for influent feeding. The activated sludge units were operated on a continuous basis.

Domestic sewage from a nearby locality was used for feeding after settling in order to prevent choking of the feed line. As the sewage was weak, a thin slurry of night soil was mixed with settled sewage to increase the BOD of the influent to a desired strength for providing the required loading.

The study was carried out at two ranges of mixed liquor temperatures **viz.,** 19-23°C (winter) and 26°-32°C (summer).

Feeding was stopped for 30-45 min to facilitate cleaning of the dosing chamber and filling it with fresh sewage daily, at a particular time in the morning. During this time, samples for MLSS and SVI determinations were collected. Since the operation of the units was continuous, samples were collected and the following analyses were carried out daily; (i) BOD, COD and pH of influent and filtered and unfiltered effluents; (ii) MLSS, MLVSS, SVI and temperature of activated sludge, and (iii) Suspended solids in the unfiltered effluents.

MLSS and Suspended solids in effluent were determined by using Whatman glass fibre filter papers, GF/C. Other tests were performed as per Standard Methods (12). Once a week, the microscopic examination of the activated sludge was carried out.

Results

Experiment 1

This experiment was conducted with three laboratory model units providing 8, 12, and 16 hr detention periods. The mixed liquor temperature during the period of study varied between 19 and 23°C. The units were started up with sludge from an oxidation ditch pilot plant in the Institute's premises at Nagpur. The influent fed to the three units was of the same strength. When the observations were commenced 8, 12 and 16 hr units had sludge volume index (SVI) of

125, 56 and 53, respectively. The MLSS in these units were respectively 3100, 4270, and 3800 mg/l with volatile fractions at 68, 60 and 56 percent. When the MLSS were over 5000 mg/l, sludge was wasted to bring it to about 4000 mg/l.

The effect of BOD loading on the following parameters **viz.** (i) BOD removals (on the basis of filtered and unfiltered effluents); (ii) Sludge volume index (SVI); (iii) Sludge yield per unit weight of BOD removed; (iv) Sludge age; and also; (v) The relationship between SVI and volatile solids in MLSS; (vi) 'a' and 'b' for summer and winter conditions; and (vii) System (k) at the two ranges of temperatures, are given in Fig. 1 to 9.

The BOD loading was gradually raised and when a loading of 0.25 kg BOD/d/kg MLVSS in the 12 and 16 hr units was reached, the sludge started to escape in the effluent in large quantities and the SVI in the units was 183 and 204 respectively. At this stage, the filamentous organisms were prominent in the sludge. This sludge wash-out could not be due to accumulation of solids in the system since the sludge was wasted regularly when the system showed MLSS concentration of 5000 mg/l and above. Fresh sludge from the oxidation ditch was added to raise the mixed liquor concentration of the units to 4000 mg/l and feeding was gradually raised from 0.14 to 0.18 kg BOD/d/kg MLVSS but the SVI in both the units increased from 70 to 170 and the sludge washout took place. This indicated that, once the *filamentous organisms predominated* in the sludge, it may be hard to retain the MLSS concentration in the system in the range of 3500-5000 mg/l.

In the case of 8 hr unit, the sludge washout occurred after a sudden accidental rise in the loading from 0.224 to 0.33 kg BOD/d/kg MLVSS.

Experiment 2

In this experiment, five activated sludge units (similar to those used in the previous experiments) were started with sludge from the oxidation ditch pilot plant. The units 1 to 5 were kept at 19, 14, 11, 10 and 9 hr detention periods respectively. The mixed liquor temperature during this experimental period was in the range of 26°-32°C. The initial MLSS concentration in these units ranged from 3500 to 4500 mg/l of which 60 percent was volatile. At the start of observations, the SVI were 45, 51, 60, 73 and 76 in 19, 14, 11, 10 and 9 hr units respectively. When the MLSS increased to about 5000 mg/l or more, the sludge was wasted to adjust it to be around 4000 mg/l. Data showing the effect of BOD loading on the various parameters as indicated in the previous experiment are presented in Fig. 1 to 9 along with those of Experiment 1.

The organic loading applied to these units varied inversely with detention period as the influent to all the units was of the same strength. Units 1, 2 and 3 working respectively at 19, 14 and 11 hr detention periods did not throw out sludge solids in effluent in excess than what was normal whereas units 4 and 5 working at detention periods 10 and 9 hr (which incidentally had high organic loading of about 0.3 kg BOD/d/kg MLVSS on account of same strength of influent used for all the units) threw out sludge within a fortnight of the observation period. The biological examination of the sludge showed that the sludges in 10 and 9 hr units had developed abundant filamentous organisms. However, the sludges in 19, 14 and 11 hr units contained normal biological organisms of a healthy activated sludge.

The pH of the influent throughout these studies was 7.1 to 7.3 while that of the effluent was 7.7 to 7.9. The organic loading applied in the first experiment was from 0.07 to 0.33 kg BOD/d/kg MLVSS and in the second experiment 0.09 to 0.35 kg BOD/d/kg MLVSS.

Discussion

The most striking feature of the experiments was that they were conducted at two ranges of temperature **viz., 19-23°C (winter)** and 26-32°C (summer). The detention periods used in the first experiment ranged from 8 to 16 hr whereas in the second experiment they ranged from 9 to 19 hr. The organic loading applied during the first experiment was between 0.07 and 0.33 kg BOD/d/kg MLVSS and during the second experiment, it was between 0.09 and 0.35 kg BOD/d/kg MLVSS.

It can be seen from Fig. 1 that the filtered effluents showed BOD removals of over 98 percent irrespective of detention period (8-19 hr), organic loading (0.07-0.35 kg BOD/d/kg MLVSS) and temperature (19-32°C). But, at higher loadings than 0.25 kg BOD/d/kg MLVSS, the percent BOD removal of unfiltered effluents (Fig. 2) was reduced. This decrease in BOD removal efficiency appears to be primarily due to the escape of suspended solids in the effluent because of poor settling properties of the sludge at higher loadings.

The values of 150 to 160 for sludge volume index (SVI) are considered to be the practical upper limit for good sludge separation. From this consideration (Fig. 3), the organic loading will have to be limited to about 0.25 kg BOD/d/kg MLVSS. It was found that sludge settling was better in summer than in winter.

Normally, the activated sludge in conventional activated sludge system has a volatile content of 80 percent or more. Pasveer (4)

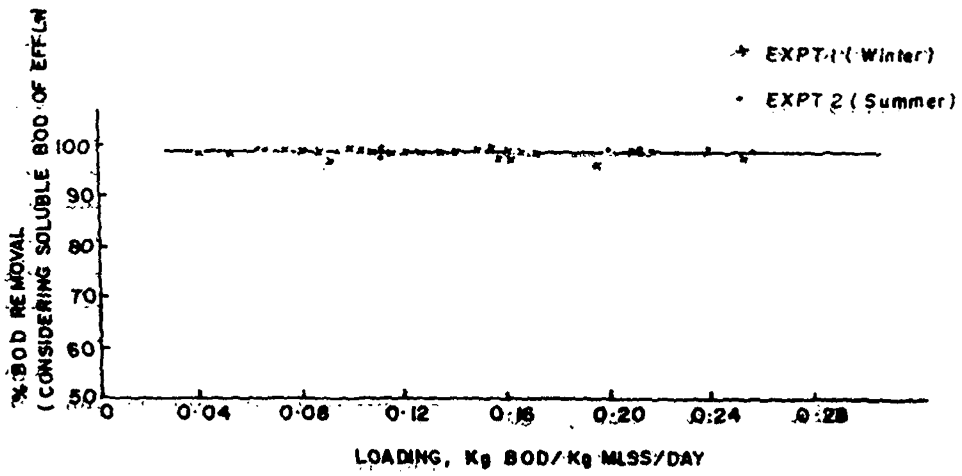

Fig. 1—Effect of BOD Loadings on BOD Removals.

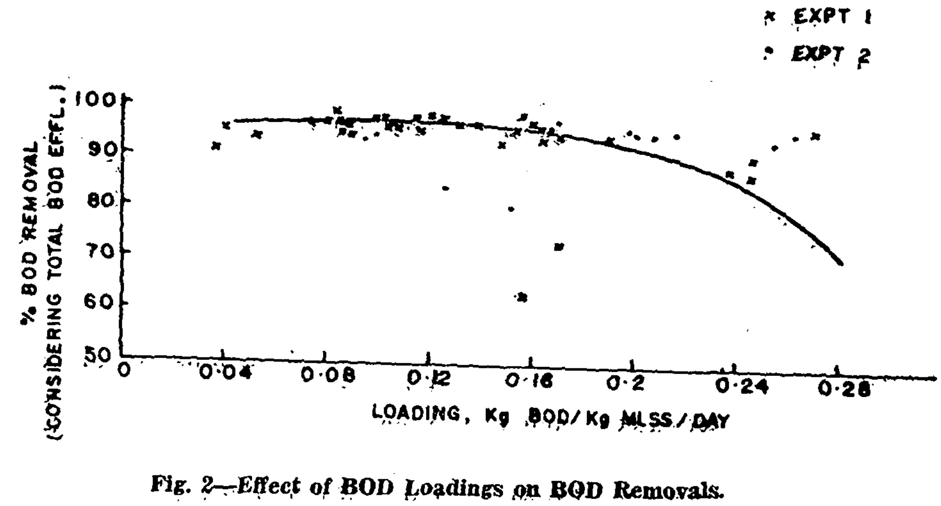

Fig. 2—Effect of BOD Loadings on BOD Removals.

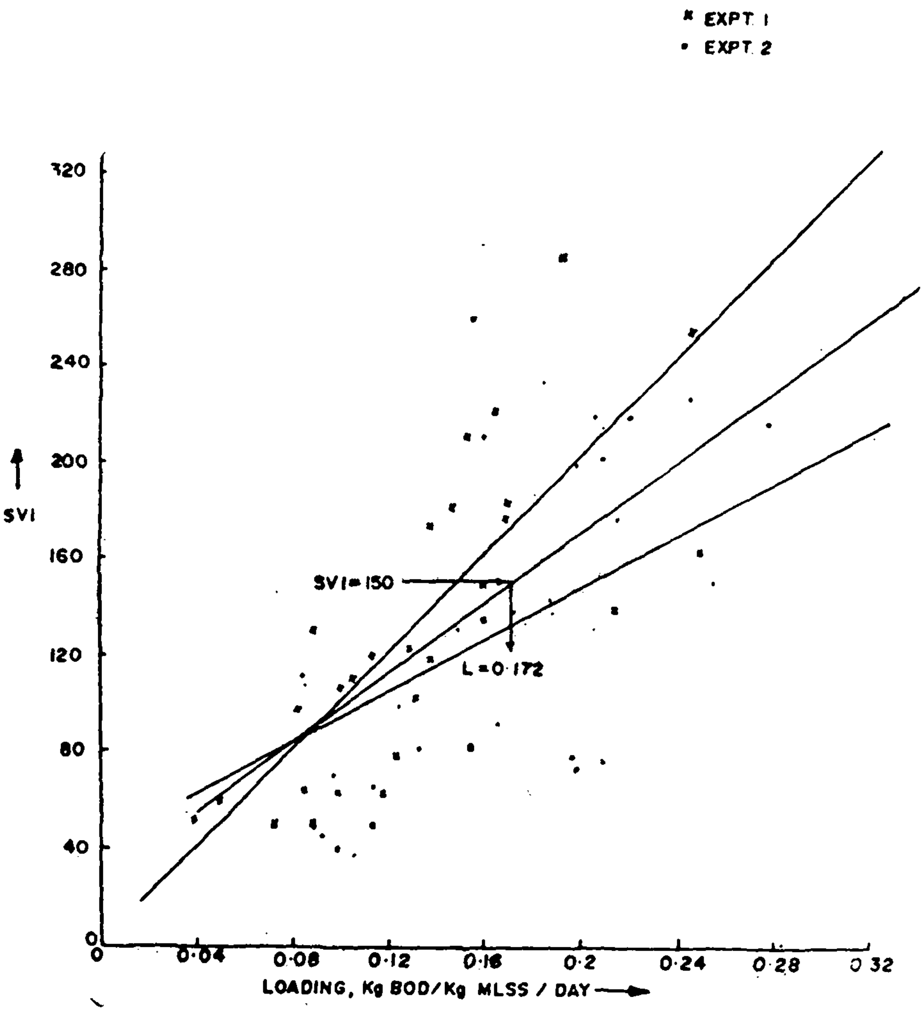

Fig. 3—Effect of BOD Loadings on Sludge Volume Index.

has observed that in oxidation ditches which operate on extended aeration principle, the volatile content of mixed liquor suspended solids goes up to the extent of 75 percent or more during winter. In these experiments, the sludge wash-out occurred when the volatile content of the sludge was around 75 percent. With the influent containing settled sludge and thin slurry of night soil (which was almost devoid of silt), the volatile content of sludge was in the range of 60-85 percent (Fig. 4). In actual practice, the silt in sewage is likely to weigh the sludge and improve the settling quality.

From Fig. 4, it is observed that the percentage of volatile solids in the mixed liquor rose along with an increase in SVI. It appears that when the volatile fraction increases beyond a certain limit, the sludge solids are likely to wash out. For a particular system, therefore, there is likely to be a good relationship between volatile fraction in MLSS and SVI. Once the relation is established, the operator can use the percentage volatile fraction in MLSS as an additional indicator for the settleability of the activated sludge and for predicting sludge wash-outs.

The relationship between the organic loading and sludge age is given in Fig. 5. Higher the sludge age, better is it's stabilised state. However, high sludge age

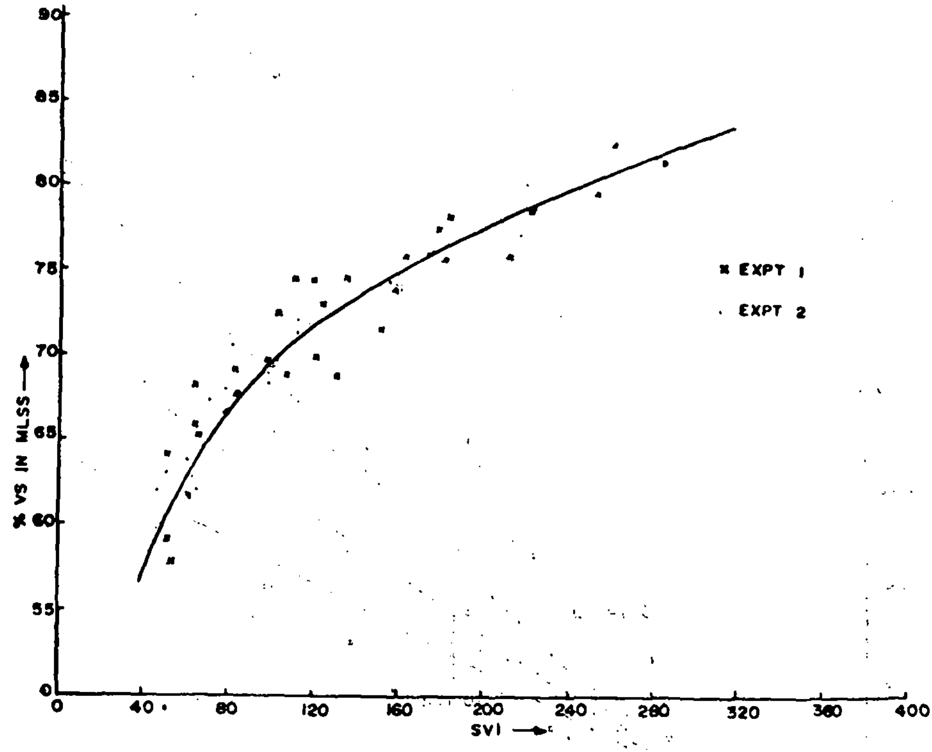

Fig. 4—Relationship between Sludge Volume Index and Volatile Solids in MLSS.

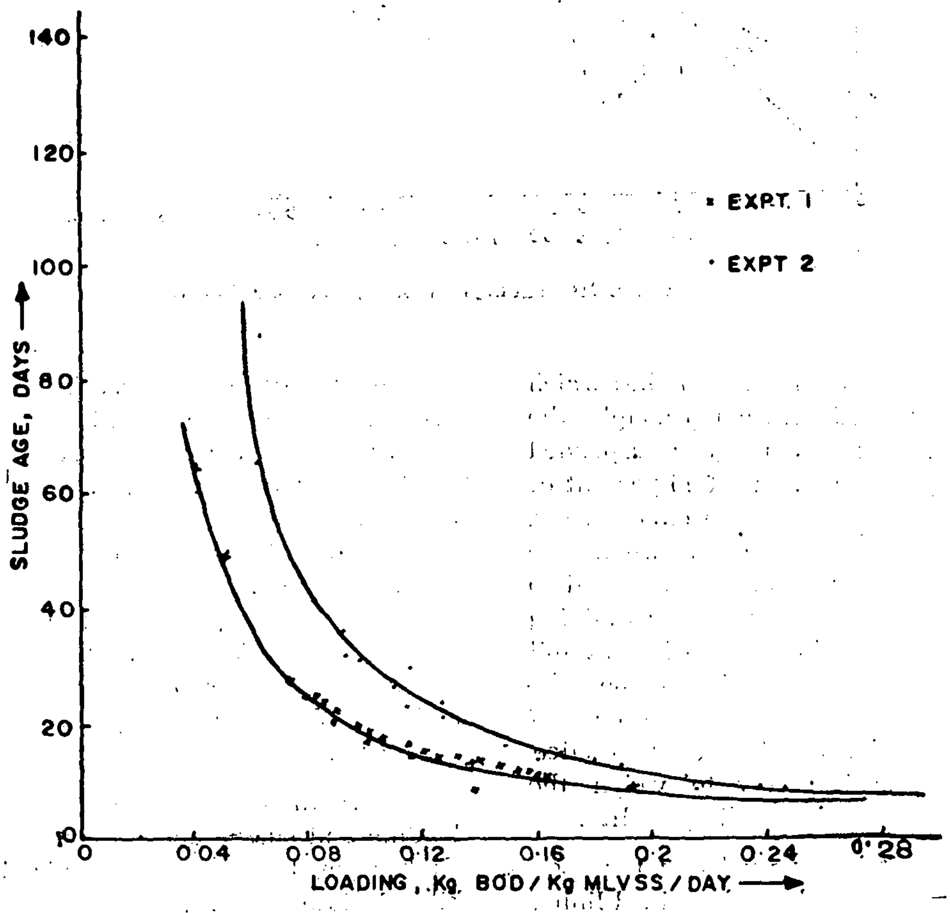

Fig. 5—Effect of BOD Loadings on Sludge Age.

does not influence stabilisation beyond a certain limit. As the sludge has a higher tendency to putrefy in summer during drying than in winter, minimum summer sludge age controls the upper loading limits. Considering a minimum sludge age of 14 days for extended aeration systems obtained by Lawerance and McCarty (13), the present studies show an optimum loading of 0.25 kg BOD/d/kg MLVSS.

Fig. 6 shows that BOD due to the effluent suspended solids (ESS) increased sharply after a minimum sludge age. At sludge age of 14 days, the ESS contributed a BOD of 0.45 mg/mg of ESS. With a recommended standard of 30 mg/l ESS in the effluent, 13 mg/l of BOD only will be contributed by the suspended solids in the effluent providing another 7 mg/l BOD for unoxidised soluble organic material, when 20 mg/l BOD is taken as standard for effluents discharged into surface waters.

An analysis of the excess sludge produced or sludge yield is necessary for the design of sludge handling and disposal facilities of the system. From the present experiments (Fig. 7), the sludge synthesis coefficient 'a' was found to be 0.66 in winter when the temperature of the mixed liquor was 19-23°C and 0.55 in summer when the temperature of the mixed liquor was 26-32°C. The endo genous respiration coefficient 'b' corresponding to winter and summer respectively were 0.017 and 0.03/day. These values are agreeing with those obtained by Middlebrooks *et al.* (14) Middlebrooks and Garland (15), Morgan (16) and Guady *et al.* (7) during their studies on extended aeration systems (Table I). Guady *et al.* (7) observed that the endogenous activity of the extended

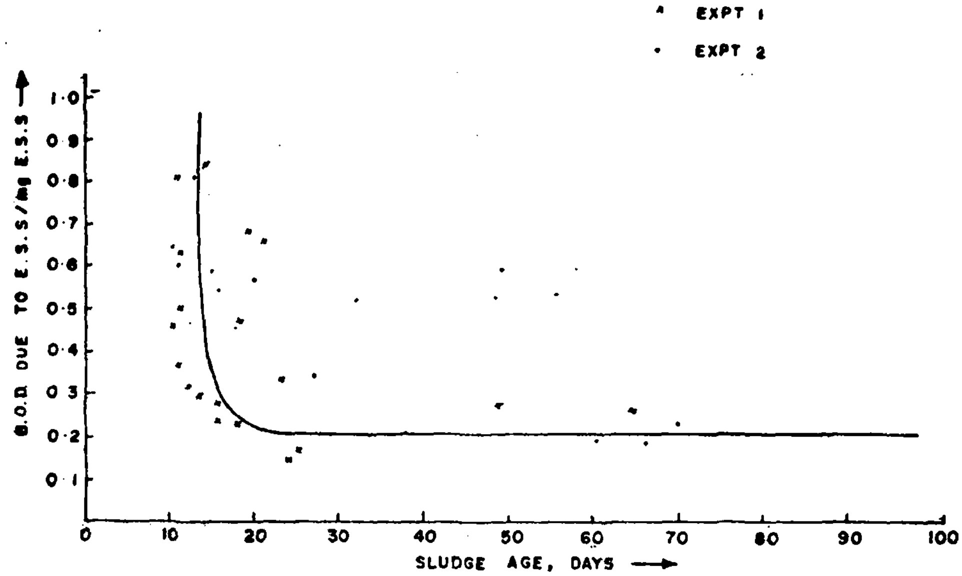

Fig. 6—Sludge Age and BOD due to Effluent Suspended Solids

TABLE I—COEFFICIENTS OF AN EXTENDED AERATION SYSTEM

Research Workers	Sludge Synthesis co-efficient 'a'	Endogenous Respiration coefficient 'b'
Middlebrooks *et al.*	0.34 lb/lb COD	0.016/d
Middlebrooks and Garland	0.54 lb/lb BOD	0.014/d
Morgan	0.5-0.7 lb/lb BOD	0.01/d
Guady *et al.*	—	0.024-0.036/d

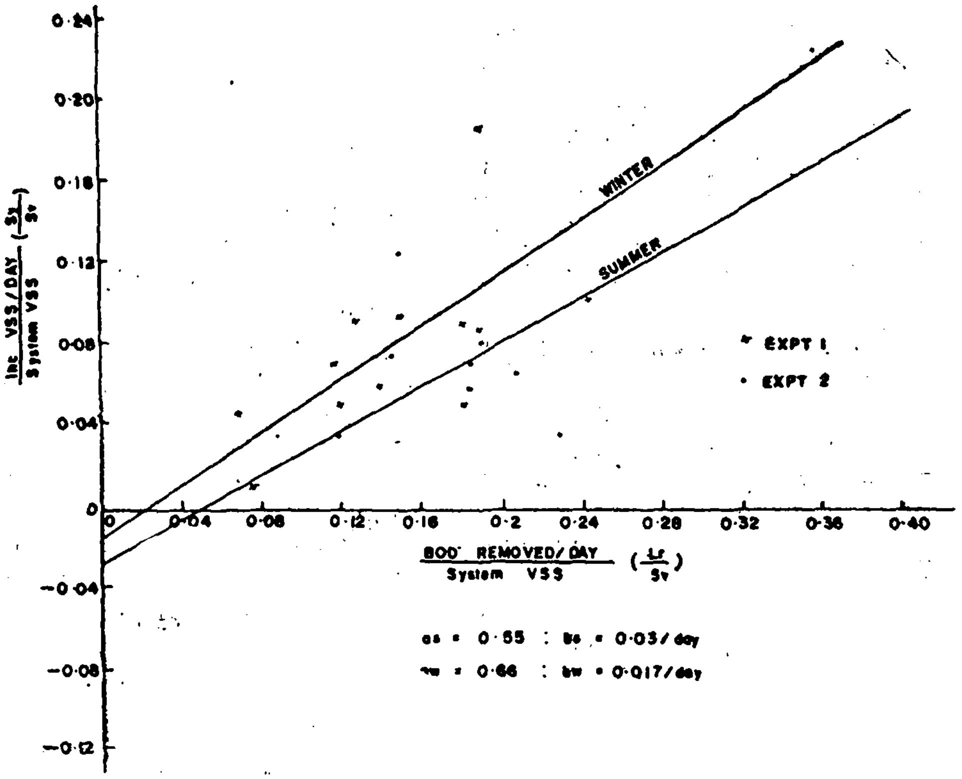

Fig. 7—Determination of Sludge Synthesis and Endogenous Respiration Coefficients, 'a' and 'b' respectively.

aeration sludge was approximately 5 to 10 percent of that for young cells of the same origin.

The net sludge produced per unit weight of BOD removed was calculated according to the Equation given below:

$$Sy = a\ Lr - b\ Sv;$$

where, Sy = Sludge yield;
Lr = kg BOD removed/day;
Sv = kg MLVSS in the system;
a = Sludge synthesis coefficient; and
b = Endogenous Respiration constant.

It appears from Fig. 8 that the net sludge accumulated is greatly influenced by temperature of the system and to a lesser extent by the organic gravimetric loading. It can be seen that the net sludge accumulated is more in winter than in summer.

Downing *et al.* (5), from the performance of three extended aeration plants, found that the first plant with a detention period of 11 hr and a loading of about 30 lb BOD/d/1000 cu ft at an average MLSS of 4590 mg/l and an average temperature of 7.7°C, the weight of sludge produced per unit weight of BOD was 1.4. For the second unit which had a detention period of 60 hr and a loading of 13.5 lb BOD/d/1000 cu ft at an average MLSS concentration of 8300 mg/l and average temperature of 9.3°C, the weight of sludge produced per unit of BOD was 0.46. For the third plant which had a detention period of 77 hr and MLSS concentration of 4720 mg/l with a loading of 8 lb BOD/d/1000 cu ft at an average temperature of 8.9°C, the weight of sludge produced per unit weight of BOD was 0.33.

Storch (17) reported that, in a well designed extended aeration plant, a sludge production of 0.4 lb/lb BOD applied should be ad-

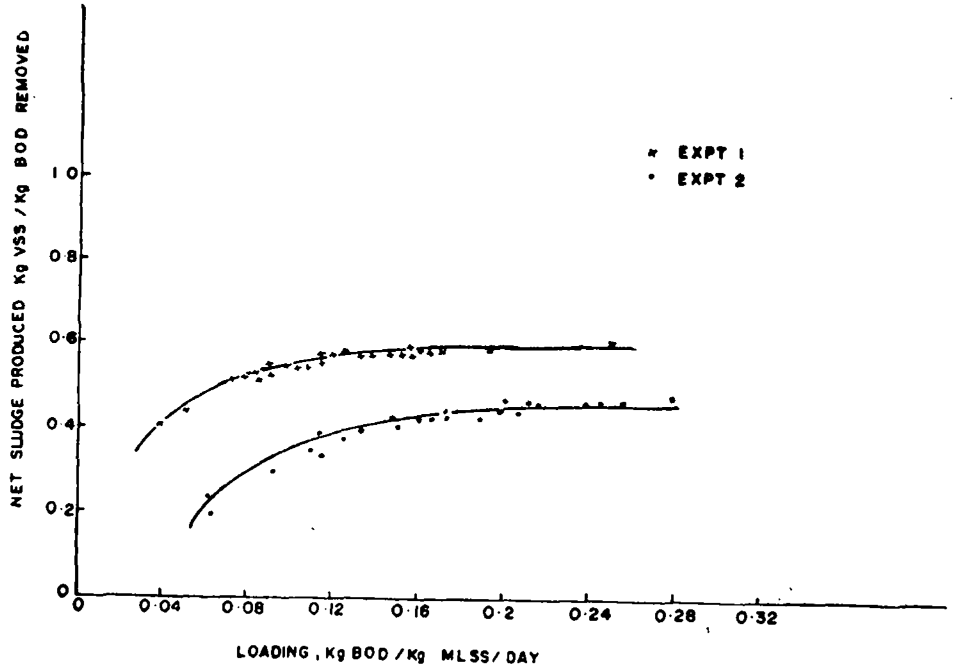

Fig. 8—Effect of BOD Loadings on Net Sludge Produced per Unit Weight of BOD Removed.

equate, the loading being between 10 and 20 lb BOD/d/1000 cu ft with a high rate of sludge return.

Lesperance (6) considered a sludge production of 0.15 lb/lb BOD reduced at an ambient temperature of 21°C when the loading of extended aeration plants was 0.03 lb BOD/d/lb MLSS.

In the present study, net sludge yields of 0.59 and 0.43 kg/kg BOD removed at average temperatures of 21° (19-23°C) and 29° (26-32°C) respectively have been obtained, both at an organic loading of 0.25 kg BOD/d/kg MLVSS. These values are in line with those reported by Downing *et al.* and other investigators.

The Fig. 9 gives the BOD removal rate constant (k), the slope of a plot between effluent soluble BOD and kg BOD removed/hr/kg MLSS and was very much dependent upon the temperature. The constant (k) increased from 0.00175 at 19-23°C to 0.00229 at 26-32°C. The (k) value over the whole range of temperature (19-32°C) was 0.00214. The values reported by the investigators in Western countries match with the winter values in this investigation (18).

Summary and Conclusions

1. The studies on extended aeration system were carried out on laboratory model units at two ranges of temperatures **viz.**, 19°-23°C (winter) and 26°-32°C (summer). The observations showed that excellent BOD removals (over 95%) were obtained at organic loadings between 0.07 and 0.25 kg BOD/d/kg MLVSS. At increased loadings of 0.25 to 0.35 kg BOD/d/kg MLVSS, the BOD removals deteriorated from 95 to 60 percent on the basis of unfiltered effluents and it was found hard to maintain the MLSS concentration in the range of 3500-5000 mg/l during these higher loadings and to keep the sludge in sufficiently mineralised condition.

2. An increase in the SVI was reflected in the increase in the volatile content of the sludge and *vice versa*.

3. Sludge age decreased with increase in loading. The minimum sludge age of 14 days recommended by many investigators could be obtained at loadings of 0.25 kg BOD/d/kg MLVSS and below.

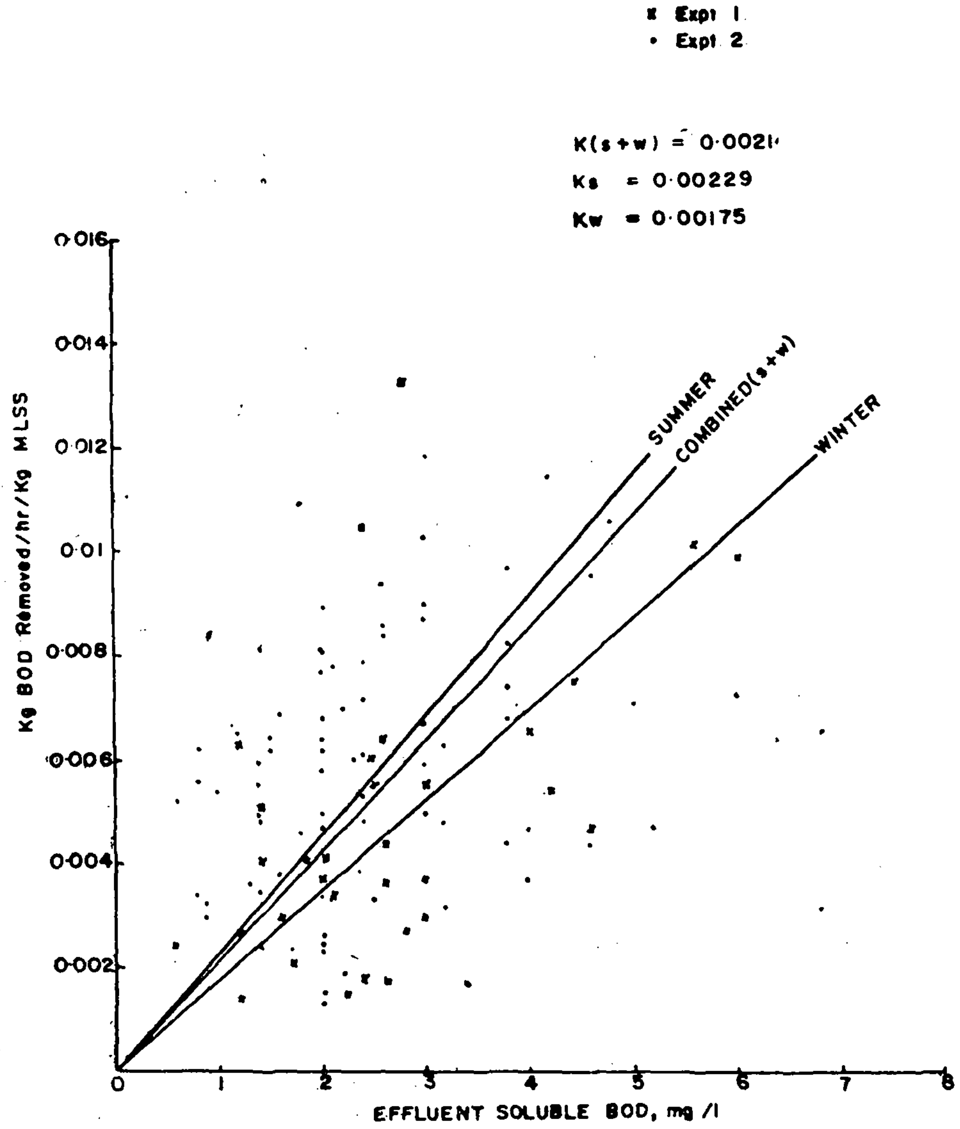

Fig. 9—Values of BOD Removal Rate Constant (K) during Temperature Range 19-32°C.

4. The sludge synthesis coefficient and endogenous respiration constants were 0.55 and 0.03/d during summer and 0.66 and 0.017/d during winter respectively.

5. Net sludge yield increased with increased loading and decreased with increase in temperature. At a loading of 0.25 kg BOD/d/kg MLVSS, the yields were 0.43 and 0.59 during summer and winter respectively.

6. The organic gravimetric loading and temperature control the performance of the extended aeration systems. It is possible to load extended aeration plants upto 0.25 kg BOD/d/kg MLVSS when the average temperature of the mixed liquor is above 21°C and obtain effluents satisfying the ISI and Royal Commission Standards.

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PROC. SYMP. ON ENVIRONMENTAL POLLUTION (1973)

Bulking Sludge and Its Control

H. K. DUBEY,* A. K. CHATURVEDI* and T. S. BHAKUNI*

Activated sludge treatment plant in Rishikesh treats combined waste from antibiotics factory and its residential township. The treatment process consists of a conventional system including units for grit and sand separation, primary clarification, aeration tanks and final clarifiers. The treatment plant has been operating satisfactorily during last five years except some interesting cases of sludge bulking. With a view to investigate into the reasons of bulking of sludge and find out remedial measures detailed studies were undertaken. The toxic effects of substances in shock organic load were the main reasons of sludge bulking which could be controlled by treatment with bordex mixture, at a dose of 20 mg/l.

Introduction

Antibiotics factory at Rishikesh treats its domestic and industrial combined liquid waste in a 17,400 cu m capacity activated sludge treatment plant. The plant was commissioned in 1967 and started receiving full hydraulic and organic load in early 1969. The main features of the plant have been given in flow diagram at Fig. 1 and salient design features have been described in statement at Table I. During operation through five years the plant has been functioning on normal parameters given in Table II. The average quality of influent waste in majority cases has been presented in Table III, and that of treated effluent has been given in Table IV. Among several interesting observations bulking of sludge was experienced on various occasions. Studies were undertaken in order to investigate into the reasons of bulking and to find out remedial measures. The results of studies have been presented and discussed in this paper.

Materials and Methods

Activated sludge was taken from aeration tanks of the main treatment plant. Raw sewage used for feeding was collected from combined incoming waste from the factory and township and its BOD varied from 200 to 300 mg/l. The materials, viz., lime, copper sulphate, chlorine water and bordex mixture (mixture of copper sulphate & lime in the ratio of 1:1 by weight) used in treatment of sludge were chemically pure and fresh solutions with concentrations ranging from 10 to 50 mg/l were prepared and added in requisite amounts. The mixed liquor was aerated with a passage of diffused compressed air allowed near the bottom of aeration units. Feeding of raw sewage, withdrawal of supernatant and recirculation of sludge were done as per schedule described in following experiments.

The samples of raw sewage fed to the system and supernatant withdrawn were tested mainly for pH, solids and BOD as per Standard Methods (1). The sludge was examined for its settling, sludge volume index and for microscopic bioassay. Microscopic examinations of mixed liquor were carried with haemocytometer and counting was done with the help of a compound microscope.

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* Antibiotics Plant, Virbhadra (Rishikesh) U.P.

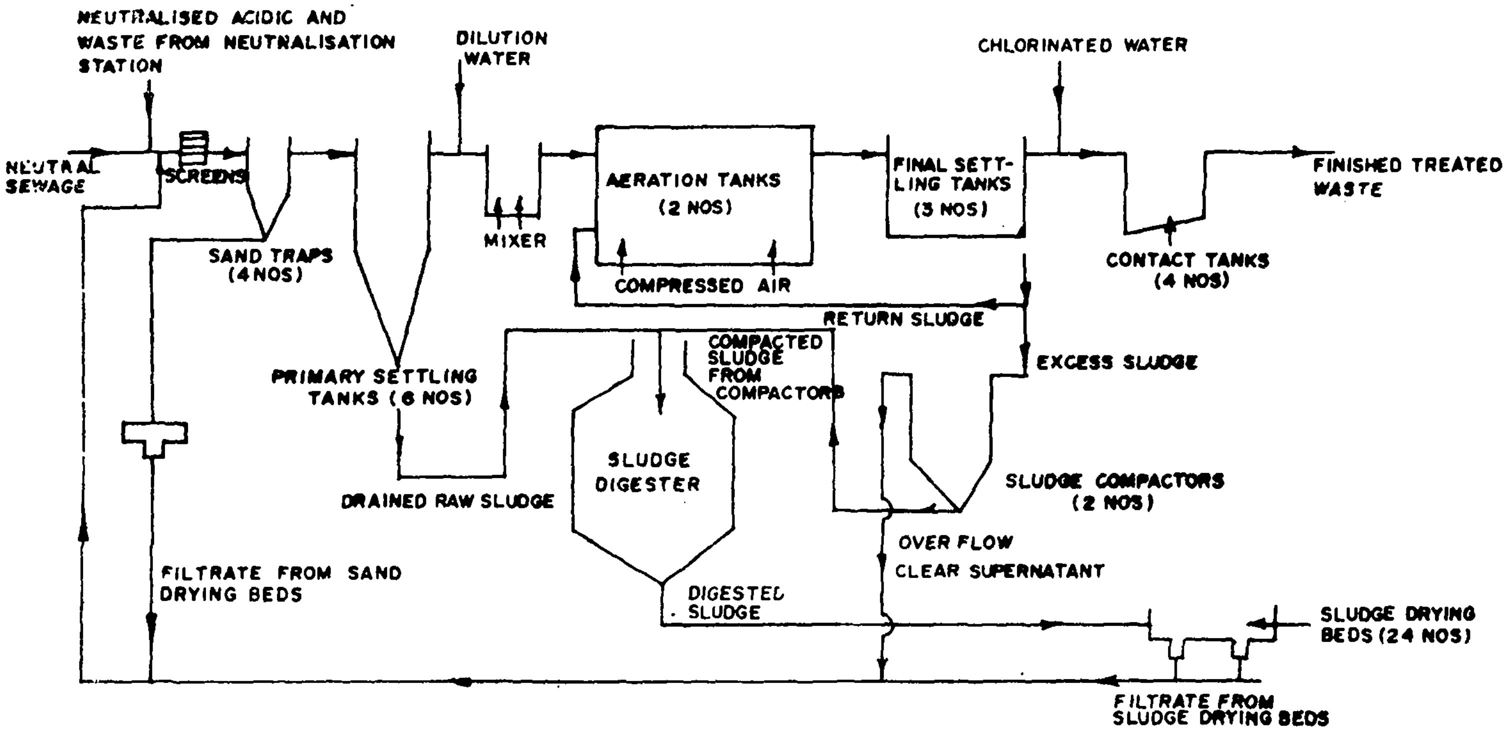


Fig. 1—Flow Diagram of Biological Treatment Plant. (Antibiotics Plant, Rishikesh)

TABLE I—DESCRIPTION OF DIFFERENT TREATMENT UNITS

Sr. No.	Units	No. of Units	Dimensions	Capacity	Function	Remarks
1.	2.	3.	4.	5.	6	7
1.	Sand traps, hopper bottom	4	Diam 4 m; depth 3.5 m	Velocity at flow 0.1 to 0.3 m/sec. Flow 50.25 1/sec.	Separation of grit and sand during tangential motion	Sand and grit deposited is pumped with the help of hydroelevators to sand drying beds.
2.	Primary settling tanks-circular, hopper bottom	6	Diam 8 m; depth 7.6 m	Overflow rate 33.5 1/sec; volume of each PVS = 270 cu m; detention time 1.5 to 2.0 hr.	Separation of heavy settleable organic matter, greasy and oily matter floats	Raw sludge deposited at the bottom is drained and charged to sludge digesters. Greasy and oily matter floats on the top and is overflown for separate disposal.
3.	Mixer tanks	2	14.5 m x 2.4 m x 4.1 m	143 cu m each	Homogeneous mixing of dilution water with waste	—
4.	Aeration tanks	2	54 m x 27 m x 4 m	Volume 5000 cu m each; detention time 12 to 14 hr.	Biological treatment of waste under aerobic conditions	Incoming waste is mixed with return activated sludge in these tanks and aerated.
5.	Final settling tanks	3	Diam. 16 m; depth 3.31 m	Overflow rate 323 1/sec; detention time 1.5 to 2 hr; volume 650 cu m.	Separation of active sludge from treated waste	Settled sludge is continuously sucked through scrapers and returned back to aeration tanks. Supernatant is allower to overflow.
6.	Contact tanks	4	6 m x 3 m x 1.5 m; slope towards pit for dragging sludge	Volume 70 cu m; detention time 20-30 min.	Contact time is allowed for complete reaction with chlorine	Chlorine is added to the supernatant after final settling tanks @ 5-6 mg/l.
7.	Sludge digesters	2	Diam. 12.5 m; height 12.0 m	Volume 980 cu m @ 50 cu m/day; detention time 19-20 days	Anaerobic digestion of sludge	Raw sludge from primary settling tanks and excess sludge from final settling tanks after compacting in condensators are charged. Digested sludge is sent to drying beds. Digester gas is used for burning.
8.	Sludge condensators—hopper bottom	2	Diam. 5 m; depth 4.6 m	Volume 40 cu m each	Compaction of excess sludge before it is charged to methane tanks	—
9.	Sludge beds	24	50 m x 12 m x 1.5 m	Working volume to a depth of 0.30 m; 180 cu m.	Drying of sludge	—

TABLE II—DATA ON OPERATING PARAMETERS

I. BOD Loading	0.42 kg to 0.63 kg/cu m/day or 26 to 40 lb/1000 cu ft/day
II. Air requirement	60 cu m/kg of BOD removed or 960 cu m/lb of BOD removed
III. Sludge age	Average 4.5 days
IV. Sludge Index	200-500

TABLE III—RANGE OF AVERAGE ANALYSIS OF INDUSTRIAL WASTE

Sl. No.	Characteristics	Range
1.	pH	6.0—8.2
2.	Colour	Colourless to brown
3.	Temperature	20°C—30°C
4.	Total solids	600—1200
5.	Dissolved solids	550—700
6.	Suspended solids	50—500
7.	Total hardness ($CaCO_3$)	110—200
8.	Calcium hardness ($CaCO_3$)	40—125
9.	Magnesium hardness ($CaCO_3$)	50—150
10.	Chloride (Cl)	80—200
11.	Alkalinity ($CaCO_3$)	150—200
12.	Sulphates (SO_4)	15—30
13.	Nitrates (NO_3)	5—200
14.	Phosphates (PO_4)	40—300
15.	Ammonia	0
16.	Total organic nitrogen (N)	50—100
17.	BOD (5 days, 20°C)	50—3000
18.	COD	200—5000
19.	Detergents	tr
20.	Antibiotic activity	Not detectable normally
21.	Grease and oil	tr
22.	Mycelium	Present occasionally

Note— (1) All values except pH, colour and temperature are expressed as mg/l.
(2) tr=traces.

Experimental Procedure

The present studies on control of bulking sludge were undertaken in a series of experiments which can be classified into three parts **viz.**

(i) Laboratory scale studies
(ii) Bench-scale experiments
(iii) Plant scale application of the above results.

(i) Laboratory Scale Studies

Known quantity of mixed liquor (2.5 l) was taken in different 3 l-capacity Winchester bottles and aerated continuously. Keeping one unit as a control mixed liquor in other bottles was treated with known volume of different chemical solution and aerated. The chemicals tried were lime, copper sulphate, chlorine water and bordex mixture. The aeration was stopped for one hr after 24 hr and supernatant removed. The units were given fresh feed with mild sewage (BOD 100-150 mg/l) and aeration restarted. The samples of feed and withdrawal liquid and sludge were examined daily. The studies were continued for over ten days and repeated three times. Results on one set of experiment have been presented in Table V. The investigations were repeated using varying concentrations of bordex mixture and

TABLE IV—RANGE OF AVERAGE ANALYSIS OF TREATED EFFLUENT

Sl. No.	Characteristics	Range
1.	pH	6.9—7.4
2.	Colour	Colourless to V. light yellow
3.	Temperature	20°C—30°C
4.	Total solids	400—600
5.	Dissolved solids	380—590
6.	Suspended solids	10—25
7.	Total hardness ($CaCO_3$)	110—200
8.	Calcium hardness ($CaCO_3$)	40—125
9.	Magnesium hardness ($CaCO_3$)	50—150
10.	Chloride (Cl)	80—200
11.	Alkalinity ($CaCO_3$)	150—200
12.	Sulphates (SO_4)	15—30
13.	Phosphates (PO_4)	1—3
14.	Nitrates (NO_3)	0.2—1.0
15.	Nitrites (NO_2)	tr
16.	Ammonia (N)	5—10
17.	Albuminoid ammonia (N)	10—15
18.	Total organic nitrogen (N)	20—80
19.	Iron (Fe)	tr
20.	Disolved oxygen	4.0—6.5
21.	BOD (5 days, 20°C)	2—30
22.	Residual chlorine (Cl_2)	0.5—1.0
23.	COD	40—100

Note— (1) All values except pH, colour and temperature are expressed in mg/l.
(2) tr=traces.

results have been given in Table VI. Samples of original untreated bulking type sludge and the one treated with bordex mixture were microphotographed as presented in Fig. 2.

(ii) Bench Scale Experiments

The efficacy of bordex mixture in eradicating the filamentous organisms and controlling the bulking sludge was studied in a bench experiment. A small aeration-cum-settling unit was fabricated by dividing a glass aquarium in three compartments (Fig. 3). One compartment (Vol 25 l) was used as aeration tank, middle one (Vol 12 l) served as secondary clarifier and the last one for receiving clarified treated effluent. Appropriate fittings for aeration of mixed liquor, overflow of liquid from one to another compartment, baffle plate to prevent disturbance in secondary clarifier unit were made. In the course of experiment sludge accumulated in the middle compartment was recirculated with the help of vacuum pump every 4 hr.

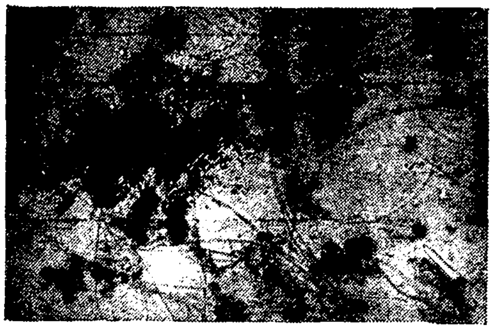
Mixed liquor (25 l) having prolific growth of filamentous organisms was filled in the aeration compartment and aeration started. It was given treatment with freshly prepared solution of bordex mixture @ 20 mg/l. No feeding and withdrawal was affected for first 48 hr, and thereafter regular feeding and overflow was started. The residence time in the aeration chamber was maintained about 12 hr. The sludge was examined daily for its settling, sludge volume index and for its microscopic character. The filamentous

TABLE V—EFFECT OF DILUTE SOLUTION OF DIFFERENT CHEMICALS ON BULKING SLUDGE

Sr. No.	Experiment	Characteristics of sludge and supernatant after 10th day					
		pH	Clarity of supernatant	Settled sludge volume in 30 min (%)	Sludge index	Microscopic Observations	
						Viability	Filamentous growth
1	Control	7.7	Clear	96	975	Good	Extremely high
2	Treatment with copper sulphate (20 mg/l)	7.3	Clear	75	530	Good	Slightly reduced
3	Treatment with lime solution (20 mg/l)	7.8	Clear	92	680	Good	Slightly reduced
4	Treatment with chlorine water (10 mg/l)	7.3	Clear	90	695	Good	Slightly reduced
5	Treatment with bordex mixture (20 mg/l)	7.3	Clear	20	145	Good	Almost eradicated

TABLE VI—EFFECT OF VARYING DOSES OF BORDEX MIXTURE ON BULKING SLUDGE

Sr. No.	Experiment	Characteristics of sludge and supernatant after 10 days aeration period					
		pH	Clarity of supernatant	Settled sludge volume in 30 min (%)	Sludge Index	Microscopic Observations	
						Viability	Filamentous growth
	Treatment with bordex mivture						
1	Dose, 10 mg/l	8.0	Clear	22	179	Good	Very few fragments
2	Dose, 20 mg/l	8.0	Clear	25	178	Good	Very few fragments
3	Dose, 30 mg/l	8.0	Clear	25	186	Good	Very few fragments
4	Dose, 40 mg/l	8.0	Clear	35	192	Good	Very few fragments



(a) Microphotograph of Untreated Bulking Sludge

(b) Microphotograph of Sludge Treated with Bordex Mixture
Fig. 2

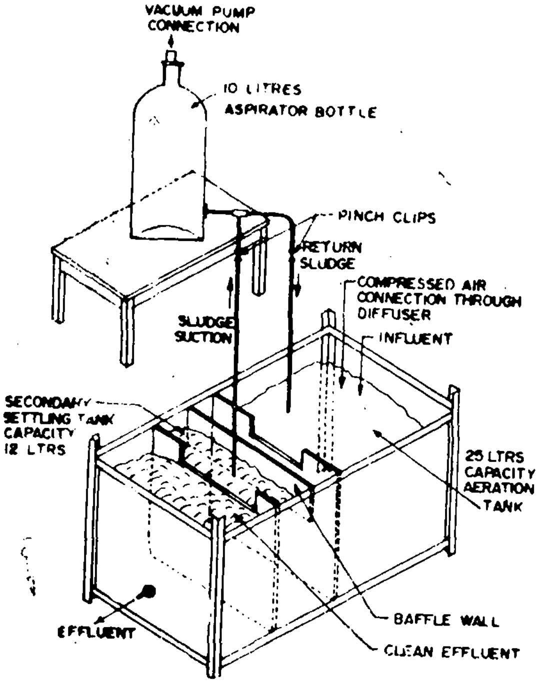


Fig. 3—Laboratory Model of Activated Sludge Treatment Unit.

forms were reduced to minimum in about 13 days.

In order to see the preventive effect of bordex mixture on fresh filamentous growth a fresh experiment was carried out. The improved sludge was given a feed containing high organic load (BOD 1300 mg/l). Bordex mixture @ 20 mg/l was also added simultaneously to the mixed liquor. No feeding and overflow was allowed for 48 hr. Continuous feeding and overflow was started after 48 hr. The samples of feed and overflow liquid and sludge were analysed daily for BOD, solids, dissolved oxygen, settled sludge and sludge index. The results have been presented in Table VII. In these studies the microflora classified as flagellates, rhizopods, ciliates (swimming, crawling and stalked) and filamentous form present in sludge were counted under microscope daily. Total bacterial count was also made. These values have been given in Table VIII.

(iii) Plant Scale Studies

The studies were extended to full plant scale and bordex mixture at a dose of 20 mg/l was used to treat bulking sludge in one of the aeration tanks. Freshly prepared solution of bordex mixture was added to the mixed liquor at well distributed points and aeration kept continued. Keeping the system starving fresh sewage feed was commenced after 48 hr and subsequently it was given daily feed for 2 hr. The quantity of feed was adjusted so as to replace approximately 20% of total liquid in aeration tank daily Samples of treated waste and sludge were examined for salient changes in their character. The results of analysis are given in Table IX.

Discussion

Literature Survey

One of the factors essential to the performance of the activated sludge process is effective flocculation of the sludge with subsequent rapid settling and compaction of the flocs. Sludge which does not settle well or settles and compacts poorly, leaving a

TABLE VII—ANALYSIS OF SLUDGE AND SUPERNATANT IN BENCH SCALE EXPERIMENT

Sr. No.	Treatment	Characteristics of sludge and supernatant				
		Clarity of supernatant	BOD (5 days, 20°C) (mg/l)	Sludge volume index	Sludge settling (%)	Filamentous growth
1	Before treatment	Clear	10	452	96	Intensive growth >90%
2	13 days after treatment with bordex mixture (20 mg/l)	Clear	13	114	21	Very much reduced < 10%
3	One day after feed (BOD, 1300 mg/l) and bordex mixture	Clear	34	138	40	No appreciable change
4	10 days after high organic load feed and bordex mixture	Clear	17	175	69	Substantial growth (approx. 50%)

TABLE VIII—DATA ON MICROFLORA ASSAY IN ACTIVATED SLUDGE TREATED WITH BORDEX MIXTURE

Sr. No.	Observation	Microflora * (per mg of dry sludge)							Total Bacterial count/ml*
		Flagellates	Rhizopods	Swimming Ciliates	Crawling Ciliates	Stalked Ciliates	Rotifers	Filamentous Fungus, etc.	
1	Before Treatment	50	—	50	250	580	—	750	9000
2	After one day	50	17	12	5.8	750	25	1100	6000
3	three days	18	18	6	6	920	18	790	180
4	five days	8	5	73	6	920	26	470	275
5	seven days	5	—	50	43	81	5	500	5
6	nine days	3	3	5	42	170	34	170	15
7	eleven days	7	—	140	120	365	153	140	680
8	thirteen days	—	4	42	21	170	62	48	350
	High organic load given on thirteenth day								
9	After fifteen days	—	8	27	21	187	62	120	—
10	seventeen days	20	8	50	5	200	45	626	—
11	nineteen days	93	6	94	7	562	62	910	—
12	twenty four days	61	—	60	8	160	83	660	—
13	twenty six days	18	—	42	17	230	54	260	—

* Multiplication factor = 10^5

small amount of clear supernatant is called bulking sludge. The tendency to bulking is measured by sludge volume index defined as the volume occupied by one g (dry weight) of sludge after 30 min settling period. Normal sewage sludge indexes vary from 50 to 150, and in cases of industrial waste the values have been reported (2) as high as 250. Higher the S.V.I. more is the bulking tendency. Bulking could be of two types (3) :

(i) a flocculated sludge with high S.V.I. and

(ii) a filamentous sludge with extremely low settling rate.

Flocculated sludge or zoogleal bulking is caused due to non-filamentous highly hydra-

TABLE IX—DATA ON ACTIVATED SLUDGE CONDITION IN 5000 cu m AERATION TANK AFTER BORDEX MIXTURE TREATMENT

Sl. No.	Characteristics	Number of days during Experimentation													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.	Clarity of supernatant	T	T	T	T	T	T	ST	ST	C	C	C	C	C	C
2.	BOD of Supernatant, mg/l.	35	48	56	44	60	48	—	—	34	39	28	25	28	24
3.	Dissolved Oxygen, mg/l	2.4	3.0	2.1	0.8	3.2	1.8	2.5	3.3	4.6	4.6	4.2	4.6	4.2	4.0
4.	Sludge settling percentage in 30 min.	96	75	50	30	32	32	28	34	35	36	40	45	42	29
5.	Sludge volume Index.	800	599	350	236	251	241	221	257	260	246	246	248	226	191
	Microscopic Examination														
6.	Viability	G	R	R	R	R	R	R	I	I	I	I	I	G	G
7.	Filamentous Growth	EH	F(s)	F(o)	F	F	R	VF	VF	VF	VF	VF	VF	VF	VF

T=Turbid, ST=Slightly Turbid, C=Clear G=Good, R=Reduced, I=Improved, EH=Extremely High, F(s)=Fragmentation Started, F(o)=Fragmentation on, F=Fragmented, VF=Very Few.

ted sludge particles. Whereas filamentous bulking is due to filaments extending from the clumps or sludge flocs and do not allow desirable compaction (3), there are many other causes (2) of bulking. Among main reasons are insufficient aeration, presence of toxic substances in the influent, frequent organic shock loads containing exceptionally high amount of carbohydrates. McKinney (4) related flocculation to the food to microorganism ratio and showed that certain organisms normally present in activated sludge flocculated rapidly under starvation conditions. More recently it has been shown that flocculation results from the production of a sticky polysaccharide slime layer to which organisms adhere (5). The slime formation does not occur during the log-growth phase and requires excess of available carbohydrates. Effective flocculation, therefore, requires a relatively low F/M value and excess available carbohydrates. Under certain circumstances specially under low oxygen tension, the growth of fungi and other filamentous forms are stimulated resulting in bulking sludge (6). Because of their high surface area to volume ratio the filamentous organisms may survive better under facultative or partially anaerobic conditions than other flocculated aerobic organisms. Floc type bacteria are replaced by ***spherotilus natans*** with higher organic loadings. Under different loading conditions ***Amoeba limax*** and flagellates, ***Oicomonas mutabilis*** **and** ***Bode sputrinus*** have been reported (7) abundantly in overloaded units.

During changing conditions in activated sludge treatment process some biological forms are replaced by others which are better adjusted to the changed physico-chemical environment e.g. replacement of zooglea floc by the sphaerotilus floc. The latter has filamentous form and with further organic loads it is replaced by non-colony former free living bacteria which have still larger surface area per unit volume. Certain workers (2) have found that the ratio of organic solids to microorganisms in sludge, quantitatively expressed as,

$$F = \frac{\text{K x Influent BOD x influent flow rate}}{\text{MLSS x aeration tank volume x detention time}}$$

termed as loading factor has great bearing on sludge bulking. It is felt that loading factor above 0.35 causes filamentous bulking. In a bulking type sludge filamentous organism is in most cases sphaerotilus. However, there are number of other filamentous bacteria including Baggiatoa, and filamentous members of the genus Bacillus and some fungi particularly Geotrichum and other yeast-like fungi Imperfect.

For correction and control of bulking brief references have been found suggesting certain remedial measures (8, 9, 10) such as increased aeration, reduced quantity of return sludge. The first two methods were tried on plant scale operation but no improvement was noticed. Other methods were tried in the laboratory and results are presented and discussed in this paper.

Experimental Results

Results obtained in the laboratory scale investigations on treatment of bulking sludge are given in Table V. The results show that the treatment with chemicals such as copper sulphate, lime and chlorine individually was not much effective. The sludge settling did not improve and sludge volume index also remained high. The filamentous growth could not be reduced to any appreciable degree. Whereas the sludge treated with bordex mixture showed appreciable changes, the sludge settling reduced down from 96% to 20% in about 10 days time, the sludge volume index came down from 975 to 145. The filamentous growth was almost eradicated. The results in Table VI shows the effect of varying dose of bordex mixture on control of bulking sludge. It is quite clear that a dose 10 to 20 mg/l is sufficient to eradicate the filamentous organisms and in all subsequent studies a dose of 20 mg/l has been used. A microphotograph of treated and untreated sludge (Fig. 2) shows that the untreated bulking sludge has an intensive degree of filamentous growth whereas the treated sludge contained very few filaments of short length and rich in ciliates both free swimming and stalked. The viability observed under microscope and total bacterial count although reduced in the beginning of treatment with bordex mixture but it steadily improved with eradication of fungi.

The results on the bench scale experiments presented in Table VII show the effect of bordex mixture on bulking sludge. Treatment of sludge with 20 mg/l of bordex mixture could bring down the S.V.I. from 452 to 114 and settling of sludge in 30 min came down from 96% to 21%. In this experiment it was tried to see the effect of giving bordex mixture dose alongwith high organic load (BOD 1300 mg/l with traces of antibiotics) and to find if filamentous growth could be prevented. The results given in the Table VII and in Table VIII show that immediately after feeding a high organic load the general viability was affected, total bacterial count was also reduced and filamentous growth started increasing. Sludge settling and sludge index also increased. However, after treatment with bordex mixture the sludge condition improved. Regular microflora assay (Table VIII) showed a downward trend in filamentous growth after treatment with bordex mixture. Simultaneous dosing of bordex mixture while high load was applied to the system controlled the filamentous growth to a great extent and bulking of sludge was checked.

Investigations on use of bordex mixture in full scale plant for treating the mixed liquor in one of the aeration tank (5000 cu m) have been quite successful. Data have been presented in Table IX. The treatment was found to be quite effective, settled volume reduced from 96% to 36% and sludge index from 800 to 246 in ten days after treatment. In the course of these investigations, it was found that the colour of sludge turned black and pH of mixed liquor fell to acidic side due to hydrolysis of copper sulphate. This happened probably due to inadequate mixing of lime with contents of the aeration tank. Additional lime was added for adjustment of pH to 7.0 or more.

In the above investigations it was observed that the supernatant remained quite clear containing low BOD irrespective of bulking of sludge. The effluent quantity became slightly inferior after giving high organic load. The high load affected overall viability of microflora and aerobic type of bacteria, throwing these out of active life cycle and driving into dormant stage. The dissolved oxygen content reduced to as low as 0.5 mg/l. In the competition for available food, the environment seemed to be more favourable to fungi and other filamentous forms and eradicated aerobic type of compact sludge formers. With the damage once caused, the system remained deficient in floc formers and filamentous organismssuch as *Sphaerotilus natans* remained dominant and did not reduce in number and size. The bulking was found almost proportional to the intensity of filamentous growth. Treatment with bordex mixture being fungicidal, affected the fungi and other filamentous organisms more selectively and these were eradicated in a short period. Total count of microorganisms increased, general viability improved and filamentous forms reduced to quite a low number.

Conclusion

The investigations on control of bulking sludge showed that the sludge got spoiled and became bulking due to toxic effect of substances in shock organic load. The settling proper deteriorated and sludge volume index increased. The sludge contained mostly filamentous organisms. However, it could be controlled by treatment with bordex mixture **i.e.** a mixture of copper sulphate and lime in the ratio 1:1 by weight, at a dose of 10 to 20 mg/l. The filamentous forms got eradicated and sludge quality improved both in settling and sludge volume index in about 10-12 days time.

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DISCUSSION

Shri K. Rudrappa (New Delhi) : The authors have stated that BOD could vary from 400 to 2000 mg/l. The BOD for which the treatment plant is designed may be stated.

Shri A. K. Chaturvedi : In cases of BOD higher than 500 mg/l, a provision has been made to dilute the incoming waste with relatively clean water so as to bring down the value to around 500 mg/l.

Shri S. S. Thakur (Brajrajnagar) : What is the most economical way of sludge disposal in case all the sludge cannot be reused or available space is limited.

Shri A. K. Chaturvedi : The conventional method of excess sludge disposal is compacting it to higher solid concentration and digestion. In case digester is under capacity land disposal or anaerobic lagooning can also be considered if land is easily available.

Shri M. L. Shah: (i) I feel that bulking of sludge possibly could be due to specificity of sludge. (ii) What is the incoming BOD to the plant? Since both domestic and industrial waste flows are combined what is the problematic BOD by industrial waste or domestic sewage. (iii) What is the type of aeration system? Probably this treatment plant can be improved upon by making some changes in the plant design and it may be economical to do so.

Shri A. K. Chaturvedi: (i) No comment. (ii) Incoming BOD to the treatment plant varies from 400 to 2000 mg/l. Dilution process as described above is used to bring down the value to 500 mg/l. It is evident that high BOD is always associated with industrial waste. (iii) Aeration is diffused type through porous plates.

PROC. SYMP. ON ENVIRONMENTAL POLLUTION (1973)

A Study on Treatment of Sewage for Industrial Uses

A. RAMAN,* S. SUNDARAMOORTHY** and A. V. VARADARAJAN+

The study was undertaken in the context of the growing demand of industries for water and the limited availability of fresh water sources at Madras City. The raw sewage quality was found suitable for industrial cooling after treatment. A pilot plant study to choose between the Activated Sludge Process (ASP) and the High Rate Trickling Filter Process (HRF) for the initial conventional treatment of the sewage showed that the former process was better suited because of its greater efficiency in removing organics and effecting nitrification.

Studies were also carried out on polishing treatment for the ASP effluent to reduce its COD, suspended solids, phosphates, etc. to acceptable levels. Excess lime treatment followed by recarbonation was highly effective in the removal of the residual organics, phosphates, hardness and suspended solids. The high cost of the process may, however, limit its practical application. Polishing treatment with excess lime followed by blending with ASP effluent gave nearly equal purification as the previous process and appears suitable for adoption because of its lesser cost. Economics of the method may improve if the problems in the recovery of lime from the sludge are solved.

Introduction

Sewage reclamation for industrial uses has become an accepted practice. The earliest and the biggest sewage reclamation plant is probably at Baltimore, Maryland, USA, where about 100 mgd of treated sewage is used by the Bethlehem steel mills for process and quenching needs (1). Several other cases of sewage reclamation for industries have been reported from USA including cases where the reclaimed water has been used even for boiler feed (2). A few cases have been reported from South Africa (3). In India, sewage reclamation plants have been recently installed in Bombay (4).

Sewage reclamation is under consideration for Madras (Tamil Nadu). The factors that determine the necessity and the feasibility of sewage reclamation are the need for water in large quantities for industries, the non-availability of fresh water sources to meet this need, and the availability of sewage and its qualitative suitability for industrial use. Other aspects which need consideration in regard to sewage reclamation are the methods of conventional and polishing treatment required for the sewage before reuse. A study has been carried out to evaluate these factors for the conditions at Madras. The details of the study are presented in this paper.

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* Executive Engineer,
** Assistant Engineer
+ Asstt. Water Analyst
Tamil Nadu Water Supply and Drainage Board, Chepauk, Madras-5.

Need for Reclamation

In recent years, there has been significant industrial growth around Madras city. An oil refinery and a fertiliser project have been established in the north of the city at Manali. Allied petrochemical industries are also springing up in this location. It is estimated that the water requirements of these industries will be about 170 million litres per day (mld) in the next few years. A major portion of this demand will be as make-up for recirculation type cooling. The fresh water available for the city is limited and at the same time the fresh water requirements for potable purposes are increasing. Therefore, it may not be possible to meet all the industrial water requirements at Madras from fresh water sources and the city may have to resort to sewage reclamation for meeting at least a part of the industrial demands.

Sewage Availability

A drainage scheme has been in operation in Madras city from 1910 onwards. The scheme is now under comprehensive improvements. The improvements envisage the division of the city into five zones. The sewage from two of the zones is to be pumped for treatment to Kodungaiyur located at the northern end of the city. As the Kodungaiyur site lies close to Manali, where the petro chemical industries are coming up, conveyance of the reclaimed seyage water to the industries will be easy. The total quantity of sewage that will be available at this location will be about 100 mld which will be a sizable portion of the industrial water demand. The availability of sewage for reclamation is expected to increase to about 200 mld in the future.

Quality Considerations

Sewage characteristics may be considered under two aspects **viz.**, (i) organic characteristics such as COD, BOD and SS and (ii) mineral characteristics such as silicates, hardness and chlorides. Conventional, biological treatment methods are highly efficient in removing organic characteristics but mineral characteristics may not be modified so easily. These mineral characteristics will, therefore, decide the industrial needs for which the reclaimed sewage can be used.

A survey of sewage characteristics at Madras has been carried out for a number of years (1966—till date). It has been found that the city sewers do not receive any significant quantities of industrial wastes. This is an advantageous factor in the context of sewage reclamation as industrial wastes may increase the dissolved solids content of the sewage significantly, impairing the utility of the reclaimed water and may also cause rapid fluctuations in other characteristics thereby affecting the efficiency of biological treatment processes.

The characteristics observed for the sewage at Madras are shown in Table I. There was normally very little change in the sewage quality from year to year, except in 1969 when very high values were recorded for all characteristics. These high values were the result of a severe drought when the water supply to the city had to be reduced considerably.

The normal characteristics of sewage show significant increase in dissolved matter over the drinking water supply (Table I). The increase may not only be due to the contribution of salts from human wastes but also due to the supplemental use of brackish ground water by the population. With augmentation of the city water supply, which is now in progress, the use of brackish water may reduce and the dissolved characteristics of sewage may improve.

The characteristics normally observed for the city sewage indicate that it can be used as make-up water for recirculation type of industrial cooling. The limiting characteristics of surface waters which have been used in the USA as make-up for recirculation cooling are shown in Table II. The characteristics of two waters which are now being used by certain industries at Madras for recirculation type cooling are also given in the table. The first is from a polluted nalla and

TABLE I—CHARACTERISTICS OF RAW SEWAGE AND CITY WATER SUPPLY AT MADRAS

Characteristics	Sewage max.	Sewage min.	Sewage max. during 1969	Water Supply
pH	8.2	7.0	7.6	—
BOD_5	410	140	650	—
COD	1120	624	1540	—
Suspended solids	730	110	1500	—
Dissolved solids	1400	750	2460	180
Total alkalinity	644	360	800	51
Ph. alkalinity	0	0	0	51
Total hardness	242	172	300	62
Ca hardness	172	96	240	—
Mg hardness	70	76	60	—
Chlorides	280	170	350	25
Sulfates	110	15	55	tr
Soluble Silica	39	10	—	—
TKN	60	40	90	0.25
$NO_2 + NO_3$	0	0	0	tr

Note— (1) All values except pH are in mg/l.
(2) tr=traces.

TABLE II—CHARACTERISTICS OF NATURAL WATERS THAT HAVE BEEN USED FOR COOLING

Characteristics	USA *	Nalla water at Madras	Ground water at Madras
Dissolved solids	1000	1980	—
Total hardness	850	228	310
Ca Hardness	500	164	200
Mg Hardness	—	64	—
Ph. alkalinity	—	0	—
Total alkalinity	500	416	—
Silica	150	—	70
Phosphates	4	18	0
Ammonia	—	25	0
Chlorides	500	320	350
pH	3.5-9.1	7.1	10—11
COD	100	260	—

Note— (1) *Please see Ref. No. 6
(2) All values except pH are in mg/l.

the second is from ground water. Comparison of these characteristics with the normal sewage characteristics indicates that the city sewage can be an acceptable alternative supply for cooling water make-up. In fact, the sewage appears to be better than the ground water source in regard to the silica content. In one of the industries using this ground water the major problem has been the formation of silica scales and the industry has been forced to increase the blow down to control silica accumulation. Another advantage with sewage appears to be its hardness which is present as temporary hardness and hence can be removed using lime alone.

Studies on Biological Treatment

Biological treatment forms the first step in sewage reclamation for industrial uses, the purpose being to improve its aesthetic acceptability and to remove the suspended and organic matter which may cause fouling of the cooling system and raise in-plant chemical dosages. The standards generally prescribed for organic characteristics in biologically treated sewage for industrial use are 25 mg/l of SS and 25 mg/l of BOD_5 (5). The permissible COD in cooling water make-up at point of use is 75 mg/l (6).

A pilot plant study was taken up to decide on a suitable method of biological treatment for reclaiming the Madras city sewage. The methods studied were single stage high rate trickling filter (HRF) process and the activated sludge (ASP) process.

The HRF treated 50,000 l of sewage per day at a loading of 10 kg BOD/cu m/day.

The filter was 1.5 m deep and the media ranged from 10 to 15 cm size. The recirculation was maintained at 1.5. Two methods of recirculation were tried **i.e.,** direct recirculation of filter effluent without settling and recirculation of secondary settling tank effluent. During operation, the HRF gave rise to an appreciable degree of fly breeding and frequent clogging. The fly breeding was greater with direct recirculation.

The ASP treated about 1,50,000 l of sewage per day. The aeration unit was of the totally mixed type with a detention period of 6 hr (based on sewage flow). The aerator was an entrainment type surface aerator of 0.77 m diam with twelve blades of 15 cm x 15 cm size and was worked at 70 rpm. Power was supplied by a 3.75 kwh motor. The aerator had an oxygen transfer capacity of 2 kg O_2 /kwh under standard conditions (20°C and no DO in tap water). The F/M ratio was generally maintained at 1:3 with an MLSS concentration of 1500 mg/l. The operation of the plant did not present any great trouble though there were occasional problems of sludge bulking.

The typical results obtained for the HRF and the ASP are indicated in Table III. The results show a superior performance of the ASP in regard to BOD, COD and SS removals. Moreover, the ASP effected almost total nitrification unlike the HRF which showed only a trade of nitrites at best. The alkalinity of the final effluent was considerably lower in the case of ASP. This may be attributed to nitrification since formation of one part NO_3^- N from one part of NH_3^-N will destroy 3.57 parts of alkalinity as $CaCO_3$. The reduction in alkalinity in the ASP may be significant when further lime softening is proposed for industrial use since lesser alkalinity will mean lesser lime requirement. (In laboratory studies, to obtain the same residual hardness after softening, the ASP effluent required 150 mg/l less of lime than the HRF effluent). The pilot plant studies indicate that the ASP would be preferable for the biological treatment in view of the high organic quality produced and also the reduction effected in alkalinity.

TABLE III—CHARACTERISTICS OF EFFLUENTS AT THE END OF BIOLOGICAL TREATMENT

Characteristics	Raw Sewage	Effluent	
		ASP	HRF
Colour	Gray	Slightly Yellowish	Yellowish
Odour	Septic	absent	absent
BOD	330	7-10	25-50
COD	1000	40	120
Suspended solids	500	60	120
Free Ammonia	35	0.4	30
Nitrite	0	1.4	1.2
Nitrate	0	28.0	0
Ph. alkalinity	0	0	0
Total alkalinity	500	280	490
pH	7.6	7.6	7.8

All values except pH are in mg/l.

Studies on Polishing Treatment

From the point of view of reuse for industrial cooling, the sewage at the end of ASP treatment remains critical in regard to hardness and phosphates. The limit for hardness in cooling water make-up at the point of use has been fixed as 130 mg/l whereas in the ASP effluent it is found to be about 200 mg/l (6).+ Orthophosphates in cooling water cycle even at 3.5 mg/l may cause dense scales. Therefore, in cooling water make-up, the concentration has to be much lower (7). In the ASP effluent, phosphates have been consistantly high at about 20 mg/l. An excess of SS has also occurred during periods of sludge bulking. Polishing treatment for correcting these characteristics. therefore, becomes necessary before the effluent is used for cooling.

Under polishing treatment, softening studies were taken up first. As in the raw sewage, all hardness in the ASP effluent was in the form of bicarbonates. Hence, only lime addition was considered. The results of the studies are shown in Table IV. Varying dosages of lime were tried. At lower dosages there was actually an increase in

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+ Loc. cit., p 194.

TABLE IV —RESULTS OF LIME TREATMENT OF ASP EFFLUENT

Dosage of Lime	0	100	200	300	400	500
Colour (% transmission in 420 filter)	84	89	91	94	96	96.5
Turbidity	10	8	7	5	2.5	< 1.0
Ca Hardness	115	160	96	82	166	236
Mg Hardness	85	54	56	22	0	0
HCO_3 Alkalinity	220	118	18	0	0	0
CO_3 Alkalinity	—	112	160	92	86	158
OH Alkalinity	—	—	—	34	97	97
Silica	28	NT	NT	NT	NT	18
Orthophosphate	16	5	3.8	1.1	0.1	0
Settling characteristic—Time for complete settling (hr)	—	2½	1½	1	¼	⅛
pH	8.2	9.4	9.9	10.4	10.9	11.4

Note— (1) Theoratical lime dosage (CO_2 was Nil; lime 90% pure)

$$= \left\{ (220+85)\frac{0.74}{0.90} \right\} + 50$$

$$= 300 \text{ mg/l}$$

(2) All values except pH are in mg/l.

hardness. At the theoratical dosage for complete softening, calculated as equivalent lime for total alkalinity plus magnesium hardness plus free CO_2 plus an excess of 50 mg/l of lime (7),+ the softening remained incomplete. These erratic results might be due to interference by the phosphates contained in the sewage effluent. Phosphate interference with lime softening has been reported earlier (8).

Addition of coagulants like sodium aluminate upto 30 mg/l or alum upto a dosage of 70 mg/l with sludge recycling did not improve hardness removal significantly. Laboratory studies were conducted with tap water to determine the level of phosphates which interfered with softening. The interference persisted even at a low concentration of 1 mg/l showing that complete removal of phosphates is necessary for successful softening. Alum coagulation was tried as a prelude to lime softening for effecting complete removal of phosphates but a very high dosage a Alum (300 mg/l) was found to be necessary. Use of such high dosages of alum prior to softening may not be practicable.

As a third alternative, excess lime treatment followed by recarbonation was tried. Sufficient lime was added to the ASP effluent to raise its pH to 11. The dosage was about 500 mg/l. At this dosage, massive and quick settling flocs were formed. The settling was complete in 10 min after quick mix without any flocculation. The effluent was found to be free of colour, phosphates and magnesium. Incidental removal of silica from 28 mg/l to 18 mg/l was also noted. On recarbonation of this effluent to pH 9.3 the excess lime in solution was precipitated out as calcium carbonate. In this case also, the flocs formed quickly and precipitation was rapid. The final effluent had a low hardness of 20 mg/l, a low COD value of 26 mg/l, and was devoid of colour, turbidity, odour and phosphates. The effluent was sparklingly clear. The analysis of the effluent is shown in Table V.

In the fourth alternative, the ASP effluent was treated with lime to raise the pH to 11.0 as a first stage and after settlement it was blended with the ASP effluent so as to lower the pH to 9.3. The ratio of blending was 3:1. The floc formation after blending was not as rapid as observed with recarbonation. However, complete settlement without the use of coagulants was achieved in a period of 30 min flocculation and 2 hr settling. It is expected that in the field flocculation and

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+ Ibid p 95.

TABLE V—RESULTS OF POLISHING TREATMENT OF ASP EFFLUENT

Characteristics	ASP effluent	Recarbonation process	Split treatment process
Colour transmission	82%	99%	97%
Odour	Nil	Nil	Nil
Turbidity	10 units	below 1.0	1.0
Ca Hardness	120	20	36
Mg Hardness	80	Nil	Nil
Total alkalinity	288	124	108
Ph. alkalinity	Nil	56	60
Dissolved solids	1000	800	840
Suspended solids	80	Nil	Nil
COD	50	26	30
Orthophosphate	16	Nil	0.5
pH	8.1	9.3	9.3
Silica	28	18	20

Note— All values except pH are in mg/l.

settling will be quicker with sludge contact. The effluent characteristics are indicated in Table V. The characteristics were almost comparable with that of the effluent from the recarbonation process with a hardness content of 40 mg/l, a COD value of 30 mg/l and a turbidity of 1 mg/l. The residual phosphates did not exceed 0.5 mg/l.

Conclusions

At Madras, treatment of the city sewage by the ASP followed by proper polishing treatment and final chlorination can yield an effluent which is suitable for industrial cooling. Polishing treatment consisting of excess lime addition followed by recarbonation may give a final effluent of a high quality. The settling properties of the precipitates formed during excess lime addition and during recarbonation may be so quick and efficient that there may not be any problems in settling. In view of the efficient final settling there may be no need for filters also. However, this process may be costly because of the requirement of excess lime and carbon dioxide.

Polishing treatment with excess lime treatment followed by blending with ASP effluent may yield a final effluent almost comparable to that obtained by the previous process. In this case, settlement of precipitates from the secondary stage may not be as quick as in the previous process. Use of sludge recycling may hasten the precipitation. Compared to the earlier process, this process may be less costly due to reduced lime requirement.

Both the processes produce considerable amounts of sludge of which the major portion will be calcium carbonate. Lime recovery from this sludge may effect considerable saving in the costs of the process. In the case of excess lime treatment and recarbonation the sludge from the secondary stage may be of very high purity permitting direct recovery of lime. However, sludge from the earlier stage may contain appreciable amounts of magnesium hydroxide and phosphates. The sludge from split treatment will carry these impurities in both the stages. For making lime recovery worthwhile in these cases, the impurities may have to be separated out. The problems in this regard need to be studied further.

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Ecology of BOD Reductions in Sewage Stabilization Ponds

S. S. RODGI,* V. V. KANABUR,* G. B. DODAKUNDI* and H. S. PATIL*

Observations were made on the sewage stabilization ponds serving different localities on the Karnatak University campus with a retention period of ten days and operated at 1.22 m depth with an average BOD loading of 336.3 kg/ha/day. The performance of these ponds over a period of about five years is discussed in the paper. Reduction in BOD was of the order of 65 percent. A linear relationship is found to exist among the factors like percent removal of BOD, its loading and the temperature of the effluent. The marked difference in the functioning of one of the ponds above the mean temperature is attributed to the constructional criteria, with two additional inlet points. It is suggested that multi-inlet ponds may serve as better ecosystems for sewage treatment because of increased turbulence effecting uniform distribution of temperature and nutrients.

Introduction

In recent years, oxidation pond treatment for raw and settled sewage has been recognised as one of the most economical methods (1). A considerable work has been done on the various aspects of the pond, since its placement on scientific basis by Caldwell (2). However, little is known regarding the influence of ecological factors such as temperature and pH on the removal of biochemical oxygen demand (BOD). The present enquiry aims at investigating into this lacuna.

Topography of Dharwar and Details of the Ponds

Dharwar is located at about 650-700 m above the sea level on the Deccan Plateau at the latitude of 15° 28′ N and 75° 00′ E longitude. The city has an average temperature of 28.8°C and receives an annual rainfall of 74.49 cm, with a relative humidity of 89 percent. The sunshine is for 9-10 hr/day. The Karnatak University campus occupies a hillock towards the west about 3 miles from the heart of the city. The population (including floating) is about 2000. The per capita water consumption is around 25 gal, supplied from the municipal water pumping station situated at Nirasagar. Prior to the installation of the oxidation ponds the sewage was treated by septic tanks which were found to be inadequate for the growing population and served as sources of public health nuisance and obnoxious odours. Later (1965) these septic tanks were replaced by the presently operating oxidation ponds for serving certain parts of the campus.

Studies were conducted on pond 2 (P 2) from October, 1966 to March, 1970 and on pond 3 (P 3) from January, 1968 to March, 1970. These ponds were constructed to serve different localities in the neighbourhood of Uday Hostel and New Gents' Hostel respectively on the campus. The data concerning the designs of the ponds are given in Table I.

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* Department of Zoology, Karnatak University, Dharwar-3 (Mysore)

TABLE I—DESIGN OF OXIDATION PONDS

Particulars	Pond 2 (P 2)	Pond 3 (P 3)
Length (m)	25.89	18.29
Breadth (m)	15.24	15.24
Depth (m)	1.22	1.22
Area (sq m)	0394.56	0278.74
Capacity (gal)	105910	74760
Population served	425	320
Daily flow (gal)	10625	8000
Detention time (days)	10.00	9.4

Materials and Methods

The domestic sewage entering the ponds and the corresponding effluents were collected in the morning (9.0 AM), 12 noon and in the after noon hours (3.00 PM). Temperature, pH and dissolved oxygen concentration (DO) were measured for all of these samples. The samples collected at 9 AM were analysed for BOD. The analysis was made as per the procedures described in Standard Methods (3).

Results

The temperatures (P 2, 23-40°C and P 3, 24-38°C) prevailing in the ponds appear to promote the photosynthetic activity of algae resulting in the supersaturation of DO (32.6 and 30.0 mg/l) followed by the increased pH (P 2: 7.0-11.2, and P 3: 7.0-9.3) In general, the values for temperature pH and DO were higher during the summer than in other seasons of the year (Fig. 1 & 2).

The BOD varied considerably. The peak occurred at 300 mg/l. Larger number of effluent samples showed 75 mg/l (Fig. 3). Extremely low values observed were 15-20 mg/l. When set for BOD after filtering, it reflected the efficiency of the ponds for purification. Maximum number of samples showed 65 percent of BOD removal (Fig. 4). The loadings for both the ponds fluctuated widely (P 2: 122-680 lb/acre/day or 136.72-762.28 kg/ha/day; P 3: 128-668 lb/acre/day or 143.49-748.83 kg/ha/day). The peak values, however, were the same (Fig. 5). Thus, it is evident that these ponds displayed unified response to temperature and pH with respect to BOD removal.

Fig. 6 and 7 illustrate the seasonal pattern in the concentrations of BOD. Consistent reductions in BOD were discernible irrespective of the seasons of the year. Higher removals were recorded during summer than

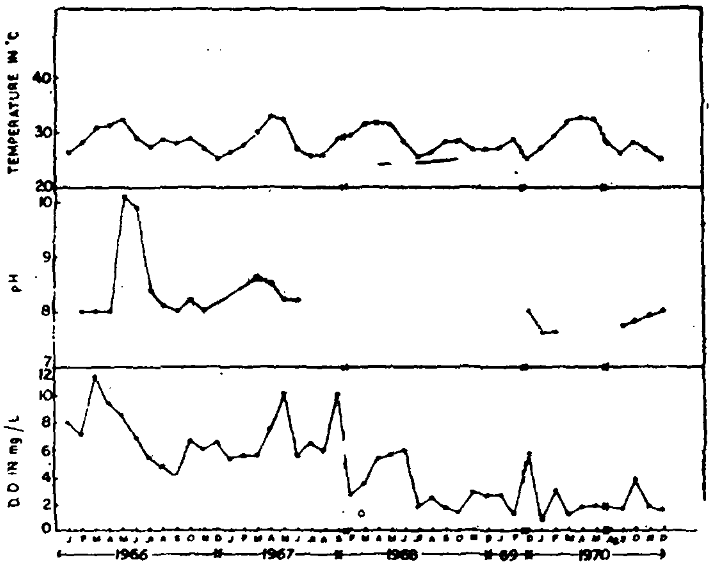


Fig. 1—Monthly Variations in DO, pH and Temperature (P 2)

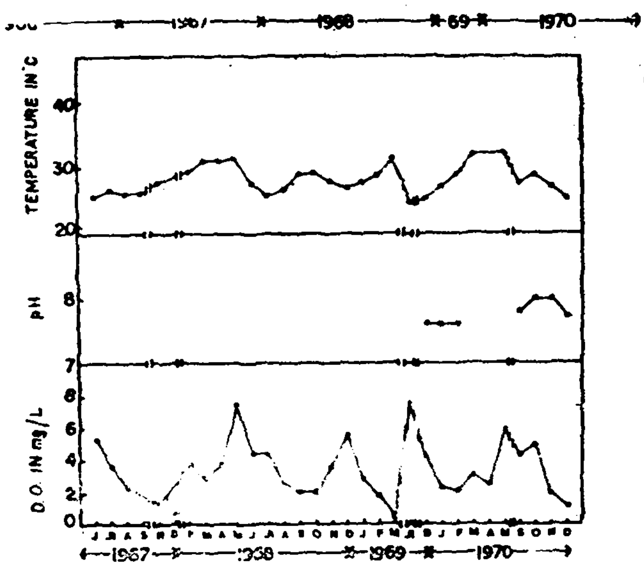


Fig. 2—Monthly Variations in DO, pH and Temperature (P 3)

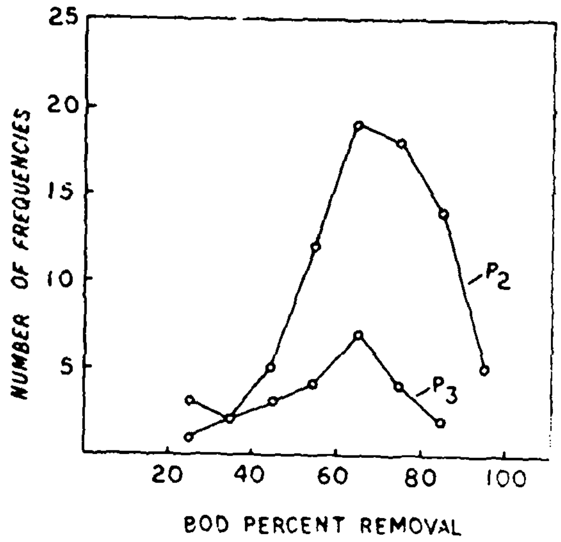


Fig. 4—Frequency Distribution Curves for Percent BOD Removal of Pond Water Samples.

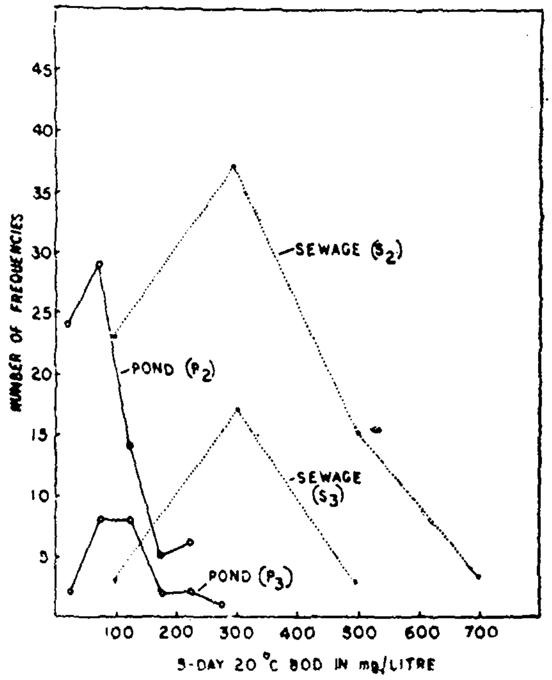


Fig. 3—Frequency Distribution Curves for BOD of Sewage and Pond Water Samples.

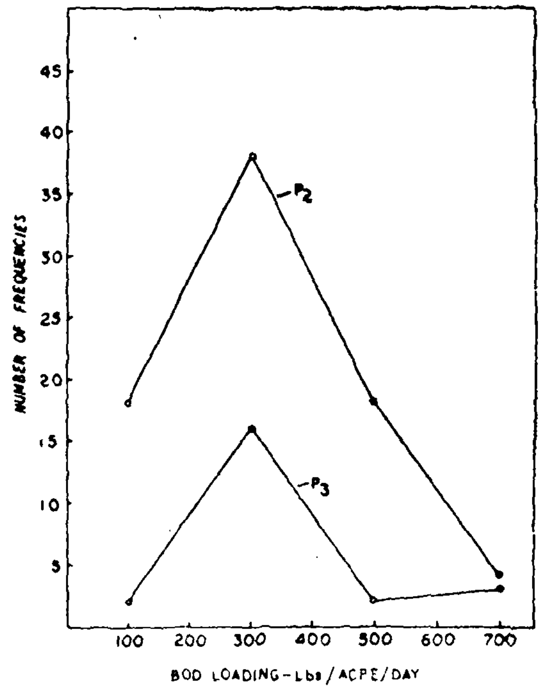


Fig. 5—Frequency Distribution Curves for BOD Loadings.

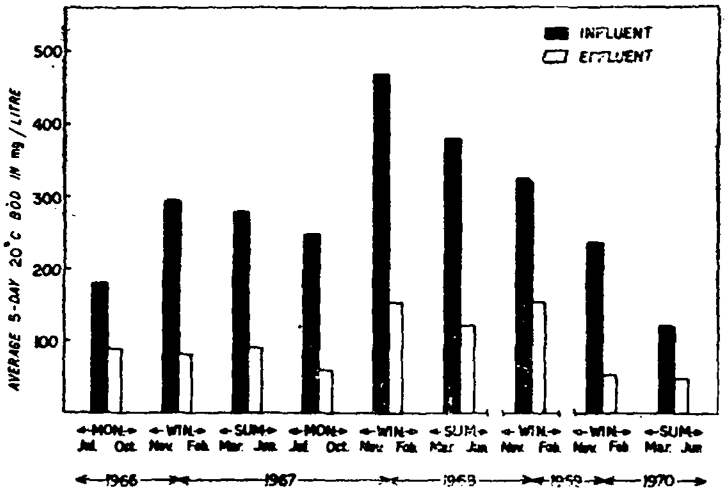


Fig. 6—Seasonal Variations in BOD of Sewage and Pond Water Samples (P-2).

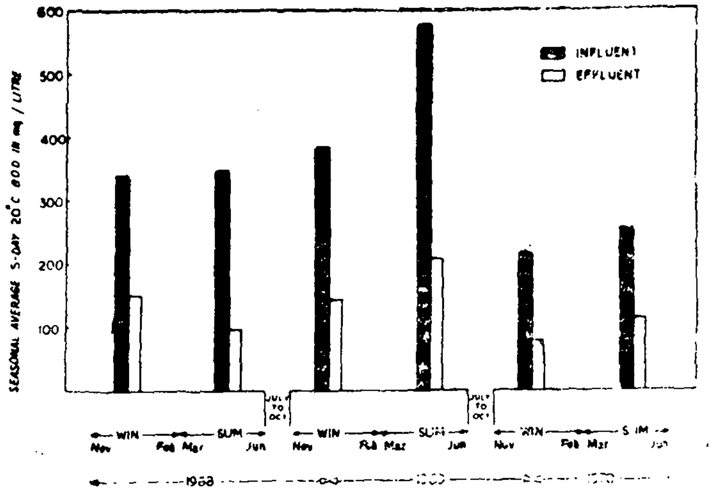


Fig. 7—Seasonal Variations in BOD of Sewage and Pond Water Samples (P-3).

in other seasons which may be due to high temperature conditions that stimulated algal and bacterial metabolism associated with increased values for pH and DO concentration.

In order to have an insight into the relationship between temperature and pond performance, the data was fitted into the linear regression equation of the form :

$$Y=a+b_1X_1+b_2X_2$$

where, Y=percent removal of BOD,

X_1=BOD loading lb/acre/day,

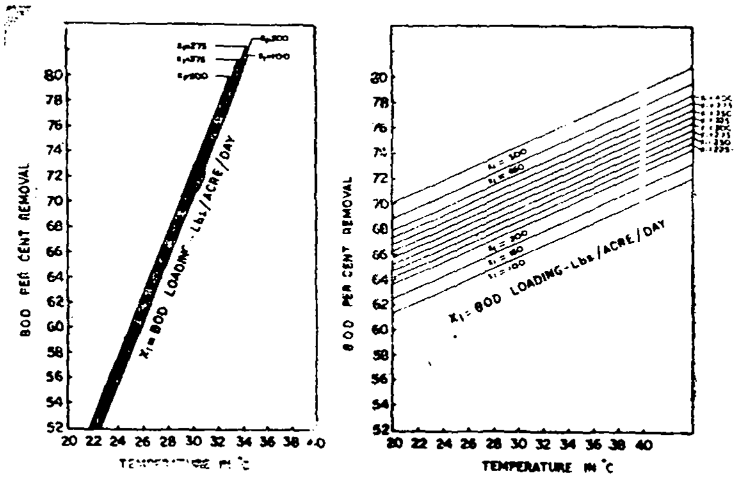
X_2=temperature of the pond water in °C, and

a, b_1 and b_2 are constants. The mean values of these variables are shown in Table II.

It is obvious from the results of the statistical analyses for both the ponds that a

TABLE II—RESULTS OF STATISTICAL ANALYSES

Ponds	X_1	X_2	Y	Standard error for mean value of Y
P 2	316.17	24.73	68.18	± 15.52
P 3	355.72	25.39	60.35	± 13.47



POND-3 **POND-2**

Fig. 8—Relationship between percent removal of BOD, its Loading and Temperature of the Pond Water Samples.

TABLE III—MICROORGANISMS OF THE PONDS

POND 2			POND 3		
Algae		Rotifers	Algae		Rotifers
Dominant	Subdominant		Dominant	Subdominant	
SUMMER SEASON					
Euglena (6 sp.)	Ankistrodesmus	Pompholyx	Euglena (9 sp.)	Scenedesmus	—
Chlorella	Phacus	Asplanchna	Ankistrodesmus	Micractinium	Brachionus
Chlamydomonas	Scenedesmus	Filinia	Carteria	Eudorina	
RAINY SEASON					
Merismopedia	Ankistrodesmus	Pompholyx	Chlorella	Euglena	Brachionus
Euglenoids	Chlorella		Merismopedia	Ankistrodesmus	
				Chlamydomonas Micractinium	Filinia
WINTER SEASON					
Euglena	Pompholyx	Pyrobotrys	Micractinium	Euglena Phacus	
			Chlamydomonas	Merismopedia	Brachionus
Chlorella	Micractinium	Filinia	Eudorina	Carteria Ankistrodesmus	
PERSISTANT FORMS OF ALGAE					
Euglena	—	—	Ankistrodesmus	—	—
Chlorella	—	—	Micractinium	—	—
			Euglena	—	—

linear relationship is found to exist between percent reductions in BOD, its loading values and prevailing temperature conditions (Fig. 8).

The algal species harbouring the ponds are listed in Table III by dividing them into dominant, subdominant and persistant forms in all of the seasons of the year. ***Carteria sp.*** was present in P 3 while it was not noticed in P 2. The number of species of Euglena recorded in P 3 were more than in P 2. Most of the time, both the ponds contained similar species of algae either in the dominant or subdominant level. The persistant algal species recorded in P 3 were ***Ankistrodesmus, Micractinium* and *Euglena*** while P 2 had ***Euglena* and *Chlorella*** as persistant forms.

Discussion

The BOD loadings hitherto recorded (300 lb/acre/day or 336.30 kg/ha/day) fall in the range reported for some of the ponds functioning in India (4), and are significantly higher than those (25-50 lb/acre/day or 28.02-60.00 kg/ha/day) operating in the temperate climatic conditions (5).

The algal bacterial symbiosis is the criterion for the purification of wastes in a lagoon; the ecological factors operating therein deserve special mention. The temperature prevailing (20-40°C) in the ponds at Dharwar appear to be optimum. The same optimal temperature conditions were reported for algal activity (6). Suwannakarn and Gloyna (7) have also stated that, under the limiting conditions of temperature, the BOD removal increased with temperature. At the average temperature (30°C), these two ponds showed almost the same BOD reductions (69 percent). However, P 3 manifested more efficiency than P 2 for temperature above 30°C, despite the loading values for the P 3 which were slightly higher than P 2. The performance of P 3 seems to be affected adversely around 20°C. Thus, the greater quantities of nutrients available might have promoted symbiotic activity of microbes rather than retarding it. The better function of P 3 may be attributed to the difference in the construction of the feed line, designed in the form of "T" which facilitated the uniform distribution of nutrients and temperature. Therefore, the multi-inlet oxidation pond may serve as a better ecosystem for sewage treatment.

The high pH levels recorded herewith were not found to be detrimental to the algal species because of the satisfactory performance of the sewage ponds. These findings confirm that the algae in sewage lagoons tolerate wide range of pH values. Nelson (8) arrived at similar conclusions while culturing the algal types from sewage lagoons. According to Oswald *et al.* **(9), an increase** in the pH adversely affected the bacterial action resulting in the increased BOD of the pond water. In this context, Pipes (10) advocated the idea of lowering the pH by increasing the flow rates. Since the diurnal shift in pH was inevitable, this method was found impracticable. A linear relationship existing between pH, percent BOD removal and its loading (11) showed that the BOD reductions slightly increased with pH.

As far as the authors' observations are concerned, the diurnal shift in physico-chemical factors appear to bear beneficial effects on the pond performance. During night, the lower pH values are favourable for bacterial activity to degrade the organic matter thereby producing the copious supply of nutrients for the algae by dawn. Thus, the algal proliferation supersaturates the medium with oxygen and hence augments the reductions in BOD and bacteria.

Summary and Conclusions

On the basis of the experiences gained out on the satisfactory performance of the oxidation pond during the last five years (under the prevailing environmental conditions at Dharwar) the following conclusions have been drawn.

1. The ponds are operated with an average BOD loading of 336.3 kg/ha/day.
2. The microorganisms are well adapted to the variations in physicochemical para-

meters such as, temperature (20-40°C), pH (7.5-11.2) and DO concentration (0.0-32.0 mg/l.).

3. A linear relationship is found to exist with percent removal of BOD, its loading and prevailing temperature of the pond water.

4. The better functioning of P 3 though operated with a higher BOD loading applied to a smaller area is probably attributed to the difference in the construction of the feed line provided with two additional inlet points.

Acknowledgements

The authors acknowledge gratefully the financial assistance awarded for the research project by Karnatak University, Dharwar; U.G.C. and C.S.I.R., New Delhi.

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DISCUSSION

Shri R. C. Dixit: (i) DO and BOD have been shown as maximum in summer. How is it? (ii) Sample was filtered for estimation of BOD. Filtration is not a proper method for removing algae because organic matter is removed by filtration and hence correct value cannot be obtained. Further, filtration will affect the immediate oxygen demand also.

Shri S. S. Rodgi: (i) The BOD of the wastewater entering the pond during the summer was more than in other seasons of the year probably due to short supply of water. Despite this high organic loading, the pond effluents showed satisfactory results. The maximum DO concentration of the pond water during summer was due to enhanced photosynthesis, which reduced the biochemical oxygen demand. Hence the effluents displayed high percent BOD reductions. (ii) The pond effluent samples were directly analysed for BOD (without either centrifuging or filtering) and yielded on an average a value of 75 mg/l. The efficacy of the pond was evaluated after removing the algae which formed the major portions of the suspended solids in the pond water. The effluent samples bereft of algae showed low BOD values. Also a few samples were analysed for BOD after centrifuging as well as after filtration wherein much difference was not noticed. However, it is likely that some of the organic matter is retained on the filter paper, which thereby may reduce the immediate oxygen demand of the water.

Shri S. R. Alagarsamy (Nagpur): Does 65% BOD removal indicate really a satisfactory performance?

Shri S. S. Rodgi: The BOD removals ranged considerably, the highest frequency fell around 65 percent. But, in the light of the stringent standards for effluents, 65% BOD removal is not considered satisfactory for performance of a pond. We, however, felt that ponds were functioning satisfactorily because the effluent water was used for irrigation since the inception of these ponds (5 years). The effluent has not produced any harmful effects either on the soil or the crops. The public health nuisance associated with mosquito breeding or odour production was experienced rarely.

Shri V. Hanumanulu: The curve for pond is steeper. It was explained that at higher temperature, because of distribution of sewage through 3 inlets, it gave higher BOD removal when compared to another pond with single inlet. But this so called better operation (with 3 inlets) gave poor performance when compared to the single inlet pond for same loading and same temperature which needs explanation from the authors.

Shri S. S. Rodgi: The steep nature of the curve in case of the pond with three inlet points is probably due to enhanced microbial activity along with increased rate of reaction generally associated with higher temperature. Further, it is supplemented by the availability of nutrients distributed uniformly throughout the pond as a result of increased turbulence. The pond P 3 was loaded more (36 kg/ha/day) than pond P2. But at lower temperature the impaired microbial activity may be responsible for comparatively reduced efficiency of the pond.

Dr. N. U. Rao: When the temperature was higher algal growth was better. Why does the pH go up when the algae grow?

Shri S. S. Rodgi: During summer, higher temperature promoted the proliferation of algae associated with active photosynthesis in the pond. The increase in pH of the pond water was due to complete utilisation of free carbon dioxide. Further, its extraction from the bicarbonate ions consequently increased the concentration of carbonates.

PROC. SYMP. ON ENVIRONMENTAL POLLUTION (1973)

Virus Removal in Sewage Treatment Pilot Plants

Part I-Oxidation Ditch

V. CHALAPATI RAO,* P. KUMARAN,* S. B. LAKHE,* PUSHPA DUBE* and N. U. RAO*

Results of investigations regarding removal of enteric viruses in the oxidation ditch, one of the pilot plants in the CPHERI campus, are reported in this paper. An optimum detention time of sewage for 13-14 hr, a sludge retention time of 6-12 days and solids concentration of 2000-4500 mg/l brought about more than 99% reduction of the virus in the raw sewage.

Though the oxidation ditch was treating sewage to an effluent quality of 5-20 mg/l BOD under different operational conditions, in 50% of the observations the quantity of virus in the effluent was less than or equal to 15 PFU/l and in 90% cases it was less than or equal to 100 PFU/l, while the quantity of virus entering the system was 2550 and 6300 PFU/l respectively.

Though the quality of effluent in terms of BOD, solids, etc. qualifies it for disposal into a stream, it is hazardous to public health, since it contains considerable quantity of enteric viruses. Such effluents should be disinfected thoroughly before discharged.

Introduction

There is a growing tendency among developing countries to evolve sewage treatment processes which suit their conditions by using indigenous materials and relying on local technical know-how.

The fact that only 7 percent of the total population of India is served by sewers and only 3 percent of sewage being treated resulted in unrestricted discharge of raw domestic wastes in water courses and on land causing serious problems of pollution. Emphasis, therefore, has been laid on developing low cost sewerage and waste treatment systems such that the treated effluent can be utilised for industry, agriculture, fish-culture and recreation.

With a view to develop design criteria for different types of low cost waste treatment plants in this country, this Institute had constructed in its premises a number of pilot plants **viz.**, the oxidation ditch, aerated lagoon and oxidation ponds, for a comprehensive study involving the removal of BOD, solids, parasites, bacterial pathogens and human enteric viruses.

The performance of these pilot plants in bringing about the reduction or elimination of human enteric viruses under various operating conditions has been studied.

In this paper, results of studies on one of the pilot plants, **viz.**, the oxidation ditch are reported.

Materials and Methods

a) *Collection of Samples*

Raw sewage from Lakshminagar, a middle income group residential area of Nagpur

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* Scientists, Central Public Health Engineering Research Institute, Nagpur-20.

city, is pumped into the pilot plant located on the premises of this Institute. Samples of raw sewage and effluent from the oxidation ditch were collected from 7 AM to 3 PM at hourly intervals, pooled and held at 4°C. Forty ml of raw sewage and 320 ml of effluent were taken from the composite sample and processed on the same day, as per the method of Rao *et al.* (1).

b) *Processing of Samples*

The sample is homogenised for 4 min in a waring blender and centrifuged at 1800 x g for 30 min. The supernatant is adjusted to pH 3.0 and is again centrifuged at 9320 x g for 30 minutes. Magnesium chloride was added to a concentration of 1200 mg of Mg ++ /liter of sample. The sample was filtered under suction through a 0.45 μ 47 mm diam millipore membrane. Virus trapped on the membrane was eluted with 5 ml of 3 percent beef extract of pH 8.0. The eluate is stored at -25°C till it is inoculated onto drained rhesus monkey kidney cultures in 4 oz. bottles by using 1 ml inoculum per bottle.

c) *Monkey Kidney Cells*

Cultures of trypsinised primary rhesus monkey kidney cells were prepared by standard procedures and propagated in 4 oz. bottles. All eluates were assayed by the plaque technique, using an overlay medium consisting of Eagle's minimum essential medium, 2 percent cow calf serum, 25 mM magnesium chloride, neutral red (1:40,000) antibiotics and 1.2 percent Difco agar. Plaques were counted daily for 10 days and the total count was reported as PFU per liter of sample.

d) *Pilot Oxidation Ditch*

The ditch is of end-less masonry channel 80 ft long, 5 ft wide and 4 ft deep with a volume of 20,000 gal (Fig. 1). Two rotors were provided to facilitate the operation of the pilot ditch under varying conditions. The depth of immersion of the rotor is adjustable.

The influent chamber consists of two compartments and is fixed with V-notches, one for raw sewage and another for return sludge. The mixed liquor is let out into a

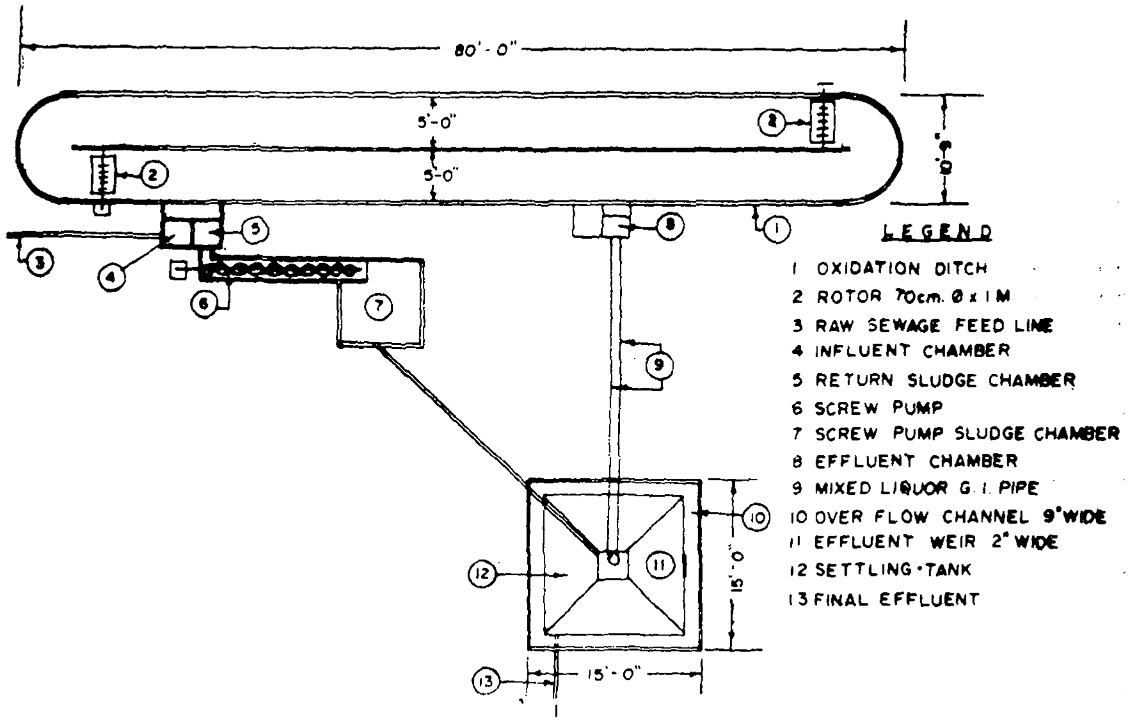

Fig. 1—Flowsheet of the Oxidation Ditch Pilot Plant on CPHERI Campus

chamber with a rectangular weir and allowed to flow through two 4″ (10 cm) diam G.I pipes to a hopper bottom sedimentation tank The supernatant over-flows from three 2 ft wide rectangular weirs. The under-flow is allowed to flow by hydrostatic pressure to a chamber from which the sludge (50-70% of the influent flow) is lifted up by an Archimedian screw pump and returned to the ditch (2).

Results

Results of analyses of raw sewage and effluent for enumeration of viruses under different operational conditions of the oxidation ditch are presented in Table I :

a) *Detention Time of Sewage and Virus Removal Efficiency of the System*

The oxidation ditch has been operated under different detention times ranging from 6.94 hr to 88 hr in different months. The average plaque forming units of viruses in raw sewage and effluent based on four observations (and in some cases three) for each detention time are presented in Table II.

It may be seen from the results that when detention time was 6.94 hr, out of 100 PFU/l entering the system through raw sewage 2.3 PFU/l were detected in the effluent thereby reducing the amount of virus by 97.7 percent. When the sewage was held for nearly double the time (13.15 hr) only 0.26 PFU/l was detected in the effluent out of 100 PFU/l entering the ditch thereby increasing the reduction of virus to 99.7 percent. Prolonged detention (29 or 88 hr) did not bring about any further reduction in the amount of virus escaping in the effluent.

A further scrutiny of the data for determining the amount of virus in the effluent on different sampling days for the same detention time (Table I) reveals apparently disparaging results. For instance, when sewage was detained for 14.4 hr on Novem-

TABLE I—RESULTS OF ANALYSES OF SAMPLES OF SEWAGE AND EFFLUENT COLLECTED FROM THE OXIDATION DITCH (PILOT PLANT) DURING 1970-71 UNDER DIFFERENT OPERATIONAL CONDITIONS

Dates	Detention time (hr)	Sludge retention time (SRT) (days)	VIRUS (PFU/l)		
			R.S.	Effl.	Reduction (%)
3-11-1970	14.4	6	2275	90	96.0
9-11-1970			1888	0	100.0
24-11-1970			4500	7	99.8
30-11-1970			6329	12	99.8
5-12-1970	13.15	11.45	7450	3	99.9
15-12-1970			6075	3	99.9
22-12-1970			1600	3	99.8
29-12-1970			3825	38	99.0
3- 2-1971	6.94	1.33	1350	50	96.6
9- 2-1971			3700	50	98.7
23- 2-1971			1550	56	96.4
2- 3-1971	29	16.5	6950	25	99.6
16- 3-1971			1325	25	98.0
24- 3-1971			2550	6	99.8
5- 5-1971	9.7	0.97			
18- 5-1971			2525	21	99.5
31- 5-1971			1225	88	92.5
14- 7-1971	88	256	1425	25	98.3
21- 7-1971			2325	6	99.9
27- 7-1971			1525	25	98.3

TABLE II—PERCENTAGE REMOVAL OF VIRUS IN THE OXIDATION DITCH UNDER VARIOUS VOLATILE SUSPENDED SOLIDS CONCENTRATION, SLUDGE RETENTION TIME AND DETENTION TIME

Volatile suspended solids (mg/l)	Sludge retention time (days)	Detention time (hr)	Months	Average PFU/l		Per cent reduction
				R.S.	Effl.	
1011	0.97	9.70	May 1971	1875	54	97.2
1574	1.33	6.94	Feb 1971	2200	52	97.7
2132	6.0	14.4	Nov. 1970	3748	27	99.28
4375	11.45	13.15	Dec. 1970	4612	12	99.7
3106	16.5	29.0	Mar. 1971	3608	19	99.5
1676	256.0	88.0	July 1971	1758	19	98.9

ber 3, there were 4 PFU/l in the effluent for 100 PFU/l in raw sewage, whereas on the other three occasions, the results were 0,0.1 and 0.2 PFU/l. This kind of variation was found for other detention times also. This may be explained by the fact that the 98 percent confidence values for enumeration reliability of virus in sewage and effluents by the method adopted in this work was ± 12 PFU from the observed values.

It may be pointed out that a detention time of 13-14 hr can effect more than 99 percent removal of virus from the system.

(b) *Sludge Retention Time of Sewage and Virus Removal Efficiency of the System*

Sludge retention time (SRT) has been varied from 0.97 days to 256 days. Results presented in Table II reveal that when sludge was retained for 0.97 days, out of 100 PFU/l entering the ditch through raw sewage, 2.3 PFU/l were detected in the effluent. When the SRT was raised to 6 days, only 0.7 PFU/l was detected in the effluent. Nearly doubling the time to 11.45 days resulted in raising the percentage removal of virus from 99.28 to 99.7. From the data presented, an optimum SRT of 6-11 hr results in more than 99 percent removal of viruses in the oxidation ditch.

(c) *Solids Concentration and Virus Removal in the Oxidation Ditch*

Concentration of volatile suspended solids (VSS) has been regulated in the ditch in the range of 1011-4375 mg/l to determine the optimum concentration of solids essential for maximum efficiency of the plant. It may be seen from Table II that an increase in solids concentration resulted in increased removal of viruses; between 2132-4375 mg/l, more than 99 percent of virus entering into the ditch has been removed.

Discussion

Treatment of sewage by oxidation ditch is an activated sludge process. Though comparable data on the performance of oxidation ditches elsewhere in the removal of viruses is not available, some of the studies on activated sludge treatment systems are pertinent to a discussion of the results obtained in the present study.

The percentage removal of virus under various operating conditions of the oxidation ditch (Table I) ranged from 92.5 to 100, which according to sewage treatment norms is considered highly satisfactory and compares well with the efficiency of conventional activated sludge treatment systems. Clarke *et al.* (3) reported 96-99% reduction of Coxsackie virus A_9 after a retention period of 6-8½ hr and 83-94% reduction of poliovirus I after 6-7½ hr of retention in bench scale activated sludge studies. In these studies, a retention time of 6.94 hr brought about 97.7% reduction of virus and when the retention time was nearly doubled (13-14 hr) more than 99% removal of virus was recorded.

Concentration of mixed liquor solids was shown to have an effect on the virus removal efficiency of the activated sludge treatment system. Experiments by Clarke *et al* (3) in which the bench model was seeded with 200-4000 mg/l of activated sludge (expressed as volatile solids) showed that at a level of 200 mg/l of volatile solids, removal of poliovirus I was low when compared to the other levels examined. In the studies on oxidation ditch where the concentration of volatile suspended solids were regulated between 1011-4375 mg/l, virus removal was seen to be increasing with an increase in solids concentration resulting in more than 99% removal of virus between 2000 and 4375 mg/l VSS.

The removal of viruses in activated sludge process is attributed to adsorption of viruses to suspended and colloidal material or by inactivation from toxic substances, (3) antagonistic activity of certain bacteria in activated sludge (4) and antagonism from bacteria like **pseudomonas aeruginosa** and *bacillus subtilis* occuring in wastewaters (5). In the case of oxidation ditch, it may be presumed that the high percentage removal of viruses obtained may be due to a combination of several factors mentioned above. It may be pointed out that there is need to plan experiments to study the influence of each one of these factors and perhaps others too on the extent of virus removal in the oxidation ditch.

The virus removal efficiency of sewage treatment plants was described in terms of percentage removal of virus (3, 4, 6), but this does not indicate a measure of the quantity of virus in absolute terms so as to give an idea of the magnitude of pollution caused by discharge of treated effluent into surface waters. As such the data are plotted on a log-normal probability paper (Figs. 2 & 3). It is seen that in fifty per cent observations the quantity of virus in the effluent was

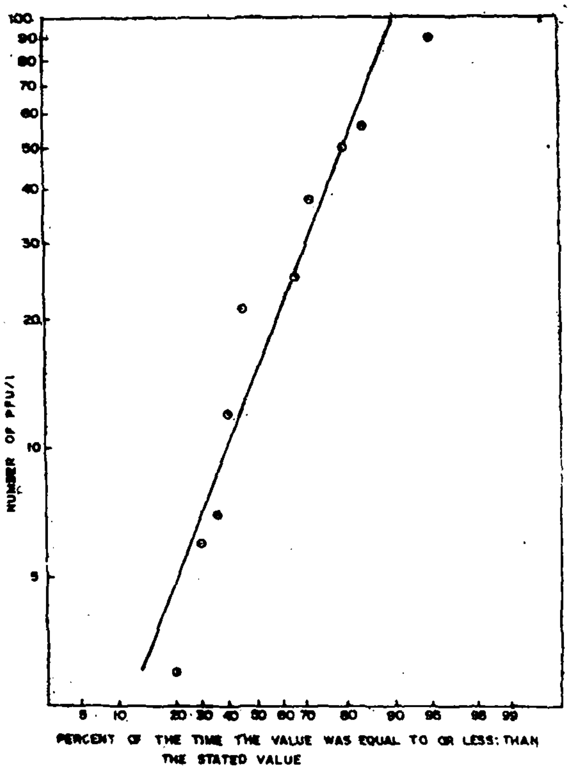

Fig. 2—Distribution of PFU of Enteroviruses in the Effluent of the Oxidation Ditch.

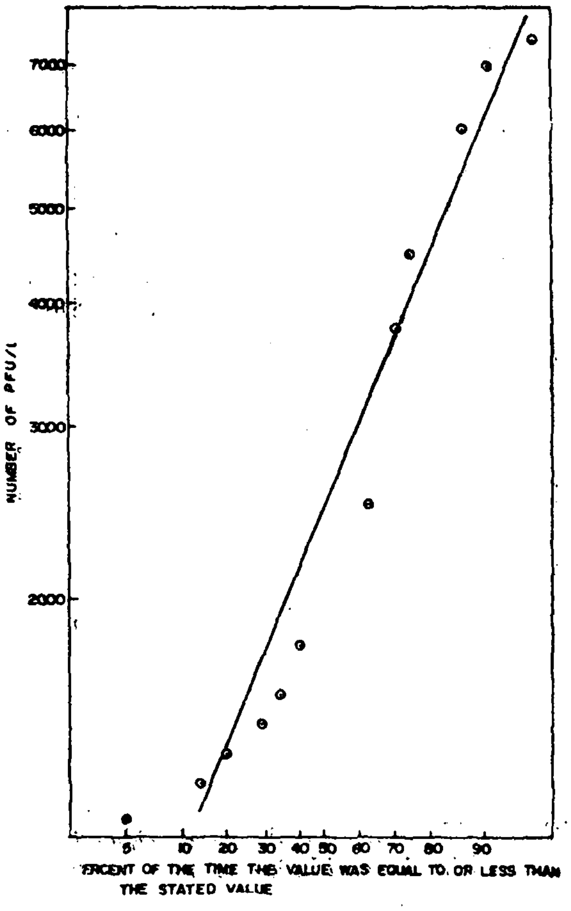

Fig. 3—Distribution of PFU of Enteroviruses in the Raw Sewage of the Oxidation Ditch.

equal to or less than 15 PFU/l and in ninety per cent cases, it was equal to or less than 100 PFU/l while in raw sewage the respective values were 2550 and 6300 PFU/l. When 20,000 gal of sewage were to be treated per day in a ditch of 80′ x 5′ x 4′, the effluent can carry a maximum load of 8 x 10^6 (80 lakhs) PFU. If the same data from Table II were presented in terms of percentage removal of viruses, the reduction of virus was in the range of 96%—100% except on one occasion when it was 92.5%. From the above discussion, it is clear that an interpretation of results regarding the efficiency of a sewage treatment system in terms of percentage removal of viruses is bound to impart a false sense of security.

Conclusions

(i) There is appreciable reduction of viruses in the oxidation ditch under varying operating conditions.

(ii) The need for evaluating the performance of sewage treatment plants in terms of probable number of viral PFU escaping in the effluent rather than in terms of percentage reduction of viruses is pointed out.

(iii) Though the quality of effluent in terms of BOD, solids etc., qualifies it for disposal into a stream, it is hazardous to public health since it contains considerable quantity of enteric viruses. Such effluents should be disinfected thoroughly before discharged.

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DISCUSSION

Shri B. N. Patil: Instead of using such a long process, some chemicals like maleic anhydride copolymer can possibly be used for recovering viruses from sewage?

Dr. V. Chalapati Rao: Polyelectrolytes like maleic anhydride were used for adsorption and recovery of viruses from sewage by some investigators. Any procedure for concentration and enumeration of viruses from sewage consists of clarification of the sample, adsorption of virus to a given material and recovery of virus. Certainly, it takes considerable time in any process. The CPHERI method described in the paper is a simple and efficient process involving only two major steps: (1) adsorption of virus from a blended and clarified sample to membrane filter at pH 3; and (2) elution of the virus from the filter with beef extract at pH 8. It takes only two hours for processing a sewage sample by this method.

Prof. M. S. Shetty: Whether raw sewage was added to the oxidation ditch with (or without) primary treatment.

Dr. V. Chalapati Rao: Unsettled raw sewage was pumped into the oxidation ditch.

Dr. K. L. Saxena (Nagpur): Table II showed decrease in percentage of virus removal from 99.7 to 99.5 while the sludge retention time (SRT) increased from 11.45 to 16.5 days. Reasons may be stated.

Dr. V. Chalapati Rao: Reference to Table II would reveal that when sludge retention time (SRT) was increased from 11.45 to 256 days, percentage reduction of virus had fallen from 99.7 to 98.9. It might be due to a reduction in the concentration of volatile suspended solids from 4375 mg/l to 1676 mg/l.

Dr. M. K. C. Sridhar: (i) What was the test organism used for cultivating the viruses? (ii) Can this organism provide information for all types of viruses present in the sewage?

Dr. V. Chalapati Rao: (i) Viruses were cultivated in primary monkey kidney cell cultures. (ii) All enteroviruses except Coxsackie A group and infectious hepatitis virus can be grown on these cultures.

Shri M. V. Nanoti (Nagpur): (i) When sewage is centrifuged for clarification, there is 20% reduction in viruses. This is possible as the viruses are adsorbed on suspended particles. Then, how is it that the same reduction has not been observed when suspended particles are precipitated? (ii) What is the mechanism of adsorption and elution of virus at pH 3 and 8 respectively?

Dr. V. Chalapati Rao: (i) Most of the settleable solids are removed from sewage during centrifugation. At pH 3, what precipitates out must be the organic matter but not the virus. (ii) Comments offered below by Shri Bulusu would partly explain the mechanism.

Shri K. R. Bulusu (Comments): Viruses are protein particulates essentially and the ionisable groups are -COOH and -NH$_2$. The charge is negative at high pH (owing to the ionisation of -COOH to -COO$^-$ and positive at a low pH value (-NH$_2$ to -NH$_3$+). Thus the net charge will be zero at some pH, if no other ions are adsorbed. The zero point of charge (ZPC) is given by the pH at which the surface charge is zero and it is different from the iso-electric point (IEP). IEP is a ZPC arising from interaction of H+ and OH$^-$, the solid surface and water. Below the IEP, the virus complex is eluted because of net positive charge and is possibly the cause for a complete recovery. At higher pH values, the virus complex is predominantly negative in character and is likely to be eluted.

I agree with the speaker that the possible mechanism of removal is 'adsorption'. The virus complex can be held at the surface when the binding energy is large as compared to thermal energy. The high dielectric constant reduces the force between the virus complex and its induced dipole. Dipoles are groups such as -COOH, -CO, -OH, etc. These are usually referred to as polar since their centres of +ve and -ve charge do not coincide giving rise to small electric doublets or dipoles, e.g., $C^+ = O^-$, $O^- - H^+$.

Often the force of attraction is physical in nature, involving an interaction between dipoles or induced dipoles but sometimes the force of attraction involves chemical bonds as and when oxygen is adsorbed on charcoal. In many cases, the adsorbed particles are only a molecule deep, the subsequent being unable to take part in the attractive force beyond the first layer adsorbed.

Shri S. Mukherjee: Modern trend in engineering design is to switch over from factor of safety to "satistical probability". In the probability calculation, the assumptions made may please be stated.

Dr. V. Chalapati Rao: It was assumed that 'PFU/l' is a random variable following log normal distribution.

CHAPTER-IV

WATER QUALITY (HEALTH)

PROC. SYMP. ON ENVIRONMENTAL POLLUTION (1973)

Prevalence of Naru Disease in Parts of Ujjain District (M.P.)

A. K. KAPOOR*

The inhabitants of the villages, Nagjheri, Piplia Malu, Unhel, Paslora, Kondla and Akia in Kachrood Tehsil of the Ujjain district in Madhya Pradesh, have been suffering from 'NARU' disease since a long time, and in order to find out the cause for the same, the well waters of the area have been chemically analysed, and the results bearing significance for the prevalence of the malady are presented in the paper.

Immediate steps are felt necessary for the control of the disease and the measures suggested include educating the residents of the villages to use filtered or boiled water, closing down of the existing wells, after developing closed wells at places, which are free from the infection.

Introduction

In the course of the geohydrological survey of parts of Ujjain district in Kachrood tahsil, the author has come across many persons suffering from Naru disease, particularly in the villages Nagjheri, Piplia Malu, Unhel, Palsora, Kondla and Akia. Having witnessed the miserable conditions of the sufferers, the problem has been pursued to find out the causes as well as the remedial steps. A brief physiographic account of the area is given before dealing with the nature of waters in the various wells, which are found to be solely responsible for the disease.

The topography of the area can be discribed, in general, as an undulating terrain having wide extent of plain country under cultivation. The climate of the area is humid with characteristic three seasons over an year. The average altitude of the area is about 500 m above the M.S.L. The area forms a part of the Malwa plateau; having pleasant climate for most part of an year. The natural vegetation is considerably thick and the palm, babul, khakra etc. are found to be the common trees.

The area is composed of Basaltic lava flows belonging to the Deccan Traps. Lithologically the rocks are highly vesicular, and the vesicles are filled with zeolite, calcite and different varieties of quartz. The soil cover overlying the rocks is comparatively of shallow thickness and can be discribed as medium black soil. The soils are, however, rich in clay and silt and are characterised by the presence of calcarious concretions. They are alkaline with the pH value ranging from 7 to 7.9.

The inhabitants of the area have been suffering from the Naru disease since a long time. In an account of this disease, Chatterjee (1) concluded that water acts as a stimulant and medium of spreading. According to him, the cyclops containing the infective larvae are swallowed by the inhabitants with raw drinking water from the wells and

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* School of Studies in Geology, Vikram University, Ujjain (M.P.)

the larvae are liberated in the stomach. From this period of infection, their growing to sexual maturity, fertilisation and selection of site from where they can discharge the large number of embryos take an year. They discharge the embryos invariably back into water and hence the whole activity is cyclic.

The cyclic process of this disease, its prevalence and survival are through the medium of well waters of the region. In order to find out the causes for the same, the well waters of the area have been chemically analysed.

Well Water Quality

The water samples have been collected from the wells of the region and have been analysed chemically following standard procedure (2).

The water is chemically hard in nature with high proportion of calcium and magnesium carbonates, and high dissolved solids ranging from 600 mg/l to 2700 mg/l. They are abnormally high in alkalinity, having the pH value in the range of 8.9 to 9.6, and their chloride content varies from 290 mg/l to as much as 740 mg/l. The results of the chemical analysis is given in Table I.

As per the standards set by the United States Public Health Service for drinking water (3), the permissible limits of the different constituents are—

Dissolved salts — 500 mg/l
Chloride — 250 mg/l
Fluoride — 1.5 mg/l
Sulphates — 250 mg/l
Magnesium — 125 mg/l
Iron & Manganese — 0.3 mg/l

From a comparative study of the chemical characteristics of water under investigation with the standard norms set for drinking purposes, it is obvious that the water is not only unhygienic for drinking purposes but also provides congenial conditions for the survival of the cyclops responsible for the disease. In other words, high alkalinity, high chloride content, and high calcium and magnesium carbonates in the water would facilitate the growth of the cyclops, which are responsible for spreading of the disease.

Water Movement

During the movement of ground water from high elevation head to lower elevation in the area, the worms are also carried through the water under circulation along the fractures, joints and voids in the rocks, and thus the disease is being spread to the adjoining wells.

Spread of the Disease

The inhabitants of the village drink water from wells and as such the nature of wells has also a direct bearing on the disease. Most of the wells in the area are open wells and are characterized by step lines. The people can reach the water conveniently by the steps and fill in their water containers. During such an action, the legs and arms of the persons suffering from the disease come in contact with the water. This facilitates the discharge of embryos back into the water

TABLE I—CHEMICAL ANALYSIS OF WELL WATER

Village	pH	HCO_3	CO_3	Cl^-	$CaCO_3$ Hardness	$MgCO_3$ Hardness	Dissolved solids
Nagjheri	9.6	150	13.7	500	21.6	146.4	720
Piplia Malu	9.5	108	3.9	290	19.2	113.8	600
Unhel	9.2	90	7.8	475	32	122	2700
Palsora	9.6	162	5.9	350	20	130	600
Kondla	8.9	260	33.6	400	17.6	126.4	1200
Akia	9.6	136	3.9	740	16	104	900

All values except pH are expressed in mg/l.

directly in the case of infected individuals. The embryos discharged are easily transferred to the well water during the filling operations. This establishes a chain of worm movement from well to man and back to well.

Remedial Measures

It is clear from the preceding account that the prevalence of disease is due to the movement of worms with water through the joints, fractures and voids of the country rocks. The chemical nature of the waters with abnormally high proportion of alkalies seems to have provided favourable environment for the growth and the survival of the cyclops. The infection could be prevented by breaking the chain of their transfer from well to man and then to well waters. Considering the seriousness of the disease immediate steps need to be taken by the concerned authorities to adopt the following measures: (i) The infected individuals should not be allowed to draw the water directly as it leads to the pollution of the water; (ii) The residents of the different villages are to be educated to the causes for the Naru disease, and the way it is spread to other persons and areas, so that they could be cautious in using the water for drinking purposes. They should be advised to use the water after its filtration and boiling; (iii) Periodical treatment of the water has to be undertaken with the necessary chemical for eradicating the cyclops; and (iv) After the water is free from the worms, the steps may be closed down, in the various wells and they should be converted into closed wells. In case it is difficult to eradicate the cyclops completely in the already existing wells by the chemical treatment, it is necessary to have new wells developed with the closure of the contaminated ones.

Acknowledgement

The author expresses his gratitude to Dr. S. Subba Rao, for his guidance in the present work. He is also thankful to Prof. K. K Singh, Head, School of Studies in Geology, Vikram University for giving laboratory facilities.

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DISCUSSION

Dr. N. S. Deodhar (Poona) (Comments): The paper implies that the guinea worm disease (*Naru Dracuntiasis*) is associated with hard water and high chlorine content. This is not true. In Maval Taluka and Poona District many villages are infected with guinea worm disease — as high as 80% of population in certain villages — and there are also draw wells with water containing 80-250 mg/l chlorides and 400-600 mg/l total solids. Thus, the relationship claimed by the author is just a coincidence and no such cause or relationship exists.

Shri A. K. Kapoor: I am thankful to Prof. N. S. Deodhar for the information on guinea worm disease prevalent in certain villages of Maval Taluka and Poona District, and the quality of water in which the cyclops thrive. The observations of the author presented in the paper are confined to some parts of the Ujjain District alone, and the relationship inferred from the data should not be construed as a generalization.

The opinion expressed in the paper is based on considerable chemical data, of which only the significant analyses are given in the Table. Having enough details to make such correlation, it is not appropriate to view it as a coincidence, though further studies need to be carried out for establishing a firm relationship. What could be the changes in the chemical composition of the waters if the strength of the cyclopes is large and have been persistent over prolonged periods, has to be examined. The role of climatic and environmental conditions on the chemical nature of waters and the biological functions require elaborate studies.

Control of Waterborne Diseases—Laboratory and Epidemiological Investigations of Cholera in Certain Parts of Andhra Pradesh

P. V. RAMANA RAO,* N. V. RAMA MOHANA RAO,** and M. SUBBA RAO+

Cholera broke out in epidemic form in some places in Andhra Pradesh in June 1972 with the onset of monsoon following prolonged dry spell. In this paper the results of laboratory examinations and epidemiological investigations undertaken to detect the source of infection, and determine the mode of transmission of disease have been reported. During the laboratory examination *Vibrio cholera* was isolated from both raw water as well as some treated water samples. Epidemiological investigations revealed the pollution of drinking waters by sewage and excremental matter and inadequate treatment was responsible for the spread of disease. It was noted that none of the persons inoculated with cholera vaccine suffered from disease.

The investigations show that regular surveillance of water pollution, continuous monitoring of quality of treated waters, periodical sanitary surveys and timely epidemiological investigations pave the way for early detection of source of infection and defects in water treatment and are invaluable tools in the control of water borne diseases.

Introduction

It is well known that contaminated water transmits typhoid, cholera, dysenteries, protozoal-helminthic diseases and enteroviral diseases such as polio, ECHO and infective hepatitis. India has been known as "Home of cholera" for centuries, various epidemics of the disease occuring periodically in different parts of the country. Andhra Pradesh is one of the endemic States for the disease (1). The whole State faced the epidemic of cholera in July, 1972. There was a short spell of rain in the last week of June and 1st week of July 1972 following a long spell of drought in the State. Detailed laboratory and epidemiological investigations were undertaken in addition to routine examination of water samples from drinking water sources and wastewaters at the State Central Public Health Laboratories and Institute of Preventive Medicine, Hyderabad, with the following objectives: (i) to detect the source of infection; (ii) to study the mode of transmission of the disease at different places; and (iii) to suggest control measures for the outbreak.

Materials and Methods

From the records of the I. D. Hospital, Hyderabad, the addresses of the patients treated for cholera were noted. The locali-

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* Director, Institute of Preventive Medicine & Central Public Health Laboratory. Hyderabad (A.P.)

** Chief Water Analyst, Institute of Preventive Medicine & Central Public Health Laboratory, Hyderabad (A.P.)

+ Assistant Director and Additional Professor of Microbiology, Institute of Preventive Medicine & Central Public Health Laboratory, Hyderabad (A.P.)

ties and the houses of the patients or their near relatives were spotted as far as possible with the assistance of corporation health staff. Several places in the districts were selected for the study on the basis of positive cultures of *V. cholera* isoloted from pathological specimens received by post. Samples of water used by the patients and relatives for drinking and other domestic purposes were examined from 7-7-1972 to 15-9-1972. For isolation of *cholera vibrios* separate samples of water of 180 ml quantities were collected into sterilized bottles (250 ml capacity) containing 20 ml of 10 times concentrated (than normal) alkaline peptone water. The residual chlorine of water was tested at the time of sample collection. In the twin cities samples of raw water and treated water of three water treatment works (Asafnagar, Miralam and Manjeera) at different stages of treatment were tested for general bacterial flora, coliforms as well as *V. cholera* to determine the pollution of raw-water and evaluate the performance of treatment plants. The physico-chemical characteristics of raw water were also studied with special reference tq chemical indicators of pollution.

The Examination of the water samples was conducted as per method given in APHA and ICMR Mannuals (2, 3). For the isolation of *V. cholera* from water sources, alkaline, peptone water bottles in which samples were collected in the field were incubated in the labratory for 48 hr. At the end of 6, 12, 18, 24 and 48 hr 1 ml of inoculum taken from surface layer was added into (10 ml) tubes of alkaline peptone water. Simultaneously material from there incubated bottles was plated on IPM modified Aronson's medium.* The morphology staining characters and biochemical characteristics of the colonies were studied following standard techniques given in Cruickshank's Practical Bacteriology (4). If the colonies on the first plating were not discrete, a second plating was done from the incubated 10 ml tubes.

Epidemiological surveys were conducted to trace the original source of the infection and possible mode of transmission. Sanitary surveys of water supplies were also made to collect accurate data on the nature of raw water, the possibility of pollutants gaining access to it, methods of treatment adopted and condition of the distribution systems.

Results

(a) *Twin cities—with protected water supply*

The twin cities of Hyderabad and Secunderabad are supplied water from three sources, namely the two lakes Osmansagar and Himayatsagar and river Manjeera (Fig. 1). An anicut was constructed on Manjeera at Rajampet 40 miles from Secunderabad and water is impounded into the reservoir. The industrial estate at Sanathnagar (Hyderabad) and some areas in Secunderabad city are supplied with Manjeera water. In Hyderabad. two filter beds, one at Asafnagar and another at Miralam. treat the water of the two lakes. Some salient features of the three treatment plants are given in Table I.

The bacteriological quality of treated waters is periodically checked twice a week in the Water Analysis Laboratory of the Institute of Preventive Medicine. The quality of treated water from the distribution system is also checked periodically once a fortnight separately for Hyderabad and Secunderabad areas. The performance of treatment plants is also routinely supervised by determining chemical and bacteriological characteristics of water samples collected at different stages of treatment. In the special investigations the frequency of testing was increased and the samples from distribution system were examined almost daily. The physico-chemical characteristics of raw waters were determined immediately after rains, to evaluate changes in the quantities of different parameters of pollution. It was found that there was no increase in either of the ammonia,

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* **Modified Aronson's Medium (I.P.M.) :** In the Institute of Preventive Medicine, Hyderabad the original Aronson's Medium is modified by way of reducing the quantity of 20% sodium carbonate from 20 ml to 6 ml. The concentration of the other ingredients remain the same.

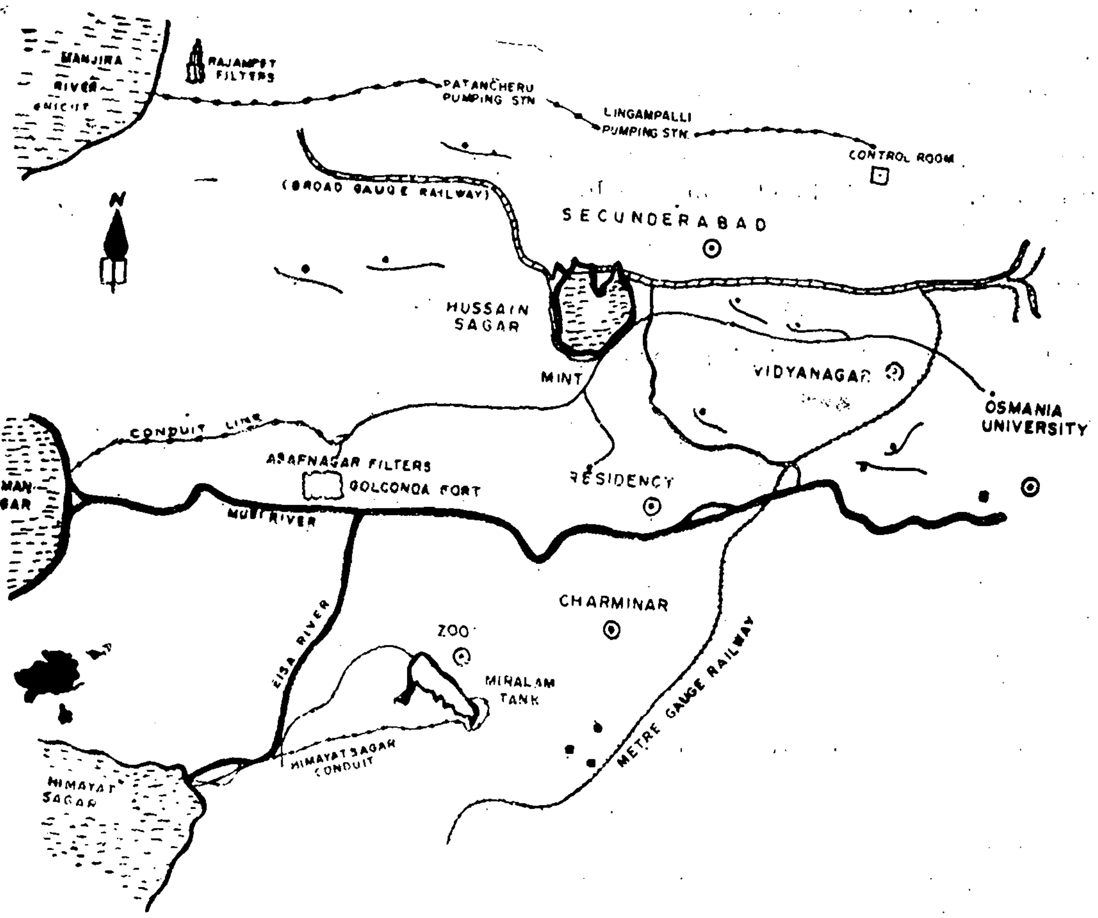

Fig. 1—Locations of Drinking Water Sources for Hyderabad and Secunderabad.

TABLE I—WATER SUPPLY FOR HYDERABAD AND SECUNDERABAD— SALIENT FEATURES OF THE WATER TREATMENT PLANTS

Particulars	Asafnagar	Miralam	Rajampet (Sangareddy)
Year of installation	1922	1937	1962
Source of Raw Water	Osmansagar lake	Himayatsagar lake	Manjeera river
Catchment Area (sq km)	740.7	1315.7	—
Capacity storage level (mil cu m)	135.2	109.1	—
Type of plant	Patterson & Candy RGF	Candy RGF	Jewel filters RGF
Capacity (mil litres)	90	90	90
(mil gal)	20	20	20
Rate of filtration (l/sq m/hr)	450	480	650
(gal/sq ft/hr)	90	96	130

chlorides, or nitrites, present in the raw water of Osmansagar and Himayatsagar lakes but there was significant rise in two ammonia values and nitrites were present in Manjeera river water indicating pollution. There was a significant increase also in the turbidity of Manjeera water. The results of examination are recorded in the Table II.

The results of bacteriological analysis of raw and treated water at different stages of purification are shown in Table III. The results indicate that the Manjeera water is grossly polluted while the pollution of Osmansagar and Himayatsagar water was less. It could also be seen that whereas the reduction of bacterial content of Manjeera water after filtration water was significantly high, there was almost no reduction in the bacterial flora in Miralam Filters and the bacterial count actually increased on filtration at Asofnagar Filter Beds. *NAG Vibrio cholera* is present only in raw water of Manjeera.

During inspection of water works it was observed from the records that the first two filter beds were overloaded, 24 mil gal of water being treated per day while their maximum capacity including 10% overload factor is 20 mil gal. Furthermore, there was residual turbidity of over 5 units in the filtered water, which may be due to ineffective flocculation of colloids and insufficient sedimentation time available (20 min). It was also noted that one presettling tank was

TABLE II—SALIENT FEATURES OF PHYSICAL AND CHEMICAL CHARACTERISTICS OF RAW WATER

Item	Osmansagar		Himayatsagar		Manjeera	
	BR	AR	BR	AR	BR	AR
Temperature (°C)	30	28	31	28	32	29
Total alkalinity ($CaCO_3$)	160	152	194	180	207	188
Chloride (Cl)	11	10	18	19	16	22
Free & Saline Ammonia (N)	0.03	0.04	0.02	0.04	0.07	0.18
Albuminoid Ammonia (N)	0.06	0.09	0.11	0.12	0.15	0.21
Oxygen absorbed	0.88	1.1	1.0	1.3	2.1	3.3
Nitrites	0	0	0	0	0	tr
Turbidity (units)	13	20	15	22	120	350
pH	8.4	8.2	8.5	8.4	8.7	8.3

Note— (1) All values except temperature, turbidity and pH are expressed in mg/l.
(2) BR=Before rains; AR=After rains; tr=traces.

TABLE III—BACTERIOLOGICAL ANALYSIS OF RAW AND FILTERED DISINFECTED WATER SAMPLES

Nature of tests	Asifnagar Filters				MRG Filters				Manjeera water works			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Total colonies per ml on agar at 37°C	36	28	52	1	22	17	26	0	64	52	20	1
MPN of coliform bacteria per 100 ml	348	245	542	0	348	278	240	0	1609	918	175	0
MPN of E. coli per 100 ml.	17	12	17	—	10	7	5	—	54	24	5	—
Tests for *NAG V. cholera*	(—)	(—)	(—)	—	(—)	(—)	(—)	—	(+)	(+)	(—)	—

(1) Raw Water; (2) Sedimented Tank, (3) Filtered Water, and (4) Disinfected water from Sump. B.

under construction along with some filter beds to take the overload.

On 13-7-1972, almost all the samples collected from different selected points in the distribution system were found to be bacteriologically unwholesome. No residual chlorine was found in the water at any of the taps examined. *NAG V. Cholera* was isolated from some of the tap waters. As all the samples of treated water from treatment works were found to be hygienically good, thorough sanitary survey was carried out to determine the condition of the distribution system. Numerous pipe lines were found leaking out jets of water while passing through open drains. There was collection of sewage and sullage water into the drains from the adjoining private houses. Among several leakages thus found the following were detected in the main pipe lines. (i) Twelve in. main pipe line from Charminar Cigarette Factory to Vidyanagar X Roads; (ii) Main pipe line at New Nallakunta Road to Central Excise employees colony; (iii) Two in. main pipe line leakages at Tilaknagar Road leading to Engineering College; (iv) Leakage at sluice valve at Kavadiguda Public tap; and (v) Leakage in main pipe line passing along open drain inside Narayanaguda Reservoir.

NAG Cholera vibrios were isoloted from good number of samples of drain water, stagnant water and sewage adjoining the above pipe lines.

Rectification of defects was achieved by prompt intimation of laboratory results and survey data to engineering personnel incharge of water supply. During inspection of the water works it was found from records that there was a break-down of the Chloronome plant on 12th and 13th of July at Asafnagar Treatment Works. Disinfection of water was therefore done manually with bleaching powder solution, till 15-7-1972 when the automatic chlorination plant was got repaired. As residual chlorine was absent at some of the places even after increasing chlorine dosage at the Water Works, booster chlorination of water was resorted to at different service reservoirs.

Out of a total of 241 samples tested on different dates during the special study as many as 64 were found unwholesome. Out of 75 samples of water tested for *NAG V. Cholera*, 16 proved to be positive. Most of the well water samples and all the 11 waste-water examples, examined, were found to contain *NAG V. Cholera*. The results of investigations are recorded in Table IV.

It could be seen from the results that there was a gradual improvement in the water quality from 25th July 1972 onwards. All the samples examined from 3rd week of August were found to possess good hygienic quality. However various waste water samples collected from drains during different periods were found to be grossly polluted. *Cholera Vibrios* were isolated from several of them.

(b) *Twin Cities—Unprotected Water*

During sanitary surveys, a number of unprotected wells were found to be in use as drinking water sources in the outskirts of the twin cities. Samples of water collected from Ameerpet, Amberpet and Chandrayangutta were found to be grossly polluted by excremental matter. *NAG V. Cholera* was isolated in the laboratory from samples collected from these unprotected wells. High incidence of gastroentritis was reported from these and adjoining localities (Wards 17 & 18) for a long time. It might be that these unprotected sources acted as unnoticed focii for dissemination of infection to other parts of the city for a long time. Cases of gastroentritis treated in Fever Hospital during July, August and September 1972 are given in Table V. Due to widespread nature of prevalence it may be presumed that several hundreds of cases might have occured and treated by local practitioners and quacks, and only a small number were admitted to Fever Hospital. It would be seen from the data that there was steep fall in the number of cases treated from the middle of August, 1972. The number of cases admitted in the

TABLE IV—BACTERIOLOGICAL EXAMINATION OF DRINKING WATER SAMPLES IN HYDERABAD AND SECUNDERABAD

Period	Nature of samples.	Number of Samples					
		Examined.	Wholesome	Unwholesome.	MPN >1800	Examined for *V. cholera*	(+) for *V. cholera NAG*
12-7-1972 to 14-7-1972	(i) Tap waters	18	0	18	14	15	3
	(ii) Wastewaters from drains etc.	3	0	3	3	3	3
15-7-1972 to 21-7-1972	(i) Tap waters	20	10	10	4	5	1
	(ii) Waste waters	2	0	2	2	2	1
22-7-1972 to 31-7-1972	Tap waters	32	30	2	0	5	0
1-8-1972 to 7-8-1972	Tap waters	24	20	4	0	8	0
8-8-1972 to 14-8-1972	Tap waters	20	16	4	0	7	0
15-8-1972 to 21-8-1972	(i) Tap waters	26	24	2	0	6	0
	(ii) Well waters	6	0	6	6	6	4
22-8-1972 to 31-8-1972	(i) Tap waters	36	31	5	0	4	0
	(ii) Waste waters	6	0	6	5	6	3
1-9-1972 to 7-9-1972	Tap waters	28	27	1	0	2	0
8-9-1972 to 14-9-1972	(i) Tap waters	16	16	0	0	2	0
	(ii) Well waters	4	3	1	1	4	1
	Total	241	177	64	35	75	16

TABLE V—STATISTICAL DATA OF GASTROENTRITIS CASES TREATED IN I.D. HOSPITAL HYDERABAD

Period	Number of cases from			
	Hyderabad		Secunderabad	
	Total	Proved as cholera	Total	Proved as cholera
1-7-1972 to 15-8-1972	443	22	49	5
16-8-1972 to 31-8-1972	164	4	23	3
1-9-1972 to 16-9-1972	32	1	3	0

1st week of September was very low. The only positive case for cholera was from Chandrayangutta and the patient used water from contaminated well.

(c) *Examination of Unprotected Water Supplies from District Places*

A total of 226 samples collected from various selected mofussil places in Hyderabad and Nizamabad districts were examined to determine the bacteriological characteristics. The results are reported in Table VI. As many as 180 samples were unwholesome and 87 of them had MPN of coliforms exceeding 1800. As many as 40 strains of *V. Cholera (NAG)* were isolated. It could be seen that all the water sources were grossly polluted by excremental matter.

TABLE VI—BACTERIOLOGICAL EXAMINATION OF SAMPLES FROM DISTRICT PLACES

			Number of samples				
Sl. No.	Place	District	Examined.	Unwholesome	MPN coliforms < 1800	MPN coliforms > 1800	(+) of *V. cholera NAG*
1.	Chintapatla	Hyderabad	40	40	5	35	20
2.	Ibrahimpatnam	,,	18	16	8	8	2
3.	Uppal	,,	12	8	6	2	0
4.	Vikarabad	,,	16	16	12	4	1
5.	Shankarpalli	,,	12	10	10	0	0
6.	Alwal	,,	6	4	4	0	0
7.	Rajenderanagar	,,	12	8	2	6	4
8.	Bodhan	Nizamabad	24	12	6	6	1
9.	Nizamabad	,,	24	14	10	4	3
10.	Yellareddy	,,	14	14	10	4	0
11.	Kamareddy	,,	14	4	4	0	0
12.	Binola village	,,	4	4	0	4	2
13.	Nehrunagar	,,	4	4	2	2	2
14.	Takklapalli	,,	6	6	4	2	0
14.	Pulkal Village	,,	4	4	2	2	1
16.	Digloor	,,	8	8	2	6	3
17.	Dongli	,,	8	8	6	2	1
	Total		226	180	193	87	40

Sanitary surveys of water sources and epidemiological investigations revealed the following facts :

1. All the wells examined have no platforms to drain the spillage waters away from the wells. Most of them are shallow and have no parapet walls. There were gaps in the brick work of several wells.
2. People bathe, wash the clothes and clean the utensils by the side of wells. There were heeps of rubbish, cattle sheds, manure heeps and latrines in the near vicinity of wells.
3. People are often ignorant of causes of diseases and the mode of their transmission.
4. In some villages the normal water sources from small rivers dried up due to drought conditions. People were seen drawing water from chelmas (small ponds dug in the sand of the dry river bed). The age long habit of open field defaecation must be a source of sustenance for the endemicity of disease in these places.
5. It is inferred from the observations that the washerman community was the first to be affected by the epidemic in several villages.
6. The disease was first reported in March, 1972 among labourers in a village situated on the border of Andhra Pradesh and Mysore States, and later spread to several adjoining villages. It is interesting to note that the disease was prevalent till September, 1972 among labourers migrated from Nizamabad District to Rajendernagar which is 10 miles away from Hyderabad.
7. Personal interrogation of medical officers revealed that there were no attacks of cholera among persons innoculated against cholera with vaccine manufactured in I.P.M. (quadriple Vaccine with the two Eltor and two classical strains added). This is yet to be supported by statistical data.
8. Effective control of the incidence of disease could be achieved only by regular and systematic chlorination of well waters by health staff, with concurrent

sanitary survey to detect the breakdowns in the distribution system.

Discussion

Although pollution of water is an age old problem, it has assumed new dimensions in recent times due to rapid rise in population, urbanisation and industrialization. In various developing countries the provision of sewage treatment plants lag behind the provision of sewerage systems. In India, only about 13 percent of rural population and 75 percent of urban population are having protected water supply whereas only about 20 percent of urban population is provided with sewerage system. Efficient sewage treatment plants are very few. The untreated or partly treated sewage, industrial wastes and drain waters from agricultural lands are indiscriminately discharged into the rivers and streams (5). The pollution of water is aggravated by peoples age long unhygienic habits of open-field-defaecation on the banks of rivers and insanitary conditions of ground water resources. The problem is further complicated in arid and semi-arid zones by the scarcity and seasonal distribution of water (6).

The results of unprotected well waters in the outskirts of the twin cities (Table IV) show that they are grossly polluted by sewage or excremental matter. Carriers of disease must have been constantly polluting these sources and the latter might be acting as focii for further dissemination of germs.

It could be inferred from the results of the twin cities protected water supply (Table II) that sewage or contaminated sullage water must have been sucked into the pipelines through the leaks during development of negative pressures caused by intermittent supply. The leaks might have developed by vibrations of the traffic or giving way of the surrounding soil or through natural stresses and strains (Fig. 1) it is evident that health hazards are not confined to sources and treatment plants alone. Carelessness and negligence in operation can convert well constructed and initially safe water supply into a lethal weapon capable of dissemination of pathogens widely and rapidly. Continuous efforts and vigilance are, therefore, essential to run the water supply system efficiently (7).

It will be seen from the results of water resources in district places (Table VI) that *cholera vibrios* could be isolated wherever heavy pollution of water occured (MPN of coliforms exceeding 1800). The survival of Vibrios may also be dependent on other factors such as temperature, pH, organic content, dissolved minerals etc.

Bhattacharji and Bose (8) have reported based on field and Laboratory observations that the transmutations of *V. cholera* is possibly responsible for the maintenance of cholera endemicity in nature. The process of transmutation of *NAG Vibrios*—in which form they are present in nature and isolated during epidemics— into agglutinable form in the patients is not clearly understood so far (9). But it can definitely be inferred that disturbances of ecological balance must be responsible for transmission and endemicity of the disease. Prompt and continous efforts should be made to mitigate the hazards of ecological crisis to achieve environmental harmony. The present investigations indicate that regular surveillance of water pollution, effective sanitary control of water resources, continous water treatment, disinfection, supervision and monitoring the quality at different stages of treatment and distribution, are effective measures in this direction.

Summary and Conclusions

Cholera broke out in epidemic form in July, 1972 in several places in Andhra Pradesh. Systematic laboratory and detailed epidemiological investigations were conducted in the twin cities of Hyderabad and Secunderabad and some mofussil places to control the outbreak.

In the twin cities, 64 samples out of a total of 241 tested, were found to be unwholesome. Sixteen strains of *V. Cholera* were isolated from tap waters, well waters, sullage water and sewage. During sanitary survey several leaks were found in the protected water distribution system. Well waters in the outskirts of the twin cities were observed to be grossly polluted. Epidemiological investigations revealed that these well waters must have been acting as focii for dissemination of the disease. Very high MPN of coliforms was recorded for all the well waters examined in mofussil places. Forty strains of *V. Cholera* were isolated from these sources.

Sanitary surveys and epidemiological findings revealed that the endemicity of the infection was due to: (a) insanitary conditions of the wells; (b) unhygienic habits of the people; and (c) lack of proper health education.

Severe drought conditions increased the severity of incidence and spread of the infection. Migration of labour from place resulted in transmission of the disease. Systematic and continuous chlorination of the water supplies on the basis of laboratory reports paved the way for early control of the epidemics.

The investigations revealed that regular surveillance of water pollution, continuous disinfection of waters and monitoring of the quality of treated waters were important tools for preventing and controlling the waterborne disease.

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DISCUSSION

Shri R. C. Dixit: Chlorine is estimated by orthotolidine because it oxidises orthotolidine to holoquinone (yellow colour) under specific conditions. Not only chlorine but also nitrites and oxidized forms of manganese and ferrous and many other oxidising agents oxidise orthotolidine to produce holoquinone (yellow colour). Due to this, false indication of chlorine residuals is obtained. Samples of unchlorinated water should be tested separately to measure the extent of the interferences and the corrections must be made. Further, OTA method should be adopted. Chlorine demand of the water should also be estimated.

Shri N. V. Ramamohana Rao: We have always found that we can definitely depend on the values of free residual chlorine to assess the satisfaction of chlorine demands of water, in contrast to the combined residual chlorine, which many a times gives false indication. For estimation of free residual chlorine, flash method can also be used provided it is done in the dark and values are instantaneously read.

Dr. C. R. Ramachandran (Poona): The belief that free residual chlorine is an index of bacteriological safety especially under field conditions, is debatable in the light of our study in Poona. The result of our study is under publication in the Indian Journal of Environmental Health.

Shri N. V. Ramamohana Rao: It is necessary to depend on the free residual chlorine under field conditions. My observations for the last 15 years definitely indicate that free residual chlorine is a dependable index of efficacy of chlorination. In this connection, it should be noted that the value to be maintained depends on pH of water.

Dr. (Smt.) S. M. Vacha: Is the author aware that by membrane filter technique as little as 100 ml water is enough to isolate *V. cholera.* This has been done in P.H. Laboratories and several times during small outbreaks of cholera, well water samples from the region have shown the presence of *V. cholera.* This was so even after the well was chlorinated previously. In a small outbreak at Gulegaon village, 11 miles from Poona on Indrani river, the water from the river was found to contain Agglutinable cholera.

As for the statement made that Maharashtra State is responsible for spreading cholera into Andhra State is baseless from the table shown in the slide that for the last three years ElT and/or Biotype Ogawa with Phage 1, 2, etc. have been identified. Perhaps the speaker is not aware that in the whole of India Eltor cholera has been prevailing since the last 8 years, except in W. Bengal and some adjoining States last year where cholera classical came up.

The identification of *V. cholera.* from recently chlorinated well water as preventive control measure for cholera epedemic needs a thorough reorientation. One is lulled into a false sense of security that once sterilization of well water with bleaching powder is done (a single dose), the well will remain safe for drinking purpose for the next few days. The chlorination needs to be a continuous process or the dose has to be administered at least once a day. Also, this entirely depends on the draw of water from the well. The small amount of residual chlorine, 0.1 to 0.2 mg/l, is not enough for taking care of fresh pollution load from the draw of water, as well as from other sources such as rope and bucket, etc.

Shri N. V. Ramamohana Rao: We do know that membrane filter technique is a valuable method for concentrating and isolating the organisms. In our present studies, we could isolate *Vibrio cholera* from 180 ml of water by special technique for concentrating the organisms by serial innoculations as mentioned in the paper.

During epidemiological surveys, we observed that the incidence of cholera during the present epidemic occurred originally in a village on the border of Andhra Pradesh and Maharashtra. Enquiries revealed that incidence of cholera prior to that date was found in some villages of Maharashtra situated on the border area between the two States. The *Cholera vibrios* isolated in our Institute for the last 4 years are also of Eltor biotype *Ogawa* and not classical types. In addition to phages 1 and 2 we have isolated phage 4 also. We have not made any conclusions in the absence of phage typing data collected in the Maharashtra State. We are all aware that bacteria know no boundaries and spread of cholera is possible from place to place. From the epidemiological and sanitary data it could be inferred that severe drought conditions and increasing rate of migration of labour might have contributed to the rapid spread of the disease.

In order to ensure effective disinfection of water it is essential to maintain continuous chlorination to keep adequate levels of residual chlorine. The chlorine demand of water should be systematically determined as it is influenced by several factors such as pH, organic matter, ammoniacal nitrogen, temperature, etc. As already mentioned, we must rely on free residual chlorine and not combined residual chlorine. It is essential to completely remove the turbidity as the colloidal particle can enmesh the bacteria and prevent chlorine acting on them.

Shri N. W. Mirchandani: During the discussions, it has been brought out that chlorination was not effective even though adequate free residual chlorine was observed in the water samples. It may be mentioned that adequate contact time must be available for the free residual chlorine to act effectively. Whether this aspect was looked into?

Shri N. V. Ramamohana Rao: In regard to doubts expressed by Dr. (Smt.) Vachha regarding unhygienic quality of recently chlorinated waters in spite of presence of free residual chlorine, I agree with the suggestion that adequacy of contact time should also be checked.

Dr. K. L. Saxena: It has been shown in Table II that albuminoid nitrogen is 9.15 mg/l and free ammonia is 0.07 mg/l. Thus total nitrogen is 9.22, chloride 16 mg/l, and oxygen observed 2.7 mg/l. I would request the authors to explain the response for high nitrogen and low chloride and oxygen absorbed values.

Shri N. V. Ramamohana Rao: The value for albuminoid ammonia recorded was 0.15 mg/l and not 9.15 mg/l. The latter is a typhographical mistake. The increase in albuminoid nitrogen, ammonical nitrogen and oxygen consumed values indicate that the water was polluted both by excremental and vegetative organic matter.

Dr. T. J. Boman: When no vibrios could be isolated, what was the number of cases of gastro entritis?

Shri N. V. Ramamohana Rao: The cases of gastro entritis not pertaining to cholera were not recorded after the control of the epidemic. It was observed that there was rapid decrease in the cases treated consequent on different measures taken to control the epidemic of cholera.

Dr. T. R. Bhaskaran: More systematic work is necessary in support of the observation made in regard to effect of chlorination on destruction of germs before this observation is put to actual practice.

Shri N. V. Ramamohana Rao: I agree with the suggestion that the effect of chlorine on different germs should be systematically investigated before the observation is used in actual practice.

Shri S. Mukherjee: It is stated that at one instance the MPN increased after filtration of water due to filtration unit not acting properly. I would like to point out that MPN is a statistical measure and we, therefore, cannot arrive at a final conclusion from a single observaion.

Shri N. V. Ramamohana Rao: After filtration both the plate count and the MPN value of coliforms increased which might have been due to "breakthrough" of filters. Both the data as well as sanitary results were taken into consideration for interpreting the findings.

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Preliminary Investigation on the Use of Coal for Removing Viruses from Water

P. P. OZA,* N. SRIRAMULU* and MALAY CHAUDHURI*

The objective of the research reported in this paper was to investigate the use of coal as sorbent for removing viruses from water. Removal of viruses from water by sorption on coal was studied in the laboratory using a bacterial virus (bacteriophage T4 against *E. coli*) as a model and high-grade Neyveli bituminous coal. A method of sampling for rapid separation of unadsorbed viruses from the adsorbent was standardised. This consisted of filtering the sample containing coal and viruses through a Whatman filter paper soaked in beef extract. Preliminary experiments indicated that the Neyveli coal was potentially useful as a sorbent for removing the model virus from water. Adsorption of viruses was maximum at pH 7.1, and it did not inactivate the virus particles.

Introduction

Environmental engineers are becoming increasingly concerned with the occurrence and transmission of viruses in the water environment. Presence of viruses of human and non-human origin in raw water supplies and transmission of viruses by the water route have been recognised (1-3). Drinking water has been identified as the mode of transmission in 50 known epidemics of infectious hepatitis (4). The Delhi epidemic of 1955-1956 is the most prominent among these (5). In a review of experimental data, Plotkin and Katz (6) concluded that one cell culture infective dose is sufficient to infect a human being. This indicates that if viruses are isolated from water that is consumed by man, there is sufficient virus in that water to infect a proportion of those who consume that water. These viruses must, therefore, be removed or destroyed if the water is to be entirely safe for public consumption. All common water or wastewater treatment processes appear to remove or destroy viruses to some extent. However, it is recognised that there is a need to improve the virus removal efficiencies of these processes as well as to investigate the potential of new methods or materials with regard to the removal of viruses from water. This becomes more significant in terms of water reuse.

Active carbon is commonly used as an adsorbent for removing organic contaminants from water. However, laboratory and field studies indicated that active carbon was not very efficient in removing viruses from water (7-9). Viruses are probably excluded from the micropores of active carbon because of their size (7). The micropores are fissures of approximately 10 to 30 A° diam (10) whereas the average particle size of picornaviruses (enteroviruses of man and other animals) is 200 to 400 A° (11).

Recently several investigations on the use of coal for removing organic contaminants from domestic and industrial wastewaters (12-15), and sorption of selected pesticides and phosphorous containing compounds (16)

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* Deptt. of Civil Engg., Indian Institute of Technology, Kanpur-16.

have been conducted with various degrees of success. Use of coals has advantages over use of other adsorbents because of their availability, lower cost and recovery of fuel value after exhaustion. Due to a lack of good quality anthracite supply in India, bituminous coals have also been evaluated as substitute media for anthracite in two-layer filtration and a full scale plant is already in operation in Jamnagar (17). Consequently, it seems quite appropriate that the potential of bituminous coals as sorbents for removing viruses from water should be evaluated.

Materials and Methods

(i) Viruses and Preparation

One of the main criteria in selecting a virus for this study was feasibility of culturing and enumeration. Assay techniques for bacterial viruses are better developed than for animal viruses. Bacterio-phage assays require 12 to 24 hr compared with 5 to 10 days for animal viruses and culture procedures are simpler for bacterial hosts. Bacterial and animal viruses have many similar physical, chemical and biological properties, i.e., size, net electric charge, protein coating, etc. (18). Thus, it may be assumed that their differences in behaviour when subjected to adsorption may not be much greater than the differences in these properties among animal viruses alone. Furthermore, more is known about the composition and properties of bacterial viruses than is known about animal viruses. This allows, for the present, for a more detailed examination of their behaviour in adsorption.

Bacteriophage T4 against *Escherichia coli* was selected as the model virus for this study because of its stability in agitated systems and its greater ease of culturing and enumeration (7). Properties of bacteriophage T4 are summarised in Table I (19-21). Stock cultures of bacteriophage T4 and its host *Escherichia coli* BB were obtained from the Department of Microbiology, University of Illinois, Urbana, Illinois. Purified stock suspensions in phage buffer were prepared according to the procedure described by Drake (22).

TABLE I—PROPERTIES OF BACTERIOPHAGE T4

Size (mμ)	6 x 95 (head) 20 x 95 (tail)
Molecular weight (g)	2.0 x 10^8
pH stability range	5.0 — 9.0
Sedimentation constant (S_{20}, w)	700 — 1000
Nucleic acid	DNA

(ii) Biological Media

L broth: tryptone 1.0 percent, yeast extract 0.5 percent, sodium chloride 1.0 percent and glucose 0.1 percent; adjusted to pH 7.0 with 1 N sodium hydroxide **T. Agar:** tryptone 1.0 percent, agar 1.3 percent and sodium chloride 0.5 percent. Soft agar overlay consisted of L broth with 0.65 percent agar. Phage buffer was 0.01 M tris (pH 7.4), 0.005 M magnesium sulphate and 0.1 M sodium chloride.

(iii) Glassware

All glassware used in this study were cleaned by soaking overnight in 0.3 percent B-300 Teepol (manufactured by Surfactants Pvt. Ltd. for National Organic Chemical Industries, Bombay) followed by rinsing with tap water and redistilled water as suggested by Rao (23). Sterilisation was accomplished in a hot air oven at 180°C for 2 hr or longer.

(iv) Coal

The coal used was bituminous coal from Neyveli supplied by the Central Public Health Engineering Research Institute, Nagpur. Physical and chemical properties of Indian bituminous coals were reported recently (24). The coal sample was ground and seived so as to get a size between 300 and 425 μ It was then washed several times with redistilled water to remove the fines and dried at 103°C for 24 hr and stored in a desiccator for use in adsorption experiments

(v) Virus Sampling and Enumeration

In spite of several washings of the coal samples with redistilled water, very fine particles of coal were always found floating on the top of the supernatant water in the reaction bottles. This could be due to further crushing of the coal particles in the agitated system used for the batch adsorption tests. However, these fine particles of coal would presumably have adsorbed some viruses and hence it was desirable to have them removed prior to the enumeration of unadsorbed viruses in the sample. Carlton *et al.* (13) were not able to quantitatively remove the coal fines from water by centrifuging at 15,000 rpm and reported that diatomaceous earth appeared to be effective as a filter for the coal fines. On the basis of microscopic observations and filtrate COD determinations they also concluded that No. 42 Whatman paper was not able to remove the coal fines quantitatively even though the Introduction of COD by the coal fines was quite low. However, Jhonson *et al.* (12) filtered their samples through No. 5 Whatman paper to remove the adsorbent (coal) particles. In view of these apparently contradictory observations it was decided to evaluate the suitability of No. 42 Whatman paper and 0.45 μ Millipore membrane in removing the coal fines.

It was evident from microscopic observations of the filtrate that both No. 42 Whatman paper and 0.45 μ Millipore membrane were quite satisfactory in removing the coal fines from water. However, it was desirable at this stage to make sure that No. 42 Whatman paper or 0.45 μ Millipore membrane was not removing any free virus by adsorption. Both untreated Whatman paper and Millipore membrane as well is the ones pretreated with various proteinaceous materials were evaluated (Table II) since Elford (Ver *et al.* (25)) recommended that membranes be treated with fluids containing proteinaceous materials to preclude virus adsorption. It is evident from Table II that No. 42 Whatman paper soaked in 3 percent beef extract for 4 hr followed by passing 5 ml redistilled water to remove the excess beef extract was quite satisfactory for virus sampling because it produced insignificant loss in virus titre when a sample containing free viruses was passed through it. In all subsequent experiments samples containing coal fines and unadsorbed viruses were filtered using a Millipore microfilter unit through No. 42 Whatman paper disc (25 mm diam) soaked in 3 percent beef extract for 4 hr and the filtrate enumerated for unadsorbed viruses.

TABLE II—VIRUS SAMPLING PROCEDURE

Filter paper/membrane and pretreatment	Virus conc. after filtration (PFU/ml)
Control*	760
No. 42 Whatman paper (untreated)	680
No. 42 Whatman paper pretreated by filtering 2.5 ml L broth	660
No. 42 Whatman paper soaked in 3 percent beef extract followed by passing 5 ml distilled water to remove excess beef extract	730
0.45 μ Millipore membrane (untreated)	Very low; detectable
0.45 μ Millipore membrane pretreated by filtering 2.5 ml L broth	60
0.45 μ Millipore membrane soaked in 3 percent beef extract followed by passing 5 ml distilled water to remove excess beef extract	290

* Not filtered

Adam's soft agar technique (18) was used for virus (bacteriophage T4) enumeration. Indicator bacteria were *Escherichia coli* BB Bacteriophage T4 concentrations are reported as plaque forming units per ml (PFU/ml). Triplicate plates were prepared from each sample to increase accuracy and the average PFU/ml are reported.

(vi) Procedure for Batch Adsorption Tests

Batch adsorption tests were carried out in non-flow agitated systems and at room temperature (25 to 30°C). Experiments were conducted at three different pH values: 5.7, 7.1 and 8.0 using 0.2 M phosphate buffer. In the procedure the reaction mixture (total volume 150 ml) was prepared with redistilled water in 500 ml screwcap plastic bottles by adding 15 ml of buffer solution of required pH value, 150 mg of coal and a suitable dilution of the T4 stock to give a final virus concentration of 1.2 to 1.4 x 10^4 PFU/ml. A control was also prepared to which no coal was added. Immediately after adding the virus, the control and the reaction bottles were mixed well and 2.5 ml samples were withdrawn for virus enumeration. The bottles were then placed in a reciprocating shaker and samples withdrawn at desired time intervals for enumerating the unadsorbed viruses.

After performing a batch adsorption test, contents of both the control and reaction bottles were filtered through a 25 mm diam No. 42 Whatman paper (pretreated with 3 percent beef extract) taking care to deposit all coal from the reaction bottle on the filter. Attempts were then made to elute the viruses adsorbed on coal with redistilled water and 3 percent beef extract to ascertain if adsorbed viruses could be desorbed.

Results and Discussion

Kinetics of adsorption of bacteriophage T4 on coal at pH values 5.7, 7.1 and 8.0 (coal conc. 1000 mg/l; ionic strength 0.06) are shown in Fig. 1. Attempts were made to keep virus concentrations constant in each system. It should be pointed out that virus concentrations reported here were determined by plaque count method and do not indicate the total number of actual particles in the sample. The latter can be estimated by an electron micrographic count. Although specific information is lacking about the precision of the plaque count method, it is of the order of 5 to 10 percent (26).

It is evident from Fig. 1 that adsorption of viruses on coal is quite rapid and the bulk of the adsorption takes place within the first 10 min or so. Slight increase in adsorption is observed with time. Equilibrium is established essentially after about 45 min.

Fig. 2 is a plot of viruses adsorbed per unit weight of coal versus square root of time. Straight line relationships are obtained for the three pH values studied. For systems in which intraparticle transport is the rate limiting step, a plot of the quantity of solute removed per unit weight of adsorbent versus square root of time should yield a linear relationship as suggested by Morris and Weber (King *et al.* (16)). Assuming a geometric mean size of coal particles used in this study as 350 μ overall size of a T4 particle

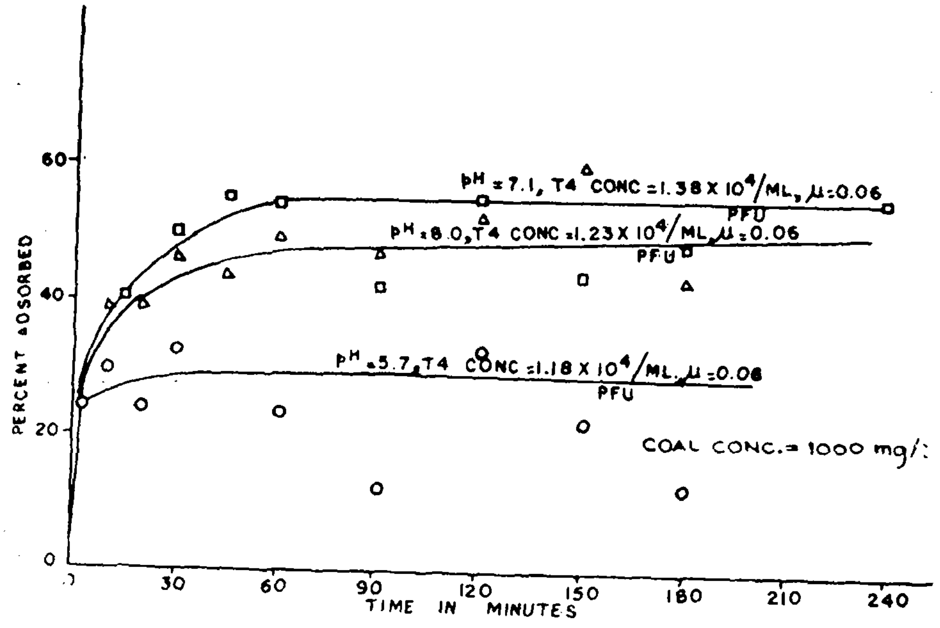

Fig. 1—Kinetics of Adsorption of Bacteriophage T4 on Bituminous Coal.

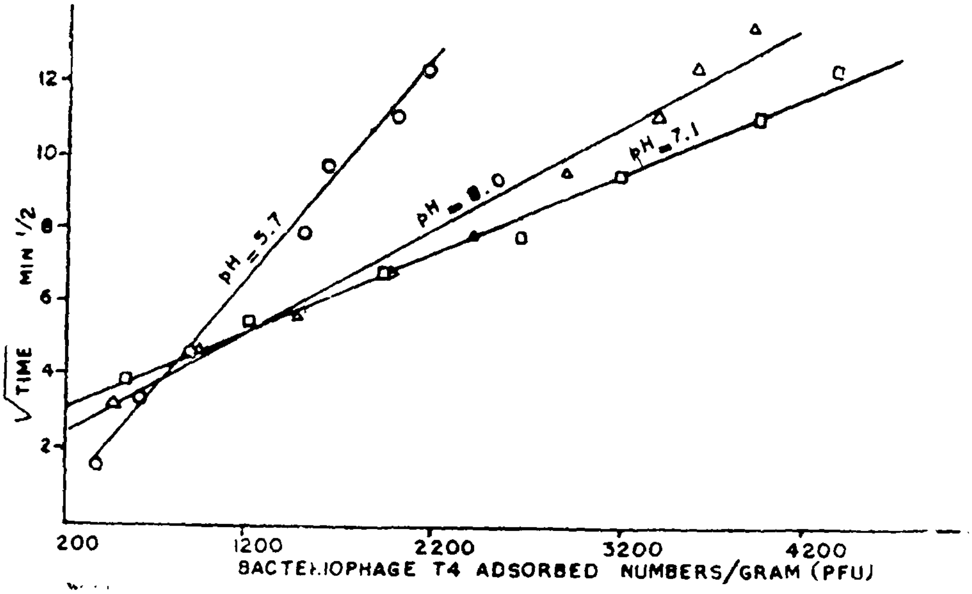

Fig. 2—Intraparticle Transport of Viruses.

with tail fibres extended as 360 mμ x 300 m μ when lying flat and plating efficiency of about 0.6 (20), Fig. 1 suggests that all external surfaces of coal particles were utilized for adsorption. Macropores in coal do not exceed 200 A° (14) and the micropores are in the order of about 25 A° with many of ultramicroscopic size (27). Presumably diffusion of the virus particles used in this study into the macropores or the micropores in coal is thus precluded. Linear plots in Fig. 2 for all pH values suggest that during the first 10 min or so, initial adsorption on external coal surfaces takes place. Conceivably, readjustment of the adsorbed viruses to reorient themselves towards the surfaces results later on with consequent availability of more surfaces for the remaining unadsorbed viruses. This reorientation of initially adsorbed viruses may be imagined analogous to diffusion into micropores (intraparticle transport in the case of adsorption of solute). The rate limiting step thus appears to be the reorientation of the adsorbed viruses on the external coal surfaces.

It would seem that the effect of pH on adsorption of viruses on coal is similar to that observed during adsorption of viruses to their host cells. The pH effect on adsorption can be explained assuming that amino groups on the virus interact with the carboxyl groups on coal (7). Maximum adsorption occurs at pH 7.1 because both the amino groups on virus and the carboxyl groups on coal are completely ionized. Adsorption is decreased at lower pH value (pH 5.7) because the carboxyl groups on coal are less completely ionized even though all the amino groups on virus are completely ionized. Adsorption decreases also at high pH value (pH 8.0) because amino groups on virus may be less completely ionized inspite of the complete ionization of the carboxyl groups on coal. Low ionization of the amino groups on virus at pH 8.0 may be attributed to the greater number of ε-ammonium groups of lysin of T4 coat protein compared to the number of terminal ammonium groups and guanidinum groups of arginine (28). Configuration of T4 tail fibres which depend on ionization of certain side groups is also important in adsorption (7). At pH values from 6.0 to 9.5, tail fibres of T-even phages are extended, whereas at pH 5.0 they adsorb to the tail sheath (29). Thus, it may be assumed that tail fibres will not be extended for adsorption on coal at pH values below

6.0 and above 9.5 (7). This explains lower adsorption observed at pH 5.7 compared to that at pH 8.0.

Attempts were also made to elute the viruses adsorbed on coal with redistilled water and 3 percent beef extract. Desorption in the range of 6 to 10 percent was observed. This would indicate that if coal is used for removing viruses from water, extreme care should be taken in disposing of the exhausted coal.

Conclusions

Based on this preliminary investigation reported herein on the adsorption potential of Neyveli bituminous coal for removing viruses from water using a bacterial virus as model, the following conclusions may be drawn :

1. External surfaces on coal appear to be important in adsorption of viruses. Reorientation of the adsorbed viruses with time seems to be in the rate limiting step.
2. Adsorption of viruses is maximum at pH 7.1.
3. Adsorption of virus particles on coal does not necessarily inactivate the virus particles. Desorption to the extent of 6 to 10 percent with redistilled water or proteinaceous materials suggests careful disposal of coal used in removing viruses from water.

Acknowledgement

The authors gratefully acknowledge Shri R. Paramasivam, Central Public Health Engineering Research Institute, Nagpur for kindly supply the coal samples used in this study.

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DISCUSSION

Dr. Malay Chaudhuri (Comments) : We fully admit the limitations involved in using a bacteriophage as a model virus. Considering the limited number of laboratories engaged in virus research and the tremendous amount of money and efforts required for developing and maintaining an animal virus laboratory, we think, our work is justified at least as a preliminary ground work. Furthermore, it is also to be appreciated that use of laboratory cultures of an animal virus, e.g., poliovirus as a model also has its limitations. We must be extremely careful in extrapolating any laboratory data obtained with a laboratory grown culture of a model virus. These viruses may behave in a completely different manner as compared to their natural counterpart. Poliovirus is no exception in this regard.

Shri S. B. Lakhe (Nagpur) : (i) Whether carboxyl group was present on bituminous coal? If there was no carboxyl group, how were viruses adsorbed on bituminous coal? (ii) Have you carried out studies on MS_2 (RNA Phage) which resembles enteric viruses? If so, what was the percentage of adsorption of viruses on (bituminous) coal? (iii) What was the percentage of adsorption of viruses on bituminous coal at pH 7.2, 7.4 and pH 7.8? (iv) Have you tried bituminous coal bed through which virus suspension could be passed and filtrate could be tested for virus present and further adsorbed viruses could be eluted using suitable solvent?

Shri P. P. Oza : (i) The nearer the coal approaches the composition of graphite, i.e., the more condensed the cyclic structure, the greater is the ratio of number of carboxylic groups to ring structures in the residual products of oxidation by aqueous oxidizing media (Ref. 1). Furthermore, the IR spectra of bituminous coal used in the present work has indicated the presence of such groups. (ii) Studies on adsorption of MS_2 (RNA Phage) on coal are at present in progress. Adsorption of MS_2 is about 20 to 30 times more as compared to that of T4. (iii) Adsorption tests were carried out at pH values 5.7, 7.1 and 8.0 and not at pH values of 7.2, 7.4 and 7.8. (iv) Data reported are for batch studies. Desorption studies have been carried out for adsorbed viruses. Desorption to the extent of 6% and 12.5% has been observed on elution with redistilled water and 3% beef extract respectively. In the present study, column tests were not carried out.

Dr. V. Chalapati Rao : Since the results obtained through bacteriophage model studies are intended to develop criteria for adsorption and elution of entero-viruses on coal, do you not think it necessary to incorporate a RNA Phage (MS) whose morphology is akin to enteroviruses?

Shri P. P. Oza : The comments made by Dr. Malay Chaudhuri partly reply the question. I fully agree that the use of either MS_2 or R17 or fr or $Q\beta$ strains is better because of similar morphological characteristics to those of enteroviruses, and the work with RNA phage is under progress in our laboratory.

CHAPTER-V

WATER TREATMENT

PROC. SYMP. ON ENVIRONMENTAL POLLUTION (1973)

Low Rate Water Filters

S. V. PATWARDHAN*

The paper compares the performance of filters using rates of flow lower than that of conventional rapid gravity filter with that of high rate filters. Theoretical consideraions discussed in the paper show that, for the same filtrate quality, the yield per unit volume of filter media decreases as the rate is increased. It is also shown that at higher rates of flow, the head loss for the same value of specific deposit (σ) is much higher for higher rates of flow. An illustrative example of a pipe grade filter with multiple raw water inlets and filtrate collector pipes has been described to show that such a system, although using a lower rate than conventional, could be compact, cheap and at the same time efficient compared to high rate filters.

Introduction

All over the world, efforts are being made to develop water filters with higher and higher rates of flow. The advantages claimed for such filters are: (i) less area requirements, resulting in economy in the capital cost; (ii) less backwash requirements per unit volume of water filtered, resulting in lesser capital cost and recurring cost on backwash arrangements; and (iii) capacity of existing units could be easily increased.

On the background of such claims, the topic "Low rate filters" looks repulsive and outdated. If some one claims that low rate water filters are likely to be more compact, efficient, simpler to operate, lesser in capital and maintenance costs, no one could possibly believe in it. This paper is an effort to prove the unbelievable. Herein, performance of filters using rates of flow lower than that of conventional rapid sand filters, have been compared with the performance of filters using rates of flow higher than that of conventional filters.

Yield per Unit Volume of Filter Media

Ives (1) has proposed the relationship,

$$\lambda_0 = \frac{k}{v.\ dm.\ \mu^2}$$

for predicting the filter coefficient of clean filter beds, where,

dm = size of media,
v = rate of flow,
μ = dynamic viscosity, and
k = constant.

λ_0 is defined by the relationship,

$$\lambda_0 = \frac{\text{Log Co/C}}{L}$$

where Co and C are suspension concentration of filter influent and effluent respectively, and L = depth of media.

This relationship indicates that if the rate of flow is increased, λ_0 will proportionately decrease and to obtain the same value of C, the depth of media has to be proportionately increased. In practice, depth requirements to obtain the same value of C at higher rates, are more than found by the above relationships. Fig. 1 gives curve between depth of media and rate of flow, for same value of C/Co, as obtained experimentally for a uniform sand column using 1.4 mm size sand. It will be seen from this curve that depths required for 6, 11 and 18 cu cm/sq cm/min rates, were 5, 15, and 35 cm respectively. In other words, the yield per

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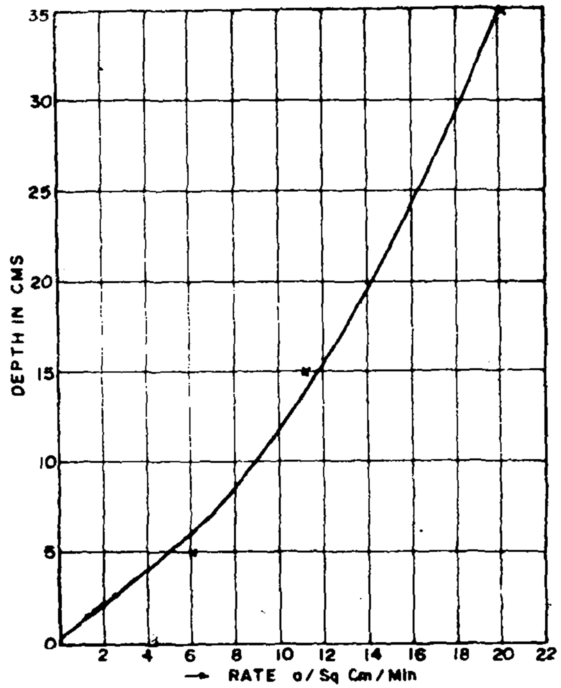
* Professor & Head, PHE Deptt., University of Roorkee, Roorkee (U.P.)

unit volume of the media decreased as the rate increased.



DEPTH REQUIREMENTS Vs RATE OF FLOW

(Constant $\frac{C}{Co}$)

Co = 40 mg/l dm = 1·4 mm

$\frac{C}{Co}$ = 0·24 Alum = 15 mg/l

Fig. 1

Energy Requirement per Unit Volume of Water Filtered

Initial head loss of a filter bed is proportional to v, the rate of flow. If higher depths are provided as indicated earlier, the initial head loss will be still higher for higher rates. As filter bed gets clogged, head loss increases. Table I gives the values of head loss and C/Co for certain values of σ (specific deposit by volume) at different rates of flow. As the depth of column was same in all the cases σ is an approximate measure of total volume of water filtered.

The values in Table I clearly show that, at higher rates of flow the head loss for the same value of σ is much higher for higher rates of flow. This means the energy requirements per unit volume of water filtered, will be much more in case of high rate filters as compared to low rate filters.

Length of Run and Filtrate Quality

Table I gives values of C/Co for different values of σ at different rates of flow. At a value of $\sigma = 0.01$, the values of C/Co for 5, 10, and 15 cu cm/sq cm/min rates of flow were 0.015, 0.14, 0.375. This clearly shows that for same depth, the filtrate quality deteriorates very rapidly, in case of high rates as compared to low rates of flow. To avoid this, either depth of the filter bed has to be considerably increased or the influent suspension concentration to be substantially brought down by improved pretreatment. If depth of bed is increased, head loss further increases. For deeper beds pressure requirements for backwash also increase. CPHERI

TABLE I—VALUES OF HEAD LOSS AND C/Co FOR DIFFERENT RATES OF FLOW

media—sand,
uniform size—2 mm,
flow direction—horizontal,
depth—50 cm,

Co—40 mg/l,
porosity—43%,
temp.—26°C,
alum—10 mg/l

Sl. No.	σ	Rate of flow (cu cm/sq cm/min)					
		5		10		15	
		H	C/Co	H	C/Co	H	C/Co
1	0.001	1.6	0.022	2.7	0.045	4.5	0.065
2	0.002	2.0	0.02	4.0	0.035	5.1	0.06
3	0.003	2.4	0.012	5.4	0.028	5.8	0.053
4	0.006	3.2	0.008	6.6	0.085	6.8	0.1
5	0.008	3.5	0.01	7.1	0.125	8.0	0.28
6	0.01	3.9	0.02	7.6	0.142	9.3	0.375

(2) report on the working of existing treatment unit reveals the poor working efficiency of the existing pretreatment units. Thus, the approach of improvising pretreatment may not bear desired fruits. The improvised pretreatment means more capital and maintenance costs. On the other hand, with lower rates, it may be possible to relax the quality requirements of the influent water, and in certain cases, pretreatment units for flocculation and sedimentation could be eliminated. This will reduce the capital cost, maintenance cost and space requirements, for pretreatment units. If it is possible to admit the coagulated water, directly the coagulant dose could be reduced considerably and considerable saving could be effected in recurring cost.

Space Requirements

Lower the rate, more will be the filtration area and if arrangements like conventional rapid sand filters are used, the space requirements will also be large. This will mean more filter units and increased capital and maintenance costs. Some saving of space may be achieved with low rate filters due to reduction in pretreatment requirements, but this saving is of very small magnitude. Major saving in space could be achieved if more raw water distribution and filtered water collection systems are provided, along the depth of media. Fig. 2 shows a pipe grade filter model (Patent under process) with four raw water distribution systems and two filtered water collection systems. Because of such an arrangement, the filter area is nearly four times the space occupied. Thus, if a rate of flow of 5 cu cm/sq cm/min is used then the effective yield will be 20 cu cm/sq cm/min. Thus, it will be seen that such a filter will need less than half the space required for the conventional rapid sand filter. By introducing more number of raw water distribution and collection water systems, the space requirements could be reduced to any desired extent. The distance between any two consecutive system of distribution of raw water and collection of raw water will depend upon the size of media and the rate of flow used. From the above discussions, it will be clear that such a low rate filter will have the following advantages as compared to high rate filter.

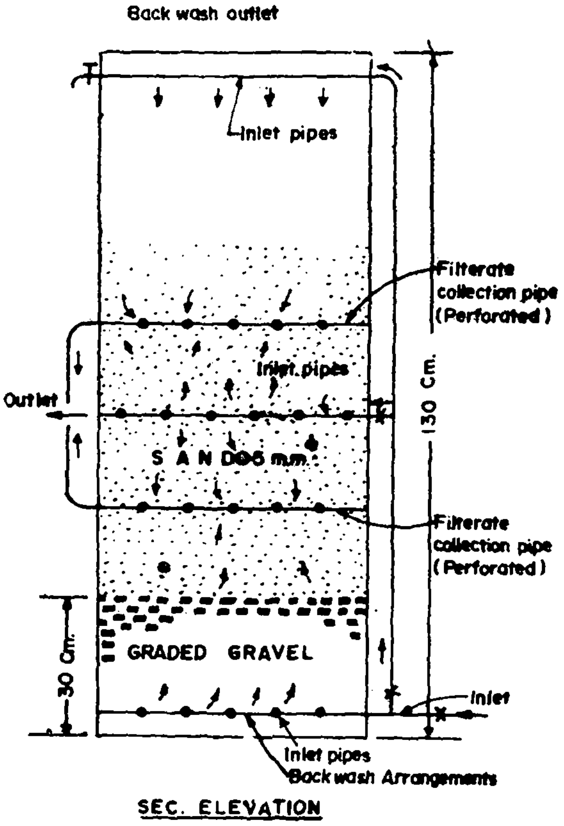


Fig. 2—Pipe Grade Low Rate Filter

1. Less space requirements.
2. Lesser head loss or longer runs.
3. Lesser quantity of filter media/unit vol of water filtered.
4. Better quality of effluent.
5. Less pretreatment and lesser coagulant dose.

Thus, a low rate filter will be more compact, will have lesser capital and maintenance costs, lesser head loss and better filtrate quality of filter effluent.

Illustrative Examples

Raw water with 20 mg/l turbidity is to be treated by filtration, without any pretreatment except coagulation. Two filters: (i) a pipe grade filter with a rate of flow 5 cu

TABLE II—COMPARATIVE RESULTS OF LOW RATE AND HIGH RATE FILTERS

Filter	Other details	Total height of filter tank (cm)	Initial Head loss (cm)	Initial Filtrate quality (mg/l)	Length of run (hr)	Filtrate quality at the end of run (mg/l)	Head loss (cm)
(1) Pipe grade low rate	$v=5$ cu cm/sq cm/min e.s.=0.5 mm u.c.=1.2 d=80 cm	130	8	0.02	36	0.3	60
(2) High rate	$v=20$ cu cm/sq cm/min e.s.=0.65 mm u.c.=1.2 d=120 cm	300	75	0.5	16	1	180

v =rate of flow; e.s.=effective size; u.c.=uniformity coefficient; d=depth of filter media.

cm/sq cm/min, and (ii) a high rate filter with 20 cu cm/sq cm/min are proposed. Important details of the filters are given in Table II. Slightly coarser sand has been proposed for high rate filter to avoid excessive head loss. From certain experiments carried out with similar filter columns, the expected performance of both the filters have been worked out and presented in Table II. The design of the two filters was based on the theortical approaches proposed by the author (3).

Both the filters will have same land requirements. But from Table II, it will be seen that low rate filter needs less media, lesser height and capacity for filter tanks, lesser head loss, gives better filter quality and has longer length of runs. In such filters, as the head loss is less, simple inlet level regulators could be used in place of costly and sophisticated rate controllers. It may also be possible to use locally available sand, even of 0.3 to 0.4 mm effective size, by making suitable changes in it's design. The low rate filters may need some what simpler backwash arrangements as it has to only serve the function of water distribution. Thus, it will be seen that the low rate filters are likely to be superior to high rate fitlers in all respects.

Conclusions

At low filter rates, the requirements of depth, and head loss are considerably reduced. The filtrate quality is superior as compared to the quality obtained with high rates. With multiple inlets and outlets at different levels the space requirements and media requirements are reduced. In most of the cases raw water could be admitted directly to the filter after coagulation. This makes such a filter more compact economical and simpler in operation than a high rate filter.

If any organization or firm wishes to use pipe grade filters or low rate filters, the Author will be glad to design such filters for them.

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DISCUSSION

Shri N. W. Mirchandani: The author has given the data regarding high rate filtration. He has stated that raw water having a turbidity of 40 units was given an alum dose of 10 mg/l and a filtration rate of 200 gal/sq ft/hr was adopted. One of the basic principles in high rate filtration is a first class pre-treatment. If this is not given as stated by the author, then the results are non-comparable. We have done some work on high rate filtration at Vaitarna pilot plants where we found that high rate filtration was more economical as the total production of water in a given period was more than the conventional rapid sand filter (even after taking into consideration the shorter filter run and the period during which filter is non-productive due to backwash operation). These were in conformity with Bailey's experiments on high rate filtration at Chicago filtration plant.

Prof. S. V. Patwardhan: In this paper, a typical case of low turbid water has been considered. For such water it will be more economical to treat them directly on the filters by eliminating the pretreatment. The performance of both the filters, high rate and the proposed low rate filter, have been compared under identical conditions. If suitable pretreatment is given both the filters will give better performance but the overall cost will be much higher. The analysis presented in the paper clearly indicates that proposed low rate filter will prove much more economical than high rate filter As compared to conventional rapid sand filter high rate filters may give economical production of water.

Shri M. L. Shah: The author has shown in one of the Tables that depth in high rate filter is 3 times the conventional filter and head loss in high rate filter is 2 times the conventional filter. I do not agree with this. There are plants in India where the high rate filters do operate satisfactorily with the same units given for the conventional filter. I think Bhilai has been one of the plants in India where high rate filters are used. I believe, we should have more data on the existing high rate conventional and slow sand filters in India.

Prof. S. V. Patwardhan: The depth of media required in the two filters and the head loss were computed by using available relationships. The values obtained tallied well with the laboratory observations. The paper does not state that high rate filters do not function satisfactorily. It only brings out the merits of proposed low rate filter in comparison with high rate filters. If field data is available it will be more helpful in such analysis.

Shri C. E. S. Rao (Bombay): How does the filter perform when the raw water turbidity exceeds 40 mg/l? What is the capacity of the plant?

Prof. S. V. Patwardhan: The 'pipe grid' filter discussed in the paper was designed to treat raw coagulated water with 40 mg/l turbidity. Such a filter could be designed to deal with waters upto 100 mg/l turbidity. With turbidities still higher, suitable pretreatment will be desirable. The filter described in the paper has been designed for a rate of flow of 5 cu cm/sq cm/min, but as it has four filtering surfaces the overall production will be 20 cu cm/sq cm/min of the area occupied, which is more than double the production of conventional rapid sand filter. If deeper tanks are used the capacity per unit area occupied can be much more.

Shri J. N. Kardile (Nagpur): There is difference in action in the filter beds of rapid sand and slow sand filters. There is biological action in slow sand bed while mechanical screening in rapid sand bed. What type of action is expected in the low rate filter as advocated by the author?

Prof. S. V. Patwardhan: Author does not fully agree with the statement that removal of impurities in rapid sand filter is due to mechanical straining only. It is mainly due to (i) electrokinetic effect, (ii) gravity settling, and (iii) mechanical straining. The contribution due to mechanical straining is not more predominent than the first two processes. In the proposed low rate filter contribution due to mechanical straining will be substantially increased. This will ensure improved filtrate quality with time. There will be no biological activity as filter will need backwash after 24 to 72 hr.

Shri V. Raman: Inlet pipes are kept in vertical layers at a spacing of 15 in or so. Actually 24 or 36 in depth of sand is not required in a filter. At a low rate same depth is divided into 2 or 4 layers thus giving an output of high rate filtration. As the thickness of layer is small good pretreatment of raw water is required for added protection.

Prof. S. V. Patwardhan: As the sand used is fine and as the rate of flow is low it is possible to treat raw coagulated turbid waters directly in such a filter. Pretreatment, if provided, will, of course, improve its performance.

Shri N. Sriramulu: (i) Is it not that the extra pipe cost involved obviate the advantage expected? (ii) Do you recommend your method, for conversion of the existing filters or for new units?

Prof. S. V. Patwardhan: (i) The extra piping will increase the cost. But the other advantages obtained will reduce the overall cost to a substantial extent. (ii) These filters are more suitable as new units and are not so much useful for conversion of existing units.

Shri I. C. Agarwal (Kanpur) : (i) How were the filter units cleaned? If backwashing was used in cleaning the units, it is felt that the constructional features along with the accessories required for effective and efficient backwash would complicate the design and the very idea of having simpler units of filtration for semi-urban and rural areas would be perhaps difficult to appreciate. (ii) Was the bacteriological quality of the filter effluent checked? In view of authors idea of providing a unit giving filter effluents of excellent bacteriological quality (as compared to filtrate from rapid sand filters), I feel, this is quite important. Since the rate of filtration is high compared to slow sand filters, it is felt that the MPN index of *E. coli* of these filter effluents would not be as low as that from slow sand filter.

Prof. S. V. Patwardhan : (i) The proposed filter unit need be backwashed. For semi-urban areas backwash with low turbidity raw waters will not complicate the construction features. For small units required for rural areas these filters could be designed where cleaning can be done manually. (ii) Bacteriological quality was checked. As expected it was better with low rate of flow. If fine sand is used major removal mechanism will be by enhanced mechanical straining and as such effluent quality will be as good as slow sand filters.

Shri K. Rudrappa : (i) What was the backwash water rate required? (ii) What type of pretreatment would be required? (iii) What was the influent and effluent quality (after filtration)? (iv) What was the ability to remove bacterial load?

Prof. S. V. Patwardhan : (i) Backwash rate depends upon the size of sand used. With 35 mm sand size, 12-14 cu cm/sq cm/min flow will be required to backwash the filter. (ii) For low turbid waters only 40% of optimum dose of alum will be needed. But for high turbid waters usual pretreatment by coagulation, flocculation and sedimentation will be needed. (iii) If influent water has a turbidity lower than 40 mg/l, the proposed filter at the stated rate of flow will yield an effluent with turbidity less than 0.5 mg/l. (iv) If fine sand is used and if rate of flow is kept low it can deal with higher bacterial load. The filter will work mainly on enhanced mechanical straining process and will give nearly same efficiency as that of slow sand filter. Due to low rate, filter efficiency will be higher, head loss will be less, and due to mechanical straining process, filtrate quality will improve with time. As inlet and outlet pipes are kept in layers, the entire depth of sand will be effectively used, filter area available will be much more and will make at possible to obtain higher yield per unit area of occupied space.

PROC. SYMP. ON ENVIRONMENTAL POLLUTION (1973)

Operating Slow Sand Filters With Alum Coagulated Water

I. C. AGARWAL* and G. D. AGRAWAL**

This paper presents the results of investigations on operation of slow sand filters with alum-coagulated water on field units, both prototype and pilot-scale. The reduction in length of run due to operation with alum-coagulated water did not seem to be appreciable. The clarification obtained as well as bacteriological quality of filtered water as indicated by coliform count was comparable to that from normal slow sand filter. The results of analysis of the top layer mat formed (which is comparable to schmutzdecke), primarily organic and algal content, are also reported.

The results of this study confirm that slow sand filters can be operated with alum-coagulated water without rapid head-loss build up and hence without appreciable reduction in the filter run.

Introduction

Pretreatment of water fed to slow sand filters in normal practice has been restricted to sedimentation and/or aeration. This has resulted in unsuitability of slow sand filters to treat raw waters of turbidity higher than about 20 jtu.@ This inflexibility in operation coupled with higher initial cost on civil works and requirements of large land areas as compared to rapid sand filters, has seriously limited the use of slow sand filters for treatment of urban water supplies. To assign a major role to slow sand filters in treatment of municipal water supplies in developing countries where their advantages of better effluent quality simplicity in construction and operation with little maintenance become all the more significant, it is desirable that the disadvantages associated with slow sand filters be eliminated or reduced.

In order that slow sand filters cope up with highly turbid raw waters, some pretreatment is essential to bring down the turbidity of filter influents to an acceptable level to avoid rapid clogging and consequent too frequent cleaning of the filter surface. In the background paper of World Health Organization (1), the pretreatment suggested for rural areas is plain sedimentation with detention period of a few days while the following four processes are recommended for urban and large water supplies: (i) Plain storage with sedimentation; (ii) Sedimentation with micro straining for algae removal; (iii) Rapid filtration or naturally filtered intakes; and (iv) Plain Sedimentation and rapid filtration.

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* Lecturer, M.N.R. Engineering College, Allahabad Presently Research Scholar, Department of Civil Engineering Indian Institute of Technology, Kanpur.

** Associate Professor and Head, Deptt. of Civil Engineering, Indian Institute of Technology, Kanpur-16 (U.P.)

@ Jackson turbidity units.

First pretreatment of storing water for long periods may be suitable in some areas, for example, impoundage of relatively clean flood water of the Thames river prior to slow sand filtration in London, but may not be possible in majority of the cases. Rapid filtration, either alone or with plain sedimentation may be costly and not preferred due to adoption of two types of filter, and consequent complexity and higher costs.

Another method of pretreatment is chemical coagulation which is universally adopted for rapid sand filtration. Chemical coagulation has not been employed in case of slow sand filters to any significant extent for many reasons to be discussed later. However, some water works including Kanpur Water Works have been operating their slow sand filters with alum coagulated and sedimented waters without any adverse effect on filter performance or other operational problems. The present study was conducted to demonstrate that slow sand filters can be successfully operated with alum coagulated water without any adverse effect. Investigations were also conducted to operate slow sand filters at much higher rates than conventional so that the other two disadvantages of large land requirements and consequent high cost of civil works can also be reduced to acceptable levels.

Experimental Filter Units

To avoid the generally inherent disadvantage associated with extrapolation of results obtained on the basis of laboratory-scale studies due to incompleteness of simulation of field conditions, it was decided to carry out the investigations at Kanpur Water Works employing both prototype and pilot-scale filter units. Kanpur Water Works, whose layout is given in Fig. 1, is presently handling about 216 mil litres per day nearly two thirds (144 mil litres) of which is supplied by River Ganga and the balance is met by Lower Ganges Canal. The turbidity of raw water from River Ganga varies between 20-3500 jtu while that of raw water from Lower Ganges Canal between 15-900 jtu. The raw water is settled, alum-coagulated, flocculated and sedimented prior to filtration. Both slow and rapid sand filters, which contribute almost equal amounts to the total quantity of water filtered, receive the alum coagulated and flocculated water. There are in all 36 slow sand filters, 20 of the size of 49 m x 8.5 m and 16 of the size of 30.5 m x 61 m. The prototype filters chosen for this study were the latter ones i.e. slow sand filters of 30.5 m x 61 m in size.

To investigate the phenomena of slow sand filtration in a detailed fashion, two pilot-scale filters of the size of 91.5 cm x 183 cm were constructed. The filters can be fed with either coagulated, flocculated and settled water or with raw Ganga Water, though the present study has been conducted using only the first type of water. The water is filtered through a sand depth of about 90 cm. The effective size of sand is 0.35 mm with a uniformity coefficient of 2.7. Below the sand bed lies about 25 cm of gravel which is underlain by bricks. The underdrainage system is formed by the open jointed bricks, the manifold being a U-shaped channel in the middle of the concrete floor. The rate of flow is adjusted by a valve and a water meter is installed for recording the flow. The long wall of the two filters has piezometric tappings and sampling ports at different depths to record the head loss and to collect filtered water at different depths down the filter bed. Plan layout of pilot-scale filter plant is sketched in Fig. 2.

Materials and Methods

The following analyses were performed on raw water and filtrate samples from different depths :

(i) *Total and soluble aluminium:* **Eriochrome Cyanine—R method (2) was employed.**

(ii) *Suspended solids or non-filterable residue* : This was determined by filtering a predetermined volume of water on a AA type millipore filter, pore size 0.45 μ, using a pyrex glass millipore filter assembly.

(iii) *Turbidity :* This was measured with a Hellige Turbidimeter employing 50

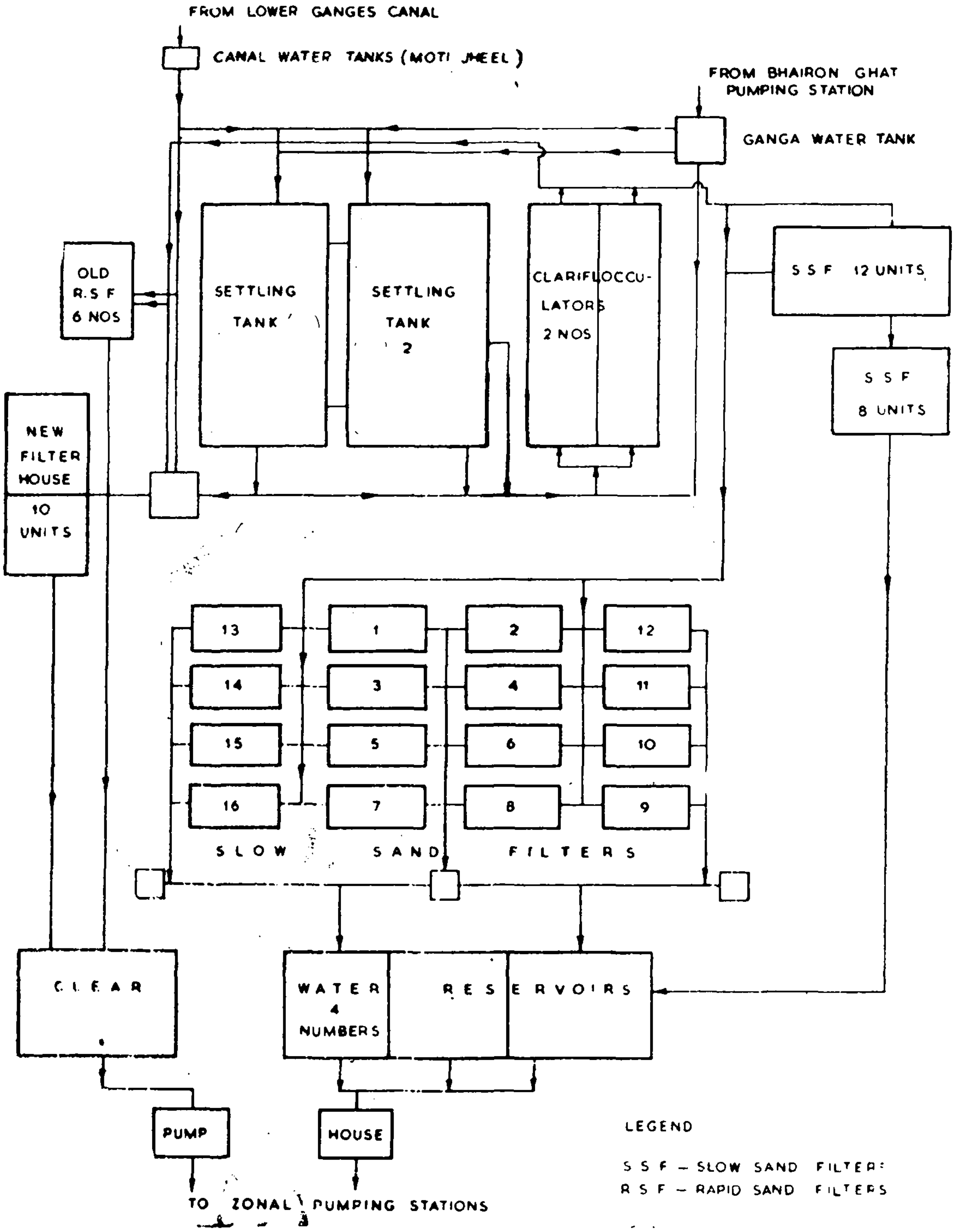

Fig. 1—Layout Plan of Kanpur Treatment Works.

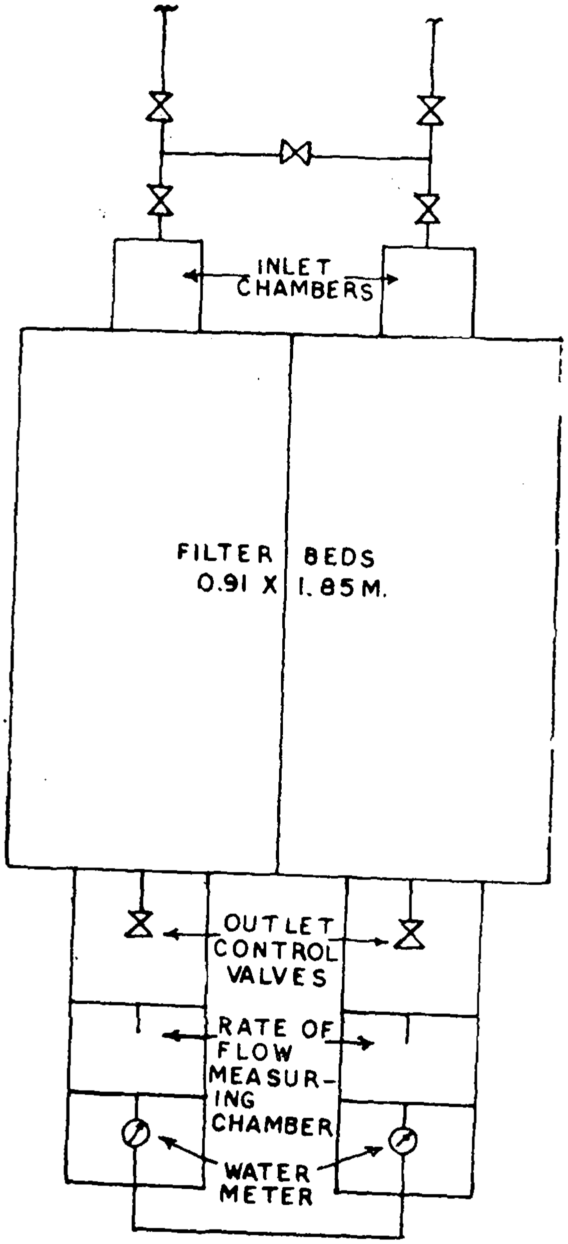

Fig. 2—Plan of Pilot Scale Filters.

mm and 20 mm tubes and various filters to cover the wide range of variation in turbidity values.

(iv) *Organic matter:* It was indirectly estimated as COD by the dichromate reflux method (3) with the modifications in the normalities of potassium dichromate and ferrous ammonium sulphate solutions as suggested by Medalia (4).

(v) *Algal content* : This was determined indirectly by chlorophyll extract method as suggested by Richards with Thompson but modified by Creitz and Richards employing AA millipore filter (5).

Organic matter in top layers of sand was determined by igniting sand at 550°C and the algal content estimated by chlrophyll extraction as per details in Standard Methods (3).

Results and Discussion

1. Alleged Dangers of Using Alum Coagulation as Pretreatment for Slow Sand Filters

As reported in literature (6), chemical coagulation should not be employed as pretreatment to influents for slow sand filters. Huisman (1) and Ives (7) have recently cautioned against the use of alum for coagulation of colloidal particles in slow sand filter influents. Ives, in his exhaustive and critical review on filtration, mentions the general agreement among various authors against coagulation as pretreatment for slow sand filters. According to Ives, this is because alum floc will rapidly seal the sand surface with a consequent rapid rise in head loss and occlude the schmutzdecke with deterioration in biological purification. Ives in his paper (8) points another danger that under certain circumstances, pH changes in the filter, together with low pH caused by alum dosing, could precipitate aluminium hydroxide in the lower layers of filters which would be undesirable for a slow sand filter from cleaning point of view.

The results of the present study which indicates that all the above three dangers may only be imaginary atleast in circumstances such as obtainable at Kanpur Water Works, are presented below.

(i) *Length of Filter Run and Head Loss Progression*

To observe whether alum coagulation resulted in rapid build-up of head loss due to sealing of sand surface, length of a filter run and head loss build up were determined on prototype filters for a period of more than one year. Table I presents the length of a

TABLE I—LENGTH OF FILTER RUN FOR VARIOUS FILTERS

S. No.	Run No.	Length of a Filter Run (days)						
		FILTER						
		1	2	3	4	5	6	7
1	I	58	60	36	24	46	60	45
2	II	46	39	20	34	32	29	36
3	III	45	23	38	46	26	26	29
4	IV	37	29	26	26	38	34	20
5	V	25	24	33	34	36	36	59
6	VI	48	61	37	31	19	27	74
7	VII	38	28	13	32	49	48	60
8	VIII	105	104	21	13	63	105	46
9	IX			25	29	65		
10	X			25	76			
11	XI			69	32			
Average		50.2	46	33	34.3	41.6	45.6	46.1

filter run for filters for a period of one year from September, 1971 to about September, 1972 depending on the termination of filter run. All these slow sand filters were operated with alum coagulated waters.

From the Table I it is seen that length of a filter run ranged between 13 and 105 days. The very low value of a filter run of the order of 15 days is primarily due to excessive algal growth on the sand surface during summer months. During summer months, both because of heavy concentration of algae in raw water and excessive growth on the sand surface, there is a thick mat of filamentous algae, primarily *spirogyra*, formed on the bed, causing rapid build up of head loss and resulting in a very short filter run. However, including even these greatly reduced filter run, it is found that the average run for various filters ranges between 33 to 50.2 with an overall average of 42.4 days. The rate of filtration for all these filters is 133 l/sq m/hr or 32 mil litres/ha/day. Fair *et al.* (6) report length of run varying in the range of 20-30-60 days for rate of filtration ranging between 9.3-37.2-93 million litres/ha/day, the middle values being the most common values. As is clear, the length of run using alum coagulation compares very favourably with the reported values for runs without alum coagulation. This establishes that alum coagulation as pretreatment to slow sand filter influents does not adversely affect the filter runs and no rapid build up of head loss occurs.

Fig. 3 presents the head loss progression for both prototype and pilot-scale filters. For prototype filter a length of run of 51 days was chosen to represent average head loss build up. Plotted alongside is the head loss progression for pilot-scale filters during the period of July. The gentle slope of both the curves reflect that head loss build up is gradual and not rapid. The much more gentle slope of curve for pilot-filters indicates a much longer filter run which is due to the run being operated during rainy season when

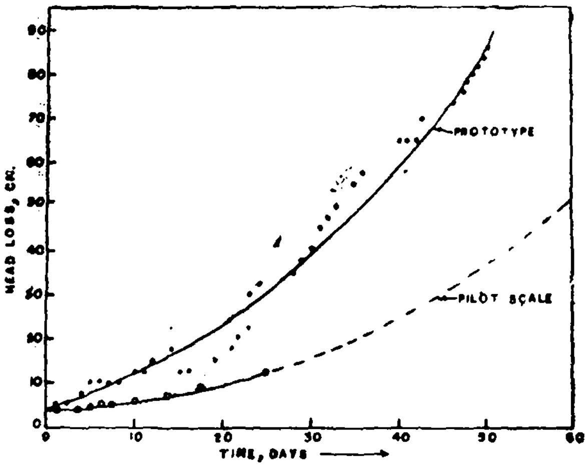

Fig. 3—Headloss Progression.

the length of run for prototype filters also increases to as high a value as 105 days (see Table I).

(ii) *Filtrate Quality*

The main parameter of filtrate quality is effluent turbidity. Bacteriological quality is also an important parameter but with post disinfection becoming an essential part of water treatment, very stringent quality requirements may not be desired. Table II presents the results of analyses performed on raw water, and influents and effluents of slow sand filters, both prototype and pilot scale. Though the turbidity of raw water varied between 25 to 3500 jtu, the filter effluents were always turbidity free and sparkling. The coliform density of filtered water from slow sand filter always being less than 9 per 100 ml is comparable to slow sand filter effluents employing no alum coagulation as pretreatment and much less than MPN of *E. Coli* in rapid filter effluents.

The low values of chlorine demand and COD of slow sand filter effluents indicate a higher degree of removal of organic matter in this type of filter. The algal content of filtrate from slow sand filters was always nil.

The top sand layers were analysed for organic matter and algal content. The typical value of organic matter in the layer of impurities deposited on top of the sand bed, generally referred to as schmutzdecke in the case of slow sand filters not using alum coagulation prior to filtration, was of the order of 1.25 kg/sq m of area. The algal content of this layer varied very much with season, raw water quality and length of filter run. A typical value, for rainy season when algal content of filter influents was of the order of 0.5 mg/l and for a length of run of about 45 days, was 3 g/sq m of surface area. The standard pour plate test conducted on top layer sand by suspending a known quantity of sand in sterile water showed a count of the order 5 x 10^6 colonies/g of sand. All these observations, together with the very sticky and slimy nature of coating on sand grains of the top layers very clearly indicate that no occlusion of schmutzdecke occurs as alleged in literature, though the nature of layer of impurities may be some what different as a result of alum coagulation.

(iii) *Danger of Precipitation of Aluminium Hydroxide in Lower Layers of Filter Beds*

To check whether aluminium precipitated in the lower layer of filter bed or not, raw water and filtrate from different depths of sand bed were analysed regularly for total and soluble aluminium. From these analyses, it was very clear that no soluble aluminium precipitated in the lower layers of sand. A typical variation of concentration of total and soluble aluminium is presented in Table III.

TABLE II—PERFORMANCE OF SLOW AND RAPID SAND FILTERS

Parameter of Fitrate quality	Raw water	Filter influent*	Effluent	
			Slow sand filter	Rapid sand filter
Turbidity, jtu	25-75	7-12	0	0
	75-200	7-12	0	0
	200-3500	10-50	0	0-0.5
MPN of E. Coli, per 100 ml.	2000 to > 11,000	21-750	0-9	20-150
Chlorine demand, mg/l	0.9-3.9	0.4-2.2	0.25-0.4	0.25-0.9
COD, mg/l	0.2-5.1	0.2-2.1	0-1.0	—
Algal content, mg/l	—	0.5-2.0	0	—

* After coagulation, flocculation and settling.

TABLE III—VARIATION OF ALUMINIUM CONCENTRATION ALONG DEPTH

Sl. No.	Depth from the top of bed (cm)	Total aluminium conc., (mg/l)	Soluble aluminium conc., (mg/l)	Estimated conc. of precipitated aluminium (mg/l)
1	Above sand bed	0.21	0.14	0.07
2	6	0.16	0.13	0.03
3	12	0.15	0.13	0.02
4	52	0.15	0.13	0.02
5	110	0.15	0.13	0.02

From the foregoing discussion, it is clearly established that the apprehensions due to using of alum coagulation as pretreatment prior to slow sand filtration as expressed by Ives and others are not true, at least in conditions as obtainable at Kanpur Water Works.

2. Steps to Reduce the Higher Land Requirements and Civil Works Costs of Slow Sand Filters

To reduce the land requirements and capital cost on civil works of slow sand filters, it would be essential to operate the filters at higher rates. Cost analysis by the authors (9) show that an optimal filtration rate would be around 600 l/sq m/hr which would result in reduction of land requirement to only one fourth of the present and about 30% reduction in overall water treatment costs. In fact, Kanpur Water Works has during the past two years operated some slow sand filters at rates 23% higher than normal (around 160 l/sq m/hr) with only 8% reduction in filter run without any adverse effect on filter performance and with considerable economic advantage as reported earlier by the authors (10). To study in detail the ramification of much higher rates of filtration, studies were conducted on pilot filters, described earlier, for rates of 216, 408 and 612 l/sq m/hr.

The criterion for terminating a filter run was either the attainment of a head loss of 90 cm or the completion of 25 days of operation, whichever occurred earlier. The effluent quality, as reflected by turbidity and coliform density, was satisfactory throughout each run.

3. Yield at Different Rates of Filtration

Table IV presents the summary of data regarding yield per day at different filtration rates. In calculating number of days lost in sand scrapping and recoupment, the average values as applicable to full size units (size, 30.5 m x 61 m in case of Kanpur Water Works) have been adopted. It is assumed that 2 days are lost in one sand-scrapping and about 2 months are spent on recoupment for full size units.

It may be observed that although the length of run became one-fourth of the original, a 360% increase in the rate of filtration from 133 to 612 l/sq m/hr has resulted in more than 270% increase in the effective yield from 2940 to 10,870 l/sq m/day.

4. Distribution of Removals and Head Loss Build Up along Depth

Though higher rates of filtration may be desirable as they reduce the land require-

TABLE IV—YIELD OF FILTER AT DIFFERENT FILTRATION RATES

Sl. No.	Rate of Filtration (l/sq m/hr)	Length of Run (days)	Quantity of water filtered per run, (l/sq m)	Period lost in scrapping and recoupment per run (days)	Yield l/sq m/day
1	133	40	1.28×10^5	3.5	2,940
2	408	15	14.65×10^4	3.5	7,920
3	612	10	14.65×10^4	3.5	10,870

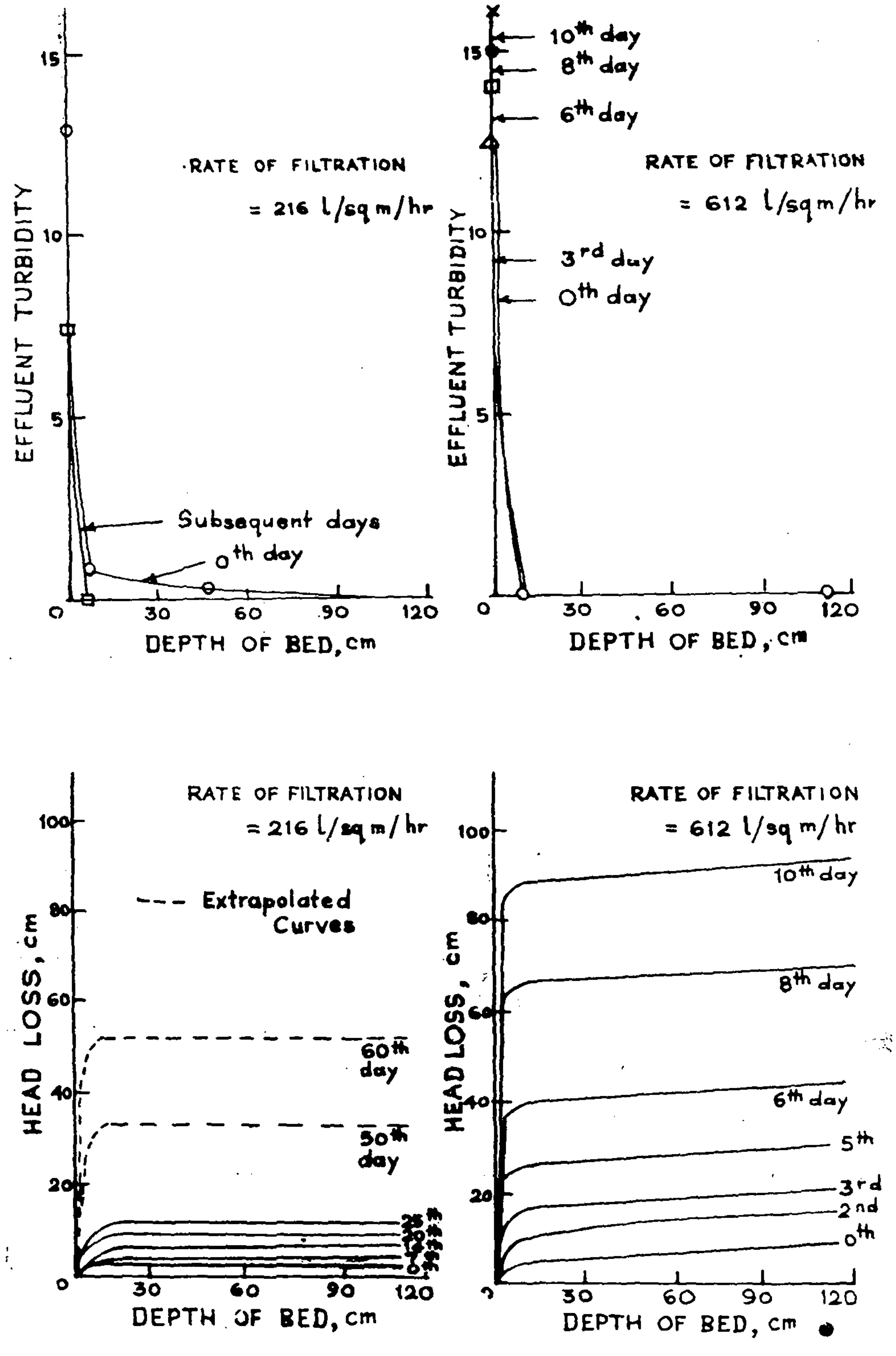

Fig. 4—Distribution of Turbidity and Head Loss along Filter Depth.

ments and cost of treatment, it should be ensured that the removal of impurities and hence build up of head loss is confined to top layers of sand. If the impurities travel deep down in the bed because of increased rate of filtration, head losses in the lower layers of bed will progressively increase and scrapping would not be effective in removing the impurities to restore the filter.

The variation of filtrate turbidities and head loss build up along the depth is plotted in Fig. 4 for lowest and highest rates of filtration at different days of operation. The nature of the curves confirm that almost all the removals are distributed in the top 10 cm or so and little impurities penetrate deeper in the bed. The filter effluent contained little or no turbidity almost from the start of filter run at both rates of filtration. This is a big advantage as the filtrate has not been wasted at all and with proper disinfection, the filtrate will be safe and acceptable for consumption. In case of slow sand filtration not employing alum coagulation as pretreatment, filter effluent has to be wasted for sufficiently long time until the ripening of filter occurs. Besides turbidity, determination of non-filtrable residue confirmed that filter effluents contained no suspended solids. The pattern of the head loss curves indicates that majority of head loss occurred in the top 5 cm or so and very little in the lower layers. The substantially parallel curves for head loss from 10 to 110 cm establish that impurities did not penetrate deeper than about 10 cm even till the last day of operation at highest filtration rate. A mathematical model to describe the head loss progress and removol of impurities is being developed by the authors.

Conclusions

From the above study conducted on prototype and pilot-scale filters at Kanpur Water Works, it is concluded that:

(1) Slow sand filters can be successfully operated with alum coagulated waters without any adverse effect on filter performance and thus increasing their suitability to treat even very highly turbid waters by proper control of coagulation and flocculation followed by settling.

(2) Slow sand filters employing alum coagulation as pretreatment can be operated at much higher rates of filtration with considerable increase in the actual quantity of water treated and with consequent reduction in land requirements and costs on civil works. A loading of 612 l/sq m/hr, being more than four times the conventional loading, was successfully employed and this resulted in reducing the land requirement to about one fourth of the present requirement and also about 30% reduction in overall cost of filtration.

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Upflow Filtration

N. W. MIRCHANDANI*

In the search for more efficient and economical methods during the last decade or so, upflow filtration has occupied an important place in water treatment technology. Many a studies, both on laboratory scale, pilot plants and actual units have been conducted, in the countries particularly in the USSR and Holland. Though some work on laboratory scale has been done and reported in India, studies on pilot plants have not been reported.

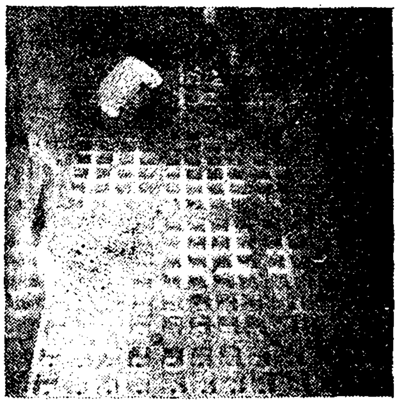
The studies and observations on a full scale pilot upflow filter plant of a capacity of 4.5 mld (1 mgd) using Vaitarna Lake water during the years 1966-69 are presented in the paper. The studies were made particularly to determine the efficiency of filter operation both during periods of low and high turbidities and the savings in coagulants used, if any.

Introduction

In the search for more efficient and economical methods during the last decade or so, upflow filtration has occupied an important place in water treatment technology. Many studies, on laboratory scale, pilot plants and actual units have been conducted, in the Western Countries particularly in the U.S.S.R. and Holland. Though some work on laboratory scale has been done and reported in India, studies on pilot plants have not been reported. The author had an apportunity to conduct certain studies and make observations on a full scale pilot upflow filter plant of a capacity of 2.25 mld (0.5 mgd) using Vaitarna Lake water during the years 1966-69. The studies were made particularly to determine the efficiency of filter operation both during periods of low and high turbidities and the savings in coagulants used, if any. The present paper describes some of these experiments.

The Experimental Plant

The pilot plant having a capacity to treat about 2.25 mld (0.5 mgd) of raw water, was constructed in R.C.C. as per the design of M/s. Imacti, Holland. The filter box size was 5000 mm x 2000 mm x 4000 mm. high. The raw water inlet was in false bottom chamber which was constructed of 15 Nos. of precast R.C.C. slabs each of size 996 mm x 666 mm resting on 16 Nos. of 200 x 100 x 700 mm. R.C.C. pillars. In each of these slabs, 24 Nos. of polypropelene nozzles were provided. Thus a total number of 360 nozzles were provided. The photograph of the under



Photograph 1—Under drainage System (Filter Floor)

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* Executive Engineer, Municipal Corporation of Greater Bombay, Mahapalika Marg, Bombay-1.

drainage system shows the filter floor at the time of construction. The provision of grid system located just below the top of the sand (2.5 cm below sand level) was made. This consisted of parallel vertical M.S. plates and helped in preventing sand expansion during filtration. The filtrate was collected in 225 mm diam C.I. perforated effluent pipe kept about 150 mm above sand bed. It had 72 Nos. of 22 mm diam perforation. A sketch of the unit is shown in Fig. 1.

Filter Media

The experiments were carried out with the media loadings indicated in Table I.

TABLE I—MEDIA LOADING

Description	Size (mm)	Depth (mm)
Gravel	30 x 40	100
—do—	10 x 15	200
—do—	2 x 3	500
Quartz sand	1 x 2	1234

Filter Operation

Raw water entered the bottom of the false bottom chamber and was measured by orifice type flow meter. The desired rate of flow was controlled by manual operation of inlet valve. The filter effluent was collected at the top in a 225 mm C.I. perforated pipe.

Commercial alum containing 17% Al_2O_3 was used as a coagulant. Alum solution was first prepared in a M.S. coated tank of 1.83 m diam and 1.22 m height. This tank was fitted with a central stirrer. The solution was then transferred to another tank of similar dimensions and alum solution was directly injected through chemical dosing pump into the raw water main before entry to the filter. The principle object is the formation of aggregates of microfloc, with which coagulation within the filter bed is more rapid and complete on contact with the surfaces of the gravel and sand as compared to normal coagulation.

At the start of the filter run, the initial head loss in the filter as indicated by water manometers was noted. The filter flow as well as head loss readings were hourly noted. Turbidity of raw as well as filtered water was noted every hour. The filter run was terminated when either (a) the loss of head in the filter reached 1.70 m, or (b) the effluent turbidity exceeded predetermined level (5 jtu), or (c) there was breakthrough of floc in the filtrate.

The filters were backwashed by giving air-cum-water wash. An air blower was installed near the filter unit and wash water was drawn from storage tanks kept at a height of about 8.3 m with respect to filter floor. Air was supplied at the rate of 0.3 cu

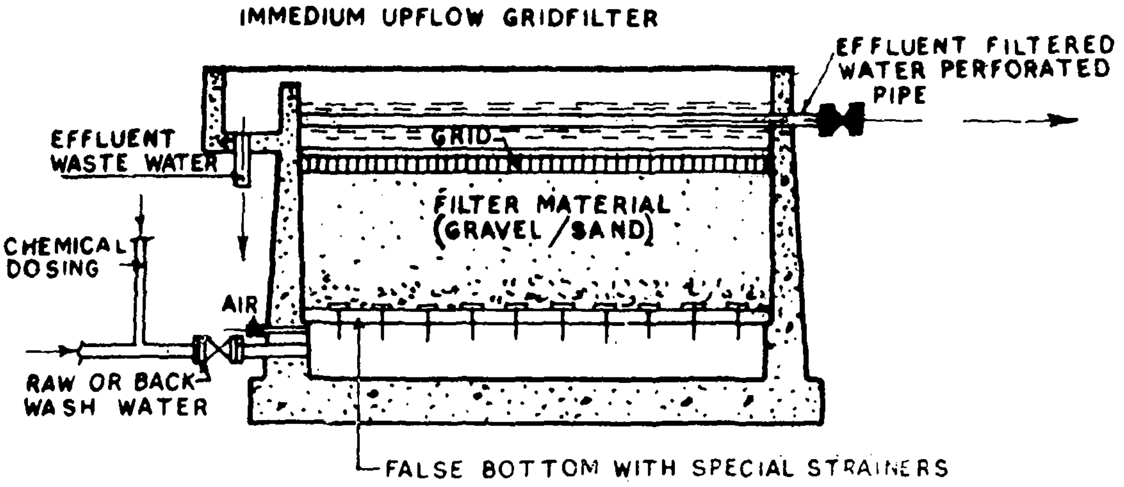

Fig. 1—The Experimental Pilot Plant

m/sq m/min (1 cu ft/sq ft/min) with a pressure of 0.35 kg/sq cm (5 lb/sq in) for a period of 5 min. This was followed by water wash at a rate of 0.5-0.65 cu m/sq m/min (10-13 gal/sq ft/min) for a period varying from 15 to 25 min.

In these experiments, the rate of filtration and the injection of alum dose could be controlled while the raw water turbidity varied due to seasonal changes. Raw water was drawn both from the surface of the Vaitarna Lake (overflow level 163 m T.H.D.) as well as from 127 m above T.H.D. After backwash the raw water inlet valve was opened gradually till the desired rate of filtration was obtained.

Raw Water Characteristics

Vaitarna Lake waters were taken in the filter unit. The lake is an impounded one and the waters have low turbidities in the fair season. The characteristics of the Vaitarna Lake waters are shown in Table II.

Experiments Conducted

Experiments were conducted both in fair season when the turbidity was low and during monsoon period when the turbidity was high. The turbidity was mostly colloidal in nature. These experiments were conducted with a view to determine (i) the limiting value of the turbidity upto which direct filtration, without the use of pretreatment units such as flocculators and clarifiers, in an upflow filter is efficient, and (ii) the effect of reduced alum dose less than the full jar test dose on the length of filter run.

The results of the tests carried out for both low turbid as well as high turbid waters are given in Tables III and IV.

Observations

During the post monsoon period (Oct. to Dec. '66) when the turbidity was moderately low, it can be seen from the results at Sl. Nos. 1, 2 and 3 (Table III), that keeping the alum dose same (**viz.**, 60% of the jar test) as well as constant filtration rate (5 cu m/sq m/hr), the filter runs decreased with increase in turbidity; for a turbidity of 36 units, the average filter run obtained was 25 hr, while for turbidity of 76 units, the filter run reduced to 17 hr. The effluent turbidity was also observed to be high (4 units) in case of filter runs tried on higher turbid waters. The loss of head did not increase sufficiently

TABLE II—CHARACTERISTICS OF VAITARNA LAKE WATER DURING THE YEAR 1965

Characteristics	Lake Water drawn at					
	Surface			127 m above T.H.D.		
	Max.	Min.	Ave.	Max.	Min.	Ave.
Turbidity, units	47	3.05	18	300	5	59
Colour, Hazen units	25	5.00	10	75	5	20
pH	9.1	7.06	8.5	7.5	7.1	7.4
Ammonical nitrogen as N	0.21	0.04	0.09	0.61	0.027	0.14
Albuminoid nitrogen as N	0.52	0.11	0.22	0.55	0.06	0.18
Nitrite nitrogen as N	0.009	0	0.008	—	—	—
Nitrate nitrogen as N	—	—	—	tr	tr	tr
Total hardness as CaCO	49	34	42	49	34	41
Alkalinity as $CaCO_3$	56	35	48	53	33	.44
$KMnO_4$ value (4 hr at 27°C)	0.80	0.13	0.36	1.60	0.22	0.52
Chlorides as Cl	9.04	7.05	8.04	9.3	5.5	8.3
Iron as Fe	0.86	0.24	0.42	8.00	0.35	1.33
Calcium as Ca	10.08	6.08	9.03	10.4	6.8	9.2
Magnesium as Mg	5.53	2.64	4.42	5.76	2.68	4.42
Total solids	97	87	92	106	82	67

Note— (1) All values except turbidity, colour and pH are expressed in mg/l
(2) tr=traces

TABLE III—RESULTS OF UPFLOW FILTER BED (FAIR SEASON)

Sr. No.	Continuous working period.	Supply of water (l/hr)	Rate of filtration (cu m/sq m/hr)	Alum doze (mg/l)	Ave. Turbidity		Length of run (hr)	Flow rate during cleaning (cu m/sq m/min)	Head loss	
					Raw Water (jtu)	Filt. Water Raw			Start of run (m)	End of run (m)
1.	1-10-66 to 31-10-66	50000	5.0	8.58	76	4	17	0.55	0.15	0.35
2.	1-11-66 to 30-11-66	,,	,,	,,	36	2.5	25	0.65	0.13	0.33
3.	1-12-66 to 10-12-66	,,	,,	,,	29	1.7	29	0.65	0.15	0.3
4.	1- 4-67 to 6- 4-67	113650	11.6	5.72	5.4	0.9	31	0.625	0.35	1.42
5.	6- 4-67 to 20- 4-67	,,	,,	3.57	6.0	0.8	31	0.6	0.43	1.42
6.	20- 4-67 to 30- 4-67	,,	,,	2.86	4.7	0.8	30	,,	0.48	1.35
7.	13- 6-67 to 15- 6-67	72750	7.5	1.43	25	5.2	12	,,	0.20	0.3
8.	15- 6-67 to 19- 6-67	,,	,,	7.15	43	1.1	31	,,	0.23	1.02

TABLE IV—RESULTS OF UPFLOW FILTER BED ((MONSOON PERIOD)

Sr. No.	Continuous working period.	Supply of water (l/hr)	Rate of filtration (cu m/sq m/hr)	Alum doze (mg/l)	Ave. Turbidity		Length of run (hr)	Flow rate during cleaning (cu m/sq m/min)	Head loss	
					Raw Water (jtu)	Filt Water (jtu)			Start of run (m)	End of run (m)
1.	2-8-66 to 15-8-66	45460	4.65	11.44	166	14	Break	0.33	0.28	1.65
2.	15-8-66 to 17-8-66	45460	7.50	11.44	106	36	through	0.36	0.46	0.74
3.	17-8-66 to 20-8-66	61400	6.25	8.58	88	13	occuring.	0.5	0.28	1.04
4.	26-7-67 to 27-7-67	95500	9.75	17.16	175	9.7	Filter	0.54	0.23	0.43
5.	27-7-67 to 28-7-67	72750	7.5	17.16	435	91	effluent	,,	0.2	0.86
6.	28-7-67 to 30-7-67	45460	4.65	14.3	327	211	uncon-	0.5	0.18	0.63
7.	30-7-67 to 31-7-67	36400	3.65	28.6	325	14	trolable	,,	,,	,,

high indicating failure by breakthrough. For comparison purposes, raw water was also directly filtered bypassing clarifiers, through an experimental conventional downflow filter of an area of 10.22 sq m, having 600 mm (24 in) of filter media, of size 0.6-0.8 mm. The average filter run was observed to be 11 hr. The longer filter runs in case of upflow filters were due to its larger capacity to hold floc in the coarse portion of the media.

During period of low turbidity (upto 6 units) as indicated in Sl. Nos. 4, 5, 6 in Table III, the filter worked satisfactorily upto an alum dose of 25% of the jar test. The average filter run was 30 hr and the head loss also built up satisfactorily.

The corresponding filter run on a conventional downflow direct filter was found to be 24 hr.

When the alum dose was reduced too much (10% jar test) (Sl. No. 12), it was observed that there was failure due to early breakthrough and an increase in alum dose to 50% of jar test gave encouraging results. This may be due to inadequate formation of microfloc. While too much addition of alum in case of low turbid waters increased the load due to alum itself thereby reducing filter runs.

Table IV gives results of directly treating high turbid bottom waters of Vaitarna lake in the upflow filter unit. The filter did not give encouraging results. The filter runs were very short. The effluent turbidity was high and the failure was mainly due to breakthrough. Full jar test alum dose was tried on a few occasions, but that worsened the matters. During another flood season, the top filter media was also replaced by finer one (229 mm of 0.5-0.8 mm) at top and next layer 1005 mm of 2 x 3 mm as against original one of 1234 mm of 1 x 2 mm size. But this also did not improve matters during periods of high turbidity. It was felt that the unit, being too large, did not allow economic modifications or change over of the filter media. A lot of variation in this respect could have been tried on model tube filters.

Practical Considerations

(1) One of the advantages of the upflow units is that for this type of treatment plant, conventional pretreatment units such as flocculators and clarifiers are not necessary and there is substantial saving in cost. As against this, it must be considered that the upflow filters are deep units and require at least double the quantity of filter media than the conventional downflow filter units. The cost due to construction of deep filters and provision of additional filter media must be considered to make a fair comparison.

(2) These units are efficient within a certain range of suspended solids load and within that range the quantity of alum required is less.

(3) If the filter bed is open to sky and water is collected from the top, the treated water is subject to atmospheric pollution, bird droppings, falling leaves etc. This can be controlled by placing the filter effluent pipe in the sand media. Alternatively, the filter bed has to be covered involving extra expenditure.

Conclusions

(1) The upflow filter unit gave a better filter performance as compared to direct downflow filter bye passing clarifying units. The filter runs were 25 to 50% longer in case of upflow filter.

(2) The filter unit was efficient upto a certain limit of turbidity, **viz.** 40 jtu. Beyond this, the filter behaved erratically. Failures occured mostly by breakthrough. It is felt that addition of filter aids, which were not tried, would have improved the situation in certain cases.

(3) Within the limiting turbidity range, (upto 40 jtu) there was saving in alum dose. The unit worked satisfactorily with alum dose of as low as 20% of the jar test alum dose.

(4) Too much reduction of alum dose (less than 20% of jar test) some times impaired the filter performance. Failures occured mostly by breakthrough.

DISCUSSION

Shri S. Mukherjee: Upflow filters hold flocs in the entire portion of the media. Even then, total depth provided is more than conventional filters. This may please be explained.

Shri N. W. Mirchandani: The filtration in an upflow filter takes place in a reverse direction. At any section, the weight of the sand above that section must counterbalance the force exerted by the water in the upward direction. Hence the depth of media is more.

Dr. K. L. Saxena: It has been shown in Table II that nitrite nitrogen as N is 0.0008 mg/l. I would like to know the method used for nitrite estimation as it is difficult to estimate nitrites in such a low quantity.

Shri N. W. Mirchandani: The nitrite nitrogen was estimated by using Ilosvay's Reagent, which consists of solution of sulphanilic acid and solution of alpha napthylamine. The method is described at page 216 in 'The Examination of Water and Water Supplies 'by E. W. Taylor, 7th Ed., (1958), published by J & A Churchill Ltd., London.

Shri J. N. Kardile: (i) What was the depth of upflow filter under experiment and what was the percentage of backwash water as compared to rapid sand filter? (ii) What was the maximum turbidity tried through the filter bed? (iii) What was the average head loss at the beginning and at the end of filter run? (iv) How the breakthrough in the bed was observed and after how much average time?

Shri N. W. Mirchandani: (i) The size of the plant is given in the paper the media loading was as per Table I. Normally, the percentage of backwash water required was about 4% as against 2% required for the rapid sand filter. However, during periods of high turbidity, this percentage sometimes increased to as high as 10-12 percent. (ii) The maximum turbidity tried was 435 units (Table IV). (iii) This information is given in Tables III & IV. (iv) Hourly readings of head loss were taken. Also, hourly samples of filtrate were collected and tested for turbidity immediately at the site laboratory. In addition, before the termination of filter run and also after every 8 hr, filtrate samples were collected and analysed for residual aluminium. At a later date, Baylis type floc-detector was also connected to the filter effluent to help in instantanous observation of the passing flocs, if any.

CHAPTER-VI

SOLID WASTE

PROC. SYMP. ON ENVIRONMENTAL POLLUTION (1973)

Seasonal Variation in Nagpur Refuse Characteristics

A. D. BHIDE,* L. M. MOTHGHARE,* A. D. PATIL* and S. S. GAUTAM*

Differing climatic conditions in different seasons are known to affect the refuse characteristics apart from several other factors. A study was hence carried out on Nagpur city refuse so as to assess the variation in characteristics in different seasons.

The city was divided occupation-wise by following the "Stratified Random Sampling Technique". After the physical and chemical analysis of 231 samples, average values were found out for different occupations in different seasons and compared. The characteristics for the city as a whole were also found out by giving proper weightage and compared in different seasons. The results are presented and discussed in the paper.

Introduction

Characteristics of city refuse depend mainly on the standard of living, dietary habits of the population and climatic conditions. For a given city, as the first two factors will remain constant throughout, it is the climatic conditions which will cause change in the characteristics. In India, we have three distinct seasons during which the rainfall, temperature and humidity conditions are entirely different. Also, the type and amount of vegetables available are different in these seasons so that the garbage fraction is expected to change. It is hence desirable to find out as to how the refuse characteristics change in these seasons.

A knowledge of these changes would enable proper decisions to be taken regarding disposal methods both from the point of view of its selection as well as operation.

Work was hence carried out during 1972 to study the seasonal variation in Nagpur city refuse characteristics.

Method of Investigation

Nagpur city having a population of 8,67,269 in 1971 and covering an area of 217.6 sq km was studied. As the refuse characteristics change with occupation and standard of living, the different areas were classified as residential, commercial, industrial, etc. The residential areas were then sub-divided into high income, middle income, low income and slum type groups. Sampling points were selected so as to clearly represent these activities. It was also ensured that these points were scattered all over the Corporation area. Thus, in all a total of 75 sampling points were selected from which samples were collected every season for analysis. Samples for any season were collected scattered over a complete week by taking care that every day a few samples from each of the occupation group were obtained. When tested with the aid of the method of Garruth and Klee (1), the number of sampling points were found to be adequate to give desired accuracy within 95% confidence limits.

Samples were collected and analysed by following standard procedures (2, 3, 4). The averages for different sub-groups were first calculated which were then multiplied by the weightage factor. This factor was found out on the basis of quantities generated by different sub-groups and was obtained by

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* Scientists, Central Public Health Engineering Research Institute, Nagpur-20

actual weighing of trucks from different areas. The weighted average figures were then used to calculate the average values for the whole city.

Tables I and II give the average physical and chemical characteristics for different sub-groups and for the whole city in different seasons.

As some refuse constituents get reclaimed enroute to the disposal site, samples were collected and analysed from disposal site also.

Results and Discussion

From Table I, it can be seen that the high income group which produces larger fruit waste, generates it maximum in winter due to availability of larger variety of fruits in plenty. Summer with larger consumption of mangoes and watermellon follows this.

The larger lawn spaces in the case of high income group area give rise to larger grass and hay which gives its peak value in rainy season when lawn moving and trimming is commonly done.

There is not much of difference in the percentage of paper produced in different occupation but the values follow similar trend and attain peak figures in winter.

The high income group is found to give maximum compostable fraction in the different seasons followed by commercial areas

TABLE I—PHYSICAL ANALYSIS OF NAGPUR CITY REFUSE*

Sl. No.	Type of Locality	Seasons	Leaves	Fruit Pealings & vegetables	Grass & hay	Plastics	Rags	Paper	Glass	Compos- matter table
1.	**Residential**									
	a) High Income	Summer	10.49	8.81	4.73	0.78	4.20	4.95	1.49	36.55
		Winter	6.14	13.16	5.20	0.61	5.81	6.84	0.2	29.80
		Rainy	5.19	6.69	10.26	0.1	3.15	3.70	0.5	28.68
	b) Middle ,,	Summer	3.59	4.71	5.14	0.60	3.15	2.84	0.88	26.49
		Winter	4.83	6.51	4.71	1.15	7.59	5.63	1.14	20.06
		Rainy	3.56	3.11	7.08	0.05	5.14	3.08	0.55	21.13
	c) Low ,,	Summer	2.58	0.99	4.65	1.12	4.31	2.89	0.36	16.35
		Winter	4.11	3.87	3.74	0.98	6.40	5.68	0.54	15.35
		Rainy	4.24	1.48	5.95	0.22	5.11	2.08	0.28	17.75
	d) Slum ,,	Summer	3.44	0.69	2.85	0.68	6.00	3.33	0.51	17.67
		Winter	8.44	5.15	7.18	1.28	5.83	4.40	0.87	21.54
		Rainy	3.39	0.59	3.16	0.21	6.92	3.58	0.13	23.42
2.	**Commercial**	Summer	2.05	8.19	6.69	3.09	2.72	4.77	0.54	32.77
		Winter	6.82	14.15	5.57	0.74	4.40	7.30	0.74	27.93
		Rainy	4.57	2.07	2.87	0.50	2.25	3.5	0.11	20.01
3.	**Industrial**	Summer	3.91	1.44	3.76	0.11	3.71	3.06	1.07	9.45
		Winter	7.02	1.64	2.98	2.99	7.08	4.31	2.21	12.23
		Rainy	2.15	1.38	1.47	0.10	5.59	3.24	0.32	5.00
4.	**City as a Whole**	Summer	3.59	2.83	4.43	0.87	2.79	3.16	0.65	20.45
		Winter	5.61	5.89	5.02	1.58	6.62	5.64	0.82	19.70
		Rainy	3.85	2.19	5.77	0.16	5.35	2.82	0.34	20.82
5.	**Dumping Ground**	Summer	3.52	3.95	3.48	0.29	2.67	2.47	0.18	21.17
		Winter	5.60	7.28	9.62	0.67	6.07	3.86	0.12	25.69
		Rainy	3.53	1.81	5.29	0.11	4.57	1.13	0.15	21.49

* All values are in percentage by wet weight basis.

TABLE II—CHEMICAL ANALYSIS OF NAGPUR CITY REFUSE

Sl. No.	Type of Locality	Seasons	Moisture Content (%)	pH	Organic Matter ((%)	Nitrogen (%)	Phosphorous as P_2O_5 (%)	Potassius as K_2O (%)	HCV (BTU/lb)
1.	**Residential**								
	a) High Income	Summer	10.91	7.7	34.52	0.74	0.61	0.52	2692.07
		Winter	29.02	8.2	42.63	0.63	0.49	0.50	2846.00
		Rainy	31.18	7.8	25.91	0.63	0.94	0.68	1899.61
	b) Middle „	Summer	11.41	7.8	34.29	0.67	0.78	0.76	2469.20
		Winter	30.29	7.9	30.06	0.66	0.50	0.51	1969.24
		Rainy	33.49	7.9	28.37	0.63	0.94	0.68	2099.01
	c) Low „	Summer	8.84	7.9	30.15	0.64	0.62	0.71	2265.66
		Winter	28.68	8.27	25.77	0.66	0.49	0.60	1849.41
		Rainy	31.07	8.41	27.17	0.51	0.86	0.80	2115.42
	d) Slum „	Summer	9.59	8.1	31.95	0.64	0.75	0.60	1949.52
		Winter	29.01	7.9	32.69	0.57	0.50	0.49	2212.25
		Rainy	31.89	7.84	25.19	0.58	0.88	0.63	1747.35
2.	**Commercial**	Summer	10.36	7.95	31.47	0.68	0.78	0.69	2052.52
		Winter	21.76	8.11	32.29	0.79	0.63	0.56	2375.48
		Rainy	26.26	8.04	21.60	0.56	0.93	0.49	1628.71
3.	**Industrial**	Summer	8.72	8.46	30.72	0.71	0.80	0.62	3337.74
		Winter	29.31	7.9	21.17	0.67	0.57	0.62	2728.66
		Rainy	35.15	8.23	20.17	0.71	1.05	0.64	2232.27
4.	**City as a Whole**	Summer	10.04	7.95	32.25	0.66	0.71	0.68	2286.86
		Winter	29.02	8.02	30.00	0.68	0.50	0.54	2060.40
		Rainy	31.96	8.04	26.77	0.57	0.90	0.69	1995.24
5.	**Dumping Ground**	Summer	9.50	8.0	29.35	0.66	0.61	0.57	2085.55
		Winter	24.36	8.2	28.29	0.87	0.62	0.61	2075.21
		Rainy	30.10	8.12	29.76	0.59	0.67	0.58	1900.99

(in which markets have also been included). However, if the values of compostable fraction for different seasons are compared, the values seem to remain more or less constant in different seasons.

The amounts of rubber leather, plastics and glass are quite small and the variations observed are not much significant and hence a firm conclusion cannot be drawn.

From Table II, it can be seen that the moisture content is maximum in rainy season and that in summer and winter it is nearly similar. This is valid in the case of all the occupation sub-groups.

On comparing the organic content of different subgroups in various seasons, it is seen that high income group gives maximum values in summer and winter but not in rainy season which, however, gives least organic matter for all occupations.

The high and middle income groups and commercial areas with comparatively higher organic content are found to give maximum pH values in winter when compared for different seasons in the same sub-group.

The combination of calorific value, moisture content and organic content, when plotted on the 'Three Component Diagram', show that in all cases, a self sustaining combustion reaction cannot be obtained and auxiliary fuel will have to be supplied, in case incineration of city refuse has to be done.

Summary and Conclusions

The analysis of the 231 samples collected in the different seasons at Nagpur revealed the following points :

1. Ash and fine earth formed a predominating fraction of Nagpur city refuse.
2. Paper and plastics content in the city refuse was quite small in all the seasons for all the sub-groups.
3. Reclamation of some refuse constituents was observed to occur enroute to disposai site. It was appreciable in the case of glass followed by paper and rags and plastics.
4. Though the compostable fraction for different occupations changed during different seasons, it remained more or less constant when considered for the city as a whole.
5. The chemical characteristics showed that a self sustaining combustion reaction cannot be obtained for city refuse from different sub-groups as well as when taken for the city as a whole.

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DISCUSSION

Shri C. E. S. Rao: (i) If the time lag between the time of dumping and the time of collection is reduced, pilferage will be less. (ii) If the material is conditioned by segregating non-combustible material and by reducing the particle size it hastens time for settling by better compaction and less moisture content.

Shri A. D. Bhide: (i) By covering of trucks and by providing separate space for the workers in the vehicle, much of the unauthorised reclamation can be prevented. (ii) If segregation and shredding is done at the disposal sites, it will increase the cost of operation and hence its adoption or otherwise will be dictated mainly by economic considerations. A better way will be to encourage, by sustained public education, the house owners to carry this out at the source only.

Shri V. Raman: In Bombay, unlike Nagpur, it is observed that the physical characteristics from area to area varies. In affluent areas, the percentage of packaging wastes in the refuse is more than in poor class areas. The percentage of plastics in rich class areas varies from 2 to 4 percent. While these are present at the collection site, these are notably absent at the disposal site due to salvaging.

The impact of packaging materials on solid wastes will be better production, increased cost of collection and the problem of disposal of non-decomposable packaging wastes like plastics. This is not yet a problem in India, but the indications are there in metropolitan cities.

PROC. SYMP. ON ENVIRONMENTAL POLLUTION (1973)

Studies on Settlement of Refuse

A. D. BHIDE * *and* P. S. ITTWALA**

Refuse, whether in a dump or in a sanitary land-fill, tends to settle and gets compacted due to various factors. It is known that the settlement thus occurring comprises of primary consolidation followed by secondary consolidation and creep and lastly by decomposition of the material. Primary consolidation forms a major part of the total settlement and consolidation was hence studied both under laboratory and field conditions using Nagpur city refuse having 30% moisture content. The optimum moisture content was found out for the city refuse by Modified Proctor Method as 45 percent.

The effects of moisture content, loading intensity and repeated loadings in hastening up the primary consolidation stage have been studied and the findings are reported in the paper. The maximum density attained was 40.5 lb cu ft under 5 psi load at 45% moisture content.

Introduction

City refuse is commonly dumped in low lying areas where it generally gets stabilised. However, such sites are often unsightly, breed flies and mosquitoes and cause fire, smoke and odour problems. To avoid the drawbacks of such uncontrolled dumps, the process has been systemised and mechanised in USA and named 'Sanitary Landfill'. These sites are then safe from hygienic point of view and also can be utilised in a better manner.

The dumped material is known to undergo settlement with the passage of time and hence the sites can be used only after further settlement is ruled out. It is hence necessary to know the exact trend of this settlement before any remedial measures can be taken to reduce the time of settlement so that the sites can be put to use earlier.

Mechanism of Refuse Settlement

The total settlement consists of: (i) primary consolidation; (ii) secondary compression and creep; and (iii) decomposition.

(i) Primary Consolidation

In this stage, a large proportion of total settlement occurs in a short duration and this is also known as 'short term shear deformation'. This stage extends upto the point where the curve changes its trend (Fig. 1).

(ii) Secondary Compression and Creep

This is also known as 'long term shear deformation'. The factors affecting this deformation are the same as in the case of primary consolidation except that the slope of the settlement curve is quite flat.

(iii) Decomposition

Settlement due to decomposition is predominant when the settlement curve again tends to bend downwards. As the organic matter is converted to stable end products, resultant increase in density is reflected by further settlement.

Out of these three stages, those at Sl. Nos. (ii) and (iii) are too slow and cannot be hastened economically. On the other hand, the

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* Scientist, Central Public Health Engineering Research Institute, Nagpur-20.

** Formerly, M. Tech. (PHE) Student, Visevesvaraya Regional College of Engineering, Nagpur.

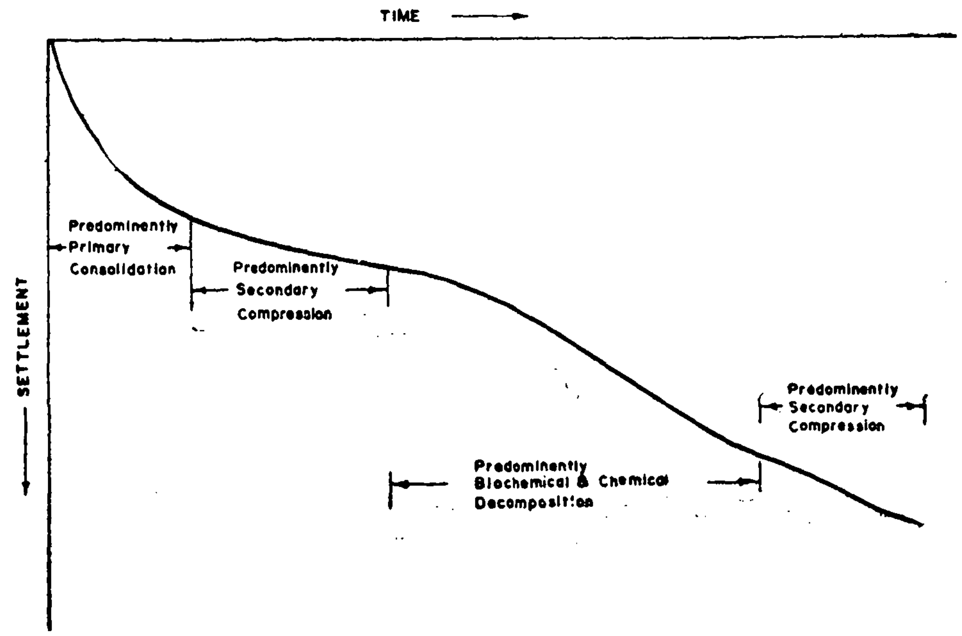

Fig. 1—Processes of Refuse Settlement

primary consolidation stage, as is well known, can be accelerated economically by various means.

Factors Affecting Primary Consolidation

Primary consolidation is mainly affected by the following factors :

(a) *Weight and composition of fill material*—If the composition of material is such that rearrangement of particles and decomposition of constituents and decomposition of constitutents occur, then larger settlement can be expected.

(b) *Depth of fill*— A larger depth will give more self-weight and hence more settlement.

(c) *Moisture penetration*— The extent of this will depend on the type of the material as well as that of the cover material. The water, while moving down, will cause readjustment of particles as well as will take some refuse constituents in solution resulting in further settlement.

It can be easily appreciated that depth of fill and moisture penetration are the variables which are difficult to control. For example, depth of fill will depend upon site conditions and moisture penetration on rainfall, etc. Composition of fill material also cannot be altered. Hence, it is only the weight of the fill material which can be artificially changed by superimposed loads.

The composition and hence unit weight of city refuse in India is much different than that encountered in Western countries owing to difference in climatic conditions, dietary habits, etc. Hence the figures as obtained from Western literature (1, 2, 3, 4) cannot be directly relied on.

Experimental Procedure

Studies were hence carried out to chart the settlement of Nagpur city refuse, mainly in the 'primary consolidation' stage under varying superimposed loads. The city refuse was analysed for physical characteristics (Table I).

Settlement of refuse and hence compaction in the primary consolidation stage essentially involves void reduction by static and dynamic forces. Voids are a function of physical bulk of waste and natural interslices within the material.

TABLE I—PHYSICAL ANALYSIS OF REFUSE TESTED

Sl. No.	Item	% by wet weight
1.	Garbage	35.58
2.	Rags	1.14
3.	Paper	1.14
4.	Iron	0.114
5.	Glass	0.570
6.	Stones, Bricks, Earthenware	14.25
7.	Earth, cinder, ashes	45.60

During the compaction process the refuse particles get rearranged and packed together in a closer state of contact. This results in decrease in porosity and increase in dry density.

The static compactive forces consist of weight of compaction equipment and overburden weight of refuse and soil cover.

Dynamic compaction forces consist of impact and vibration. Impact forces cause fragmentation of material. Vibrations result in settling and shifting action and give increased consolidation of refuse and settlement of smaller particles into voids. Qualification of these dynamic compactive forces is a complex problem requiring extensive analytical and experimental work.

Based on the extensive studies at Santa Clara landfill, California, Ralph Sone & Co. Inc. (5), Engineers have expressed these forces as a proportion of static weight for different types of equipment, and the same have been used in the calculations here.

The optimum moisture content was found out by using Modified Proctor Method (6, 7). This was found to give a maximum dry density of 64 lb/cu ft, at 45% moisture content.

Experiments were hence simultaneously conducted at both these moisture contents (30% and 45%) under various loading intensities.

In field, 6 pits were exacavated of 4 ft x 4 ft size and 5 ft. depth in which the refuse was filled to a depth of 4 ft. & then covered with 1 ft. earth layer. A wooden plate was placed on its top and then loaded with the aid of concrete blocks and sand bags placed over the plank. To find out the settlement occuring, settlement plates were fixed both on the pit bottom as well as on the top of the refuse (Fig. 2) and by taking levels at their top, the settlement was continuously monitored (8).

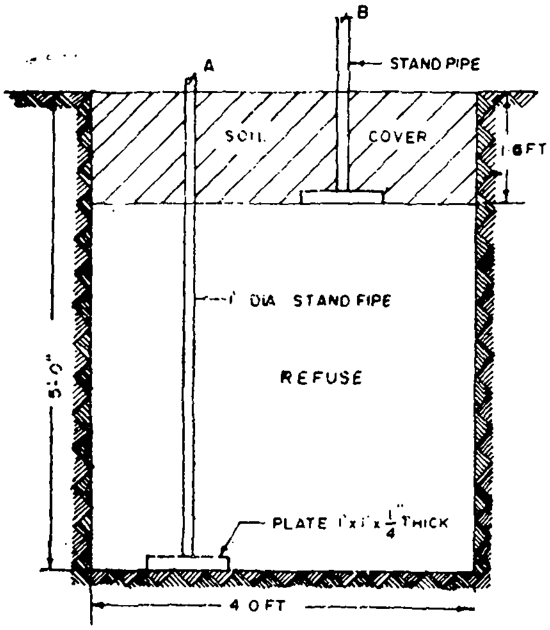

Fig. 2—Details of Pit and Settlement Plates

In laboratory steel cylinders of 4 in. diam, 18 in. ht. were filled with the material and were provided with settlement plates with a pointer. The cylinder was placed on stable surface and a weight equal to that of earth cover was placed on its top. Different tubes were then loaded to different loading intensities for specified duration and the loads removed. The settlement was then continuously monitored.

In the case of repeated loading, after loading once as mentioned above, the same cycle was repeated on the next day and again on third day and the settlement of original layer was observed everyday.

Observations and Discussion

Field Studies

The results of settlement, both obtained immediately after the application of load and total settlement, are summarised in Table II. The settlement is expressed as a % of total depth of refuse at the start of the experiments.

From Table II, it could be seen that the maximum immediate settlement occurred at a loading intensity of 7.5 psi at 45% moisture content. If the difference in immediate settlement between the values obtained at same load but at different moisture contents were compared, maximum increase occurred at the highest loading tested when moisture content was increased from 30% to 45%.

On comparing the subsequent settlement, the reverse trend was observed i. e., maximum values were obtained at least loading intensity tested at 30% moisture content while minimum values were obtained at 7.5 psi and 45% moisture content.

Thus it could be seen that heavier loads and optimum moisture content gave higher initial settlement but resulted in lesser subsequent settlement.

On comparing the total settlement at the same loading but at the different moisture contents tested, it is found that use of the optimum moisture content always resulted in more settlement.

If the total settlement values for different loading were compared at the same moisture content, then at both the moisture contents tested, the totol settlement increased with increase in load. However, the increase was more pronounced at the optimum moisture content.

Laboratory Studies

Simultaneously, tests on exactly similar loading intensities and moisture contents were carried out in the laboratory. As the quantity of material being tested in laboratory was smaller, duplicate tubes were used and the average values adopted (Table III). On perusal of this data, it was seen that they gave the same trend as discussed earlier, in the case of field study.

To assess the applicability of laboratory data to field tests, the results of both the studies are put together in Table IV. It could be seen that both the studies gave the same trend when compared for various aspects such as behaviour of immediate, subsequent and total settlement for different loading and moisture content values. The absolute values of settlement obtained in the laboratory studies are always on the higher side, mainly due to: (i) the smaller depth of refuse fill used, (ii) the more effective mixing of moisture with refuse that could be achieved, and (iii) the lesser resistance offered by the smooth sides of the tubes. However, the studies clearly indicate that laboratory studies can help to predict the behaviour in field. Hence further tests were conducted only in laboratory where controlled conditions can be better obtained.

TABLE II—SETTLEMENT DURING 2 MONTHS PERIOD IN THE FIELD STUDY

Pit No.	Static load applied (psi)	Moisture content (%)	Immediate settlement (%)	Subsequent settlement (%)	Total settlement (%)
1.	3.0	30	9.75	3.0	12.75
2.	5.0	30	11.0	2.25	13.25
3.	7.5	30	12.50	3.0	15.50
4.	3.0	45	11.75	2.75	14.50
5.	5.0	45	15.50	2.50	18.0
6.	7.5	45	19.0	1.75	20.75

TABLE III—AVERAGE SETTLEMENT DURING 2 MONTHS PERIOD IN LABORATORY STUDIES

Sl. No.	Static load applied (psi)	Moisture content (%)	Immediate settlement (%)	Subsequent settlement (%)	Total settlement (%)
1.	3.0	30	12.10	2.45	14.55
2.	5.0	30	24.70	2.0	26.70
3.	7.5	30	32.70	1.4	34.10
4.	3.0	45	15.50	1.9	17.40
5.	5.0	45	26.55	1.85	28.40
6.	7.5	45	32.85	1.4	34.25

TABLE IV—COMPARATIVE DATA ON FIELD AND LABORATORY STUDIES

Sl. No.	Moisture content (%)	Load (psi)	Immediate settlement (%)		Subsequent settlement (%)		Total settlement (%)	
			Pits	Tubes	Pits	Tubes	Pits	Tubes
1.	30	3.0	9.75	12.10	3.0	2.45	12.75	14.55
2.	30	5.0	11.0	24.70	2.25	2.0	13.25	26.70
3.	30	7.5	12.50	32.70	3.0	1.4	15.5	34.10
4.	45	3.0	11.75	15.50	2.75	1.9	14.5	17.40
5.	45	5.0	15.55	26.55	2.5	1.85	18.0	28.40
6.	45	7.5	19.0	32.85	1.75	1.4	20.75	34.25

TABLE V—EFFECT OF REPEATED LOADING OF REFUSE

Sl. No.	Load (psi)	Moisture content (%)	Settlement (%)			Subsequent settlement (%)	Total settlement (%)
			1st Day	2nd Day	3rd Day		
1.	3.0	30	11.25	19.40	21.70	2.15	23.85
2.	5.0	30	21.85	25.0	27.35	2.0	29.35
3.	7.5	30	26.25	29.35	31.85	1.6	33.45
4.	3.0	45	18.35	22.30	25.90	6.6	32.50
5.	5.0	45	22.85	26.25	28.50	0.6	29.10
6.	7.5	45	30.25	33.00	35.15	0.7	35.85

In this set the effect of repeated loading of refuse was studied, assuming that the sanitary landfill was operated by spreading and compacting refuse in 3 layers of 18 in. and 3 ft. and 3 ft. thickness respectively. These 3 layers were placed on 3 successive days and the first two layers were covered with 6 in. earth cover while the final earth layer was 1½ ft. thick. The method of loading has already been discussed earlier. The results of the settlement occuring during the two months period are summarised in Table V.

Effect of Change in Moisture Content on Total Settlement for Same Intensity of Load

The total settlement increased by 2.4% at 7.5 psi, while it increased by 8.65% at 3 psi and remained approximately constant at 5 psi when the moisture content was changed from 30 to 45 percent. Thus the increase in total settlement was more pronounced at 3 psi than at heavier loads. This indicates that if the initial compaction of refuse is less, effect of repeated loads on subsequent settlement will be more.

The additional settlement obtained by the 2nd and 3rd application of load is not appreciable and goes on decreasing. In other words, on additional benefits in terms of extra compaction can be expected by repeated compaction. However, in deeper fills, these repeated loads may occur naturally due to the number of layers that will have to be laid.

Summary & Conclusions

1. For same loading intensities, greater settlement rate was obtained at 45% moisture content.
2. In the case of heavier loads, a high initial settlement followed by low rate of subsequent settlement was observed, while in the case of lower loading intensities, the reverse trend was observed.
3. This obviously indicates that the total settlement can be achieved within a shorter period by heavier loads.

4. The maximum density attained after 2 months was 40.5 lb/cu ft. under 5 psi load at 45% moisture content. As compared to this, the test for optimum moisture content gave maximum density of 64 lb/cu ft.
5. In the case of repeated loading, subsequent settlement after the initial settlement were not appreciable.

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DISCUSSION

Dr. V. Chalapati Rao: What are the temperatures attained in the pits and tubes? This information is essential to guess the survival time of viruses in the compost.

Shri A. D. Bhide: Continuous measurement of temperature was not done in these experiments. However, composting of refuse in pits, when properly done, is known to generate and sustain temperature in the range of 50°—60°C. These conditions are known to help kill most of the pathogens and parasites.

Shri M. Miakhan (Madras): Would the author recommend the dumping ground as building sites after critically examining the results of his experiments? From item (4) of the conclusions as given in the paper the density obtained in the field at optimum moisture content is 40.5 lb/cu ft and the laboratory result is 64 lb/cu ft. The natural soil dry density at optimum moisture content is about 90 lb/cu ft. Hence, there is likely to be continued settlement which will include quicker or very early use of these sites as building sites, etc.

Shri A. D. Bhide: It may be mentioned that the density of 40.5 lb/cu ft was obtained only after 2 months at the end of the primary consolidation phase. It will be desirable to use such site for construction purpose only after the total settlement has occurred.

It may be mentioned that in USA, by using some modified methods of sanitary landfilling, airports for jet aircraft have been constructed on such sites.

Shri N. M. Basu (Durgapur): Whether the effect of cohesive forces from soil and refuse on stems of settling plate were considered while calculating the settlement.

Shri A. D. Bhide: The factors given by R. Stone and his associates which were used in this study consider them.

Shri V. D. Kothiwale: Regarding the use of the recovered land after refilling with solid refuse, it seems that buildings construction may not be possible. Can one consider the possibility of growing plants or vegetables on such a land using feed of controlled nutrients? This case is similar to 'Hydroponics'.

Shri A. D. Bhide: Plants and vegetables can be grown over such sites quite profitably.

Shri V. Krishnamurthy (Chanda): The straw dumped in refuse dumps, with the contact of moisture, attract white ants and affect the buildings in vicinity gradually. How can this be erradicated?

Shri A. D. Bhide: Spraying of chemical disinfectants, when done properly, can prevent such a situation.

Shri R. Paramasivam (Nagpur): For the compaction studies in the field, the depth of filling of refuse has been chosen as 4 ft. Since the percentage of compaction for a particular loading would depend upon the depth of filling, it is essential to correlate the degree of compaction with depth of filling for different loading intensities. This would help to evolve the optimum depth of filling required to obtain maximum compaction for a particular load intensity. Also, this factor may be partly responsible for the difference in the degree of compaction obtained in the laboratory studies using cylinders.

Shri A. D. Bhide: In the field, the filling depth varies from 3 to 15 ft, depending upon site conditions, equipment being used and refuse characteristics. However, commonly a depth of 3 to 5 ft is used. Hence, a depth of 4 ft was used in this study. The lesser depth in the cylinders was one of the factors responsible for larger settlement, as mentioned in the paper.

Dr. K. L. Saxena: It has been shown in settlement studies that at 7.5 psi at 30% and 45% moisture contents the settlement is more or less same but at 2.5 and 5 psi the values are very small. I would request the authors to explain the reasons and also explain how the moisture content was kept constant.

Shri A. D. Bhide: The heavier loads give comparatively larger immediate settlement which gives a high density which is nearest to that obtained at optimum moisture content. Consequently, the difference in settlement at such heavy loads at normal and optimum moisture content was not much appreciable. The moisture content given was measured at start of the experiments and as the material was not directly exposed to outside forces, it was presumed to remain constant.

PROC. SYMP. ON ENVIRONMENTAL POLLUTION (1973)

Studies on Pollution of Ground Water by Solid Wastes

A. D. BHIDE* and V. U. MULEY*

Studies have been carried out on a field model to study the nature and amount of impurities introduced into the ground water, due to the present practice of dumping of solid wastes by many municipalities in low lying areas below or near the ground water table. The amount of pollution caused will obviously depend mainly upon the characteristics of the solid wastes. In this study, water was allowed to flow horizontally through a mass of Nagpur city refuse (750 kg) at the same rate as that of ground water. The leachate was collected and analysed every day for various characteristics. Some important observations are presented in the paper.

Introduction

Presently, most of the Indian Municipalities are observed to dump the city refuse in low lying areas. At such low lying areas the dumped material often comes in contact with the ground water and pollutes it. Run-off from solid waste mass is reported to cause pollution of surface waters. The movement of water to and away from such sites located near sea shore also leads to pollution of the sea water.

The physical pollution introduced into such water can be in terms of turbidity and colour introduced by the waste. In the case of waste mass undergoing anaerobic decomposition, H_2S adds to tastes and odour.

The major pollution introduced by the city refuse is chemical in nature and the extent of pollution increases as the size of refuse particles is reduced. This has been noticed in U. K. where refuse is commonly pulverised before tipping(1). Carbon dioxide produced during the aerobic reaction combines with water to form H_2CO_3 and dissolve Mg, Ca and Fe from surrounding strata. These wastes are also observed to contribute a large amount of hardness, BOD and chlorides.

The amount and type of pollution introduced will naturally vary depending upon the characteristics of the refuse. As Indian city refuse is known to have much different characteristics than reported elsewhere, it is necessary to study these for Indian conditions.

It is well known that the maximum pollution will be caused when the water is in continuous contact with the refuse. Such a situation occurs when the refuse is placed below ground water table. Studies carried out to assess the pollution under such conditions are reported in this paper.

Nagpur city refuse was used in this study and its physical and chemical characteristics are given in Table I and Table II respectively.

Experimental Set-up

Studies were carried out on a M. S. field unit of 1.60 m x 0.84 m x 1.66 m deep **(Fig. 1)** Stiffened honycombed jaalis were provided

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* Scientists, Central Public Health Engineering Research Institute, Nagpur-20

TABLE I—PHYSICAL CHARACTERISTICS OF REFUSE

Particulars		Values
Leaves	...	1.45
Fruit & Vegetable Matter	...	3.79
Hay & Straw	...	12.90
Paper & Cardboards	...	1.99
Plastics	...	0.27
Rags	...	0.64
Glass	...	0.19

Note : All values are given in percentages and are calculated on wet weight basis.

TABLE II—CHEMICAL ANALYSIS OF REFUSE

Particulars		Values
Moisture	...	41.88
pH	...	7.9
Organic Matter	...	32.54
Carbon	...	18.87
Nitrogen	...	0.697
Phosphorous as P_2O_5	...	0.867
Potash as K O	...	0.842
C/N Ratio	...	27.02

Note : All values are calculated on dry weight basis, except moisture, and all values are given in percentage, except pH & C/N.

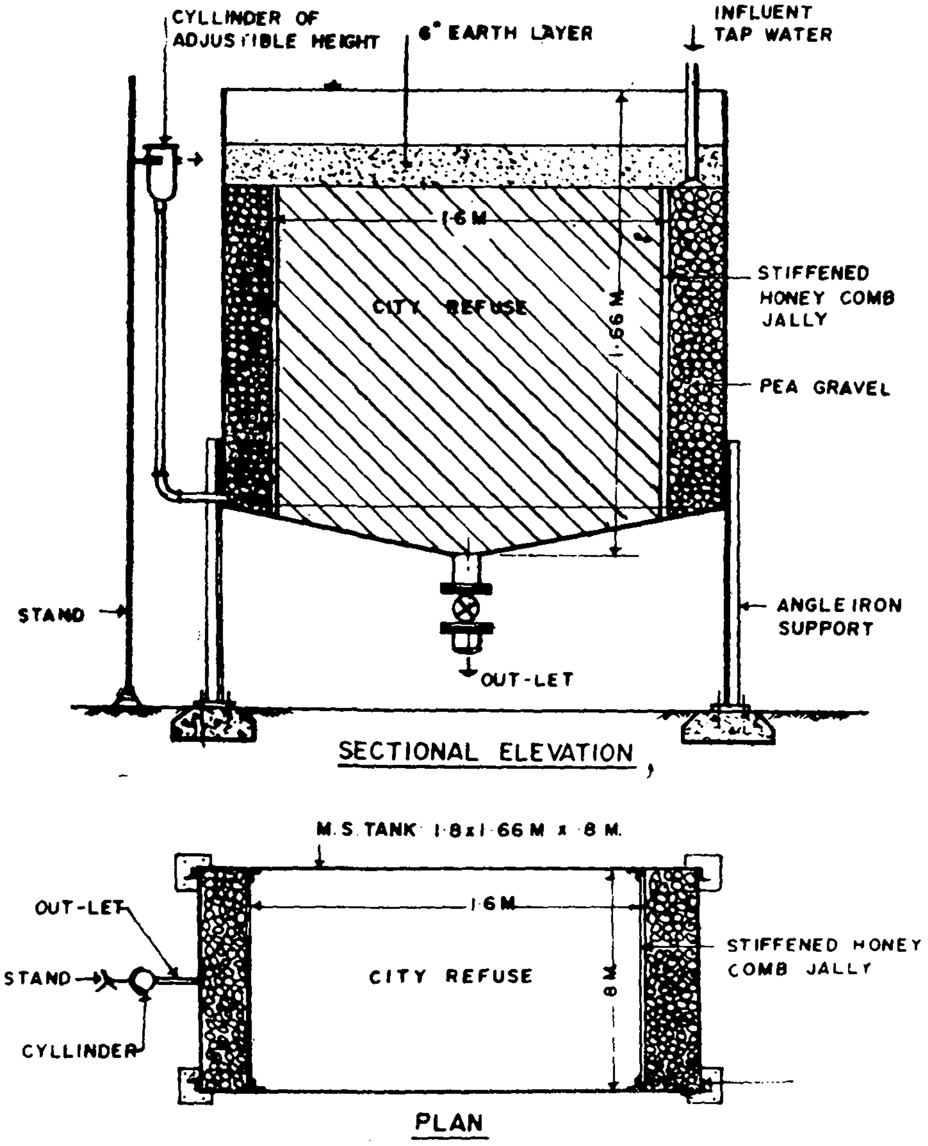

Fig. 1—Experimental Unit for Leachate Characterisation

6 in. from either end of the tank throughout the depth, so as to support pea gravel. These jaalis and pea gravel provided physical support to refuse to be placed in the tank and also checked its caving in. The pea gravel was also helpful in equally distributing the influent water and thus maintaining a constant velocity of flow of ground water.

The space between the two screens was filled with refuse in layers 9 in. thick compacted to 6 in. thickness. The effluent was taken out of the tank through an opening at the bottom on outlet side via a PVC tubing into an adjustable cylinder. The overflow from this cylinder was collected in a tank. Tap water was fed over the pea gravel at a constant rate at the influent end of the tank. The adjustable cylinder on outlet side was adjusted at a level so as to give outflow at the desired rate.

After filling the tank with refuse for 1 m depth, it was covered with 0.3 m thick earth layer. Water was allowed to flow through the refuse at the same rate as in the case of ground water and the leachate was collected in a cylinder. Leachate collected during 24 hr. period was thoroughly mixed and then sample was taken from it for analysis. The sample was analysed for the various parameters such as pH, hardness, alkalinity, chlorides, sulfates and BOD by following the 'Standard Methods'(2).

Results and Discussion

Chlorides:: At the start of the run, very high values such as 1500 mg/l were obtained which, however, immediately came down below 1000 mg/l within a week's time. Within a fortnight, the values further came down below 200 mg/l and in one month, below 100 mg/l. After this, the values were further decreasing but at a much slower rate and after the sixth week, values below 50 mg/l were always recorded. The values obtained are plotted in Fig. 2.

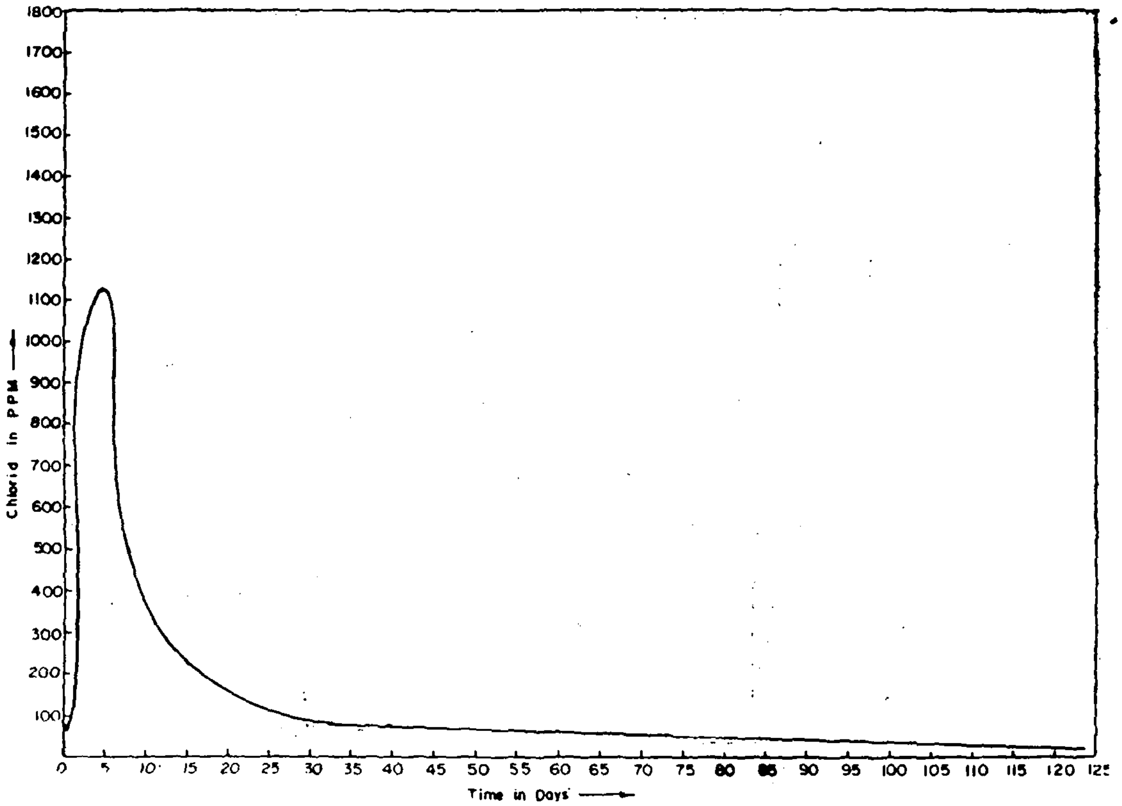

Fig. 2—Characteristics of Leachate—Chlorides in PPM

***Hardness*:** After attaining a high value of 2704 mg/l, the values rapidly decreased and were less than 1000 mg/l by the end of first week. The hardness on subsequent days further decreased and were below 500 mg/l at the end of the second week. After this, the hardness was always less than 500 mg/l, the values fluctuated in the region between 100 and 200 mg/l, till 4½ months when the run was discontinued (Fig. 3).

BOD: The initial high values (5900 mg/l) decreased at a rapid rate and were below 1000 mg/l after about 2½ weeks. The values continued to decrease further and were 300, 100 and 50 mg/l after 1, 2 and 2½ months respectively. After 3 months the values were below 10 mg/l and remained in this region (Fig. 4).

***Sulphates*:** After registering high values for a week, the sulphates were absent later on. However, after about 7 weeks, concentrations less than 10 mg/l were again recorded (Fig. 5).

***pH*:** In the initial stages pH was just alkaline (7-8) and it was in the acidic range of 6-7 after 2 months. However, after 2 more months, pH came back to the alkaline range of 7—8 and continued to be in this range. Thereafter, it was always less than 8.3, indicating bicrabonate alkalinity only (Fig. 6).

Thus, it could be seen that upto 1 month from the time refuse was exposed to leaching action, the leachate contained excessive pollutants. After 2 months, the values of all other pollutants were within limits, except hardness which continued to be quite high. The pH also changed to acidic range After about 4 months from the start, most of the parameters, except hardness, registered values below permissible limits.

The total quantities of chlorides, sulphates and hardness that were leached during 4½ months from Nagpur city refuse were 3.904, 0.278 and 9.586 kg respectively. These quantities were higher than the values reported in U. S. conditions (3, 4, 5).

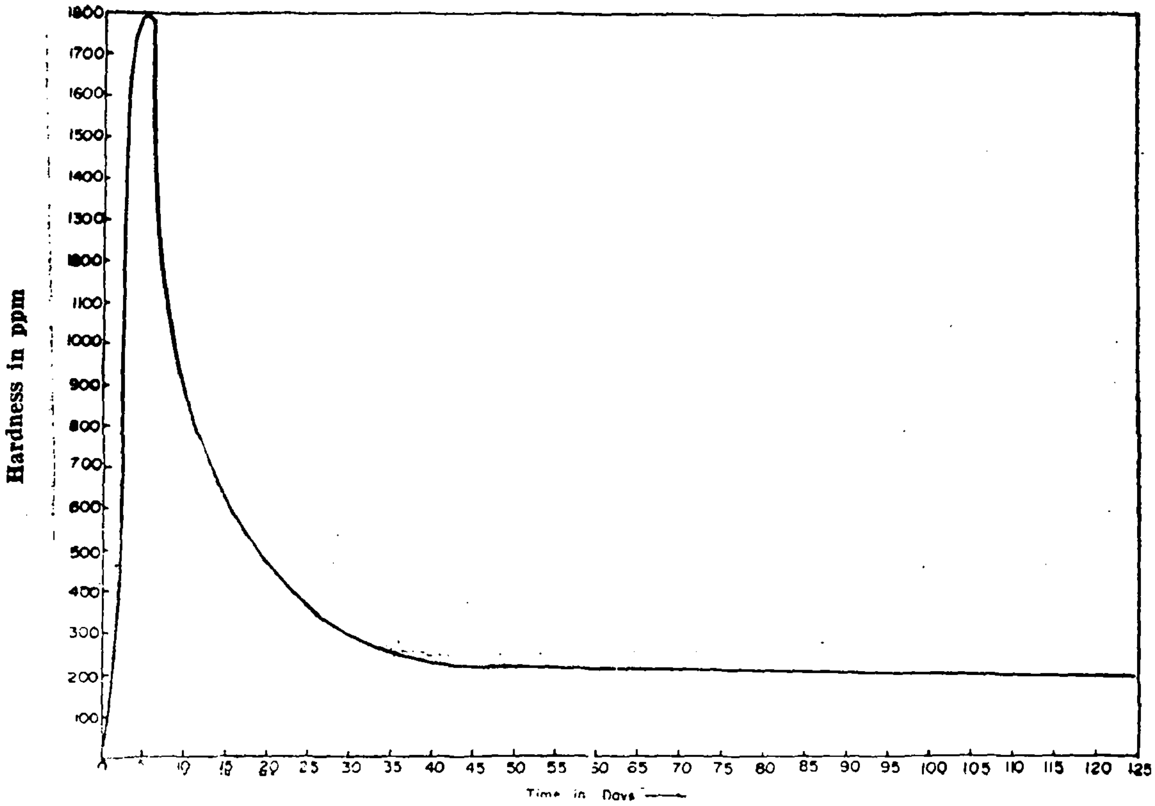

Fig. 3—Characteristics of Leachate—Hardness

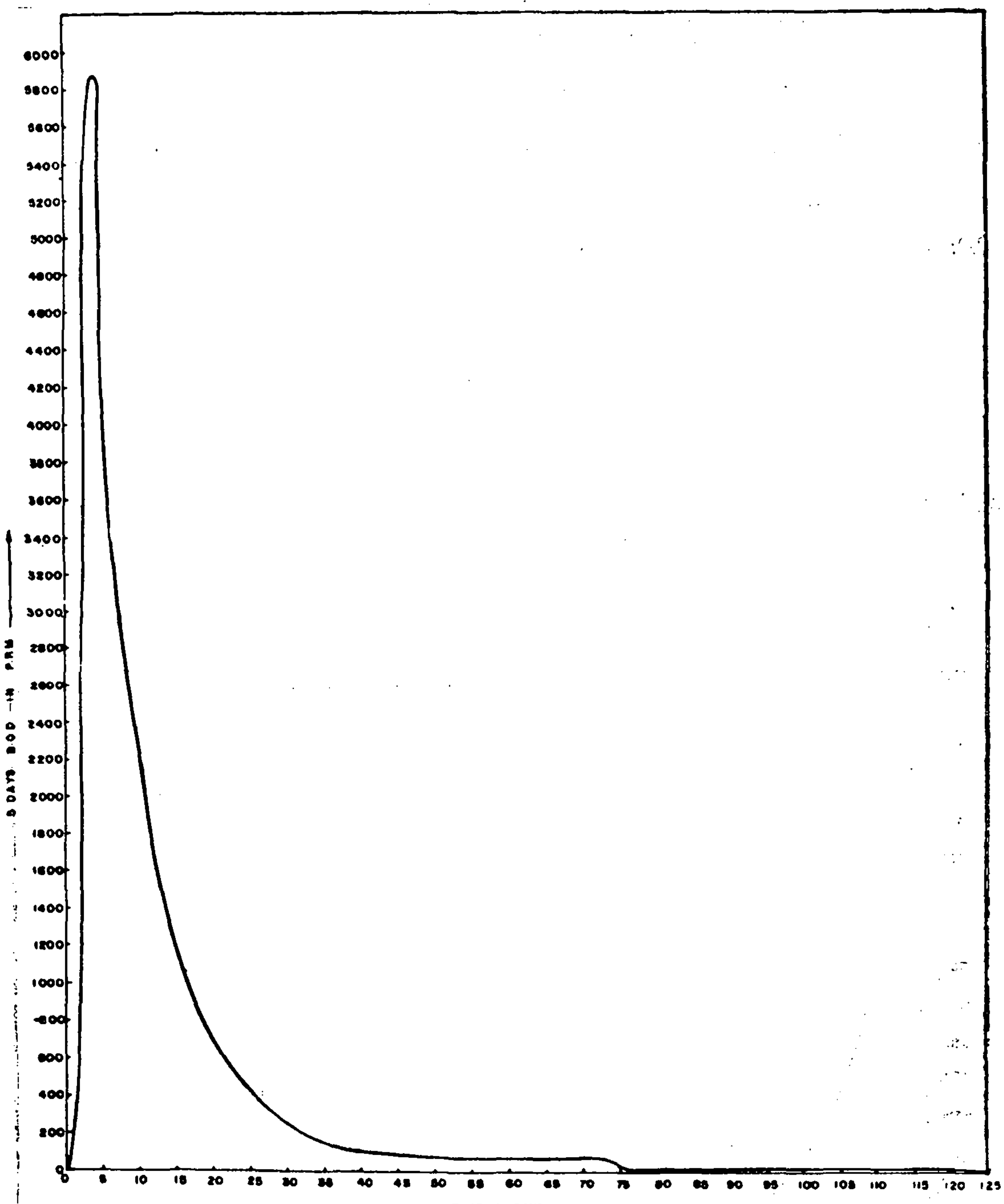

Fig. 4—Characteristics of Leachate—BOD

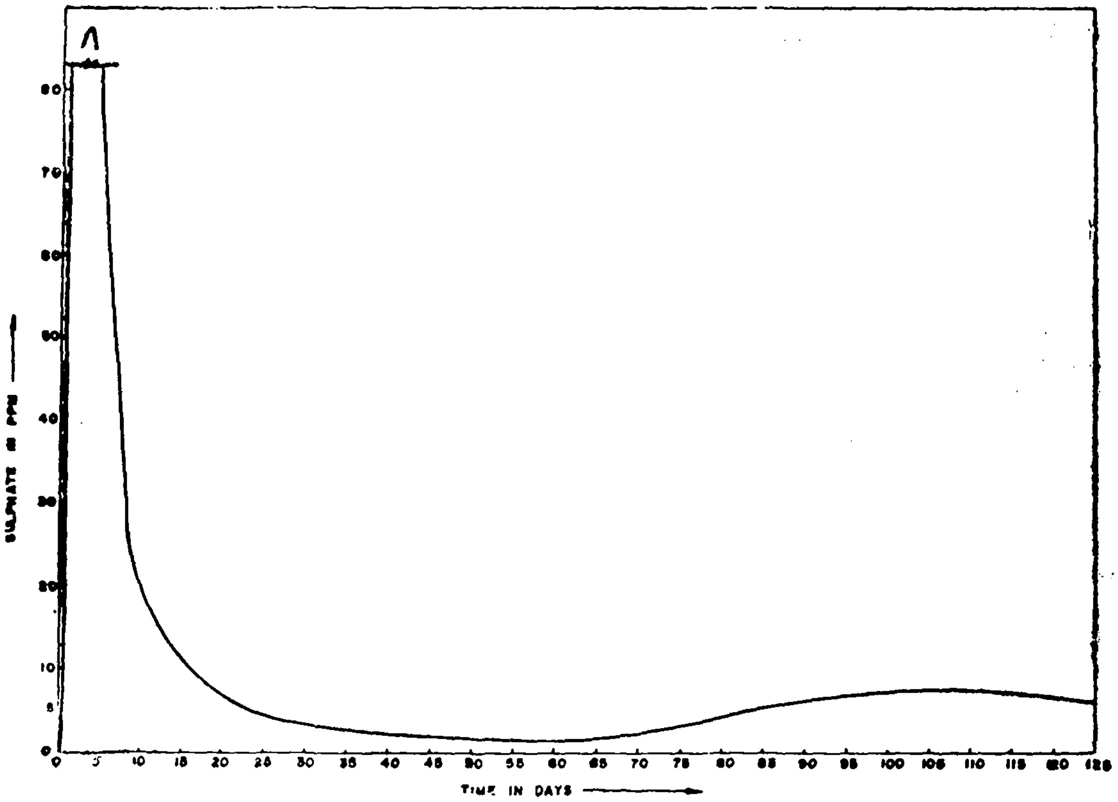

Fig. 5—Characteristics of Leachate—Sulphates

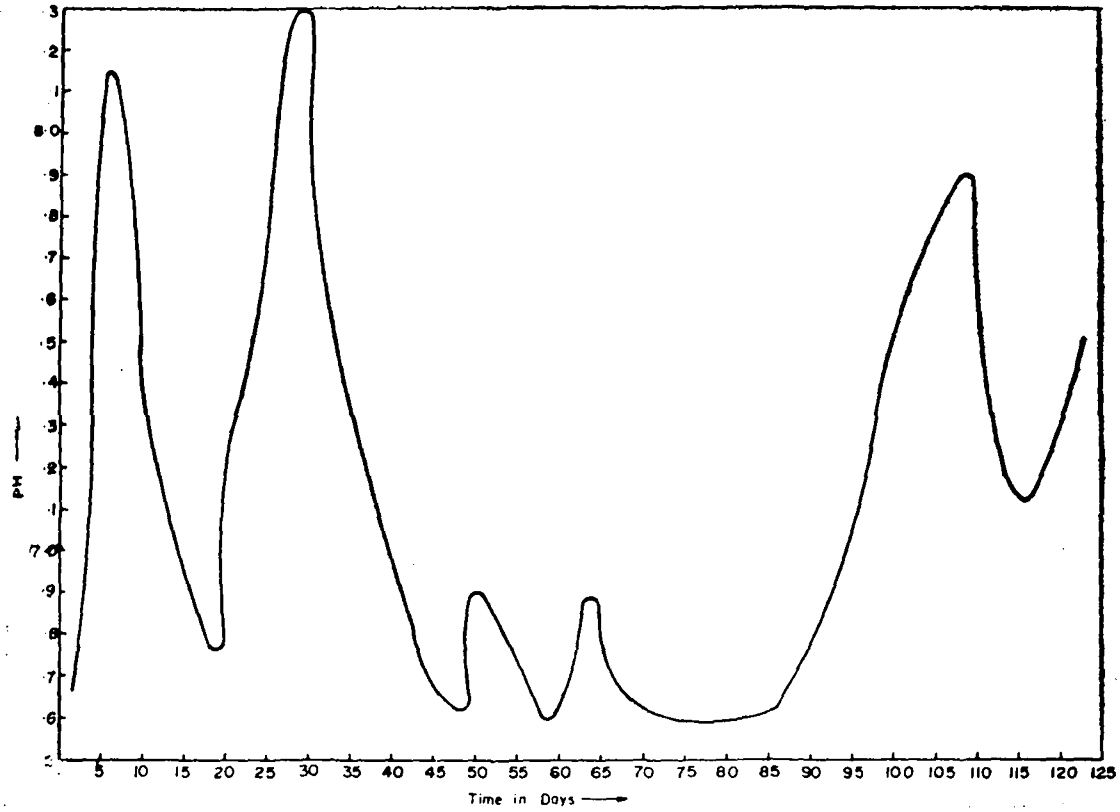

Fig. 6—Characteristics of Leachate—pH

Summary and Conclusions

Studies carried out on the concentration of pollutants in the leachate coming out of Nagpur city refuse showed that the quantities of chlorides, sulphates and hardness were much larger than those reported elsewhere.

Upto 1 month from the time the refuse is exposed to the leaching action, the leachate contains excessive pollutants. After 2 months, the values of all other pollutants are much less, while hardness continues to give quite high values. After about 4 months from the start, most of the parameters, except hardness, are within the permissible limits.

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DISCUSSION

Dr. N. A. N. Rao (New Delhi) : Is there any study on the pollution of air by noxious gases produced from solid wastes being dumped for disposal.

Shri A. D. Bhide : Gases resulting from spontaneous combustion of material at such dumps are known to cause a lot of air pollution. However, no specific analysis of such pollutants has been reported.

Dr. K. L. Saxena : It has been shown in graphs that sulphate values rise after fall but chloride and hardness show steady decrease. I would request the authors to explain this increase in SO_4 concentration.

Shri A. D. Bhide : The leachate contained sulphate in low concentration after about 7 weeks. These were found to change with changes in sulphate content in the influent tap water.

Shri J. M. Dave (New Delhi) : Leachate characteristics do not give the pollution potential unless worked out quantitatively, say as percent content per unit weight of refuse. Also, extent of travel and its effect on soil should have been studied.

Prof. S. V. Patwardhan : The pollution effect worked out was on a closed system. It is likely to vary considerably in the field with dilution and diffusion in different directions. Perhaps pollution load per kg of dry refuse will be a good indicator. I would like to know author's views on this aspect.

Shri A. D. Bhide : The quantities of chlorides, sulphates and hardness leached out from 750 kg Nagpur city refuse, were 3.9, 0.28 and 9.6 kg respectively during 4½ months of this study.

This study was directed mainly to assess the quality and quantity of pollutants introduced in ground water by city refuse.

The travel of such pollutants through soil layer can form an interesting subject of a separate study.

Shri S. Mukherjee : I wish to know whether any analysis was made regarding bacterial pollution of water. If so, what was the result?

Shri A. D. Bhide : Estimation of bacterial pollution did not form a part of this study.

Dr. C. K. Ramachandar : Solid wastes from chemical and fertiliser industrial area are also dumped in municipal dumping area or industries own dumping area. How are these leached and how do they pollute water sources?

Shri A. D. Bhide : The industrial solid wastes encountered in this study were mainly textile based and did not pose any problem. The extent and type of pollution introduced by industrial solid wastes mentioned, will have to be found out experimentally.

Shri V. Raman : Leaching of refuse dumps into the creeks and polluting them is a problem in Bombay. Trial bores going upto 8 ft depth indicate that the leachates contain a BOD varying from 200 to 800 mg/l for filtered and from 600 to 2000 mg/l for unfiltered ones. Some of these areas are 4 to 5 years old and still continue to leach out highly polluted liquid. The creeks nearby also show high BOD. Sometimes undecomposed rags are also found 4 to 8 ft below the dump even if they are 4 to 6 years old. During high tides the creek water enters into the dumps and during low tide the water goes back to the creek after leaching through the dumps.

Shri A. D. Bhide: As compared to the conditions mentioned by Shri V. Raman, in the experiment setup as described in this paper, the tap water was used which had sufficient dissolved oxygen in it. Due to this dissolved oxygen, reaction was essentially aerobic in nature though in some stages partial anaerobic conditions also developed. Due to this nature of reaction the material was stabilised much earlier.

PROC. SYMP. ON ENVIRONMENTAL POLLUTION (1973)

Solid Waste Disposal in Field Areas

M. S. BOPARAI* and R. N. VARMA**

It is well documented in military history that the losses of men in War from sickness far exceed the losses due to battle wounds The Diarrhoea-dysentery complex is one notable example of an excremental infection that thrives under "tropical" conditions with depressed standards of environmental sanitation. One of the most troublesome problems in field areas is satisfactory disposal of human excreta and an important aspect governing its disposal is that the method(s) used should be simple though based on scientific principles.

The paper outlines principles of waste disposal in the field and presents advantages and disadvantages of the different types of latrines for use in the field areas, *viz.*, hand flushed water seal, deep trench and pan type latrines. It is stated that water seal and field flush latrines are now taken into use in the services for disposal of human excreta in the field areas.

Introduction

Health is intimately linked with environment. Hazards to man's health arising from environmental factors are multifaceted; environmentally transmitted diseases alone being responsible for untold sufferings inflicted on mankind. Provision of adequate and wholesome water supplies, sanitary disposal of excreta and other waste products, and community sanitation are important in promoting physical, mental and social well-being of man.

Solid waste disposal is a serious problem all the world over and a number of W.H.O. Expert Groups have highlighted the close association between an unhealthy environment and the health status and economic conditions of a community; they have recommended that high priority should be given to waste disposal projects on a global basis. The same holds true for the health and fighting efficiency of the "Soldier"@, with added importance in field areas.

Military hygiene has many achievements to it's credit, which have added materially to the fighting efficiency of the Armed Forces. Hygienic disposal of solid waste matter which is important aspect of the practice of military hygiene, is an essential component of the soldier's environment, particularly so in field areas where conditions remain fluid and ever changing in response to operational commitments. Efficient disposal of human excreta is one of the most important but difficult sanitary tasks, in such situations. Intestinal infections common to man are transmitted by faecal discharges of sick persons or carriers of disease. Unhygienic disposal allows these discharges being carried to the mouth of the next victim by way of flies, drinking water, food or soiled hands.

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* Director Medical Research.
** Asst Director General (Health)
} Office of the DG AFMS, Ministry of Defence, 'M' Block, New Delhi-1.

@ Connotes a member of the Armed Forces, namely Army, Navy and Air Force.

It is well documented in military history that the losses of men in war from sickness originating from the germ seeds sown in the environment by faulty hygiene far exceed the losses in the battle wounds. In almost every campaign, intestinal diseases make their appearance, the incidence of which varies inversely with the efficiency of the disposal of waste matter; its successful accomplishment playing an important part in the conservation of manpower. The diarrhoea-dysentery complex is one notable example of an exceremental infection that thrives under tropical conditions with depressed standards of environmental sanitation. When insanitary conditions, in particular, unhygienic disposal of human excreta prevail in unit lines, the latent reservoir of infection, already present amongst the unit personnel gets triggered off by the agency of flies, which also find in human excreta ideal sanctuaries for breeding, thus perpetuating the vicious cycle. The person-to-person spread of infectious hepatitis culminating invariably in an outbreak is another troublesome disease which occurs when disposal of human excreta is faulty, and raises its ugly head off and on, thus impinging on the soldiers' health, vitality and stamina.

Principles of Waste Disposal in the Field

Solid waste matter in field areas can be grouped into: (i) human excreta; (ii) animal excreta and (iii) general camp refuse including kitchen garbage; dead animals and offals from slaughtering places.

The primary object in the sanitary disposal of solid waste matter is to render it harmless, which means that (i) pathogenic germs are eliminated and hence sources of infection reduced; (ii) its nature is so changed that it does not become a breeding ground for disease carrying and other annoying and obnoxious insects; and (iii) it causes no offence by vapours, smell etc., either before or during the process of disposal.

In order to achieve a high standard of field sanitation, strict sanitary discipline is enforced; but success can be achieved only if it is supported by willing coopeation based on a knowledge of the elementary principles of camp sanitation. Health education, therefore, assumes a significant role in imparting adequate information to the soldier on the methods of waste disposal , which on active service have to be necessarily simple and based on practicable principles rather than theory. Improvisations have often to be resorted to, particularly in mobile warfare. Overelaboration is often a more serious fault than defect in principle, and should be avoided. A high standard of sanitation need to be set and the methods should be those which are capable of being attained by all under active service conditions, as modified by the season, place, climate and type of campaign. Modifications to the standard sanitary methods and equipment should, however, be as few as possible, the principle should be to have one simple design with only such minor modifications permitted as are essential to meet the local conditions. Additionaly, the standards adopted should demand minimum of men, material and effort.

The various methods of disposal of solid waste matter depend on the length of stay in a particular place and based on this Armed Forces camps are grouped as permanent, semi-permanent and temporary. Permanent camps are the peace time Garrison Stations and Cantonments; semi-permanent camps are those lasting less than a year and temporary ones lasting six days or less. This grouping serves only as a guide. In peace stations, the Armed Forces to a large extent are served by the civil sanitary services but in field areas they have to be self-sufficient in all methods of solid waste disposal.

Sanitary Disposal of Human Excreta in the Field

Of all the solid waste matter required to be hygienically disposed off in field areas, efficient disposal of human waste is the most important. In mobile warfare, improvised methods based on trenching and incineration are used for disposal of human excreta while under static conditions in semi-permanent camps Deep Trench Latrines have been traditionally and are currently being used for this purpose.

A satisfactory latrine installation according to Ehlers *et al.* (1) as adopted by Wagner (2) should satisfy the following criteria :

(i) The surface soil should not be contaminated.
(ii) There should be no contamination of the ground water that may enter springs or wells.
(iii) There should be no contamination of surface water.
(iv) Excreta should not be accessible to flies or animals.
(v) There should be no handling of fresh excreta; or when this is indispensable, it should be kept to a strict minimum.
(vi) There should be no odours or unsightly conditions.
(vii) The method used should be simple and inexpensive in construction and operation.

Deep Trench Latrine

This latrine consists of a trench which is 3 ft wide; at least 8 ft deep; and of a length suitable to the size of the wooden superstructure provided, 10 ft being the usual length (Fig. 1). If there is any danger of the sides collapsing, they should be revetted with sand bags, wire netting, or bamboos. If sand bags are used, the trench should be 4 ft, 6 in wide to allow for the bags. The ground for a distance of 4 ft all round the trench should be dug to a depth of 3 in. and the loosened soil removed. Strips of oiled sacking, each 5 ft wide, should be spread over this prepared area, as a barrier against ingress/egress of flies.

The superstructure is of squatting type consisting of flat table top like structure fitted with five lidded apertures; each aperture being 14 in x 10 in. The superstructure is borne on a suitable number of joints which should overlap the edges of trench by 2 ft.

The latrine needs a high level of efficiency in its maintenance; bad one resulting in fly breeding and early filling of the trench.

This latrine has the following advantages over all other possible systems of disposal in a semi-permanent camp **viz.** pan system and trenching :

(i) Faeces do not need to be removed from one place to another for final disposal.
(ii) Once the trench is prepared and the superstructure erected no further effort is required until the contents reach within 2 ft of the surface.
(iii) No pails to receive, nor carts to remove faeces are neded.
(iv) No incinerators, with their special staff and fuel problems are required.
(v) Sweepers can be reduced from ten per battalion to one or perhaps two.
(vi) Above all, the surface of the ground does not become contaminated by spillage.
(vii) Provided the trench is not sited within 100 ft of the source of water supply, there is no danger of contaminating the underground water supplies.

The DTLs though provide a method for "on-the-spot" disposal of human excreta are difficult to maintain, particularly in terrains where subsoil water is high and the carriage of bulky wooden superstructure at times becomes a problem in actual operations. They may also provide access to flies if proper care is not taken in their use, creating positive health hazards for troops.

Pan type latrines which unfortunately are also used, in some areas, violate most, if not all, of the criteria of a satisfactory latrine. Though they are cheap in their initial cost, they prove to be very expensive to operate and maintain and in addition pose health hazards.

Efforts have, therefore, been made to develop substitute methods of disposal of human excreta in field areas to replace DTLs and the pan type by a better type of latrine installation.

Water Seal Latrine

As a part of the programme to improve environmental sanitation in the villages, a

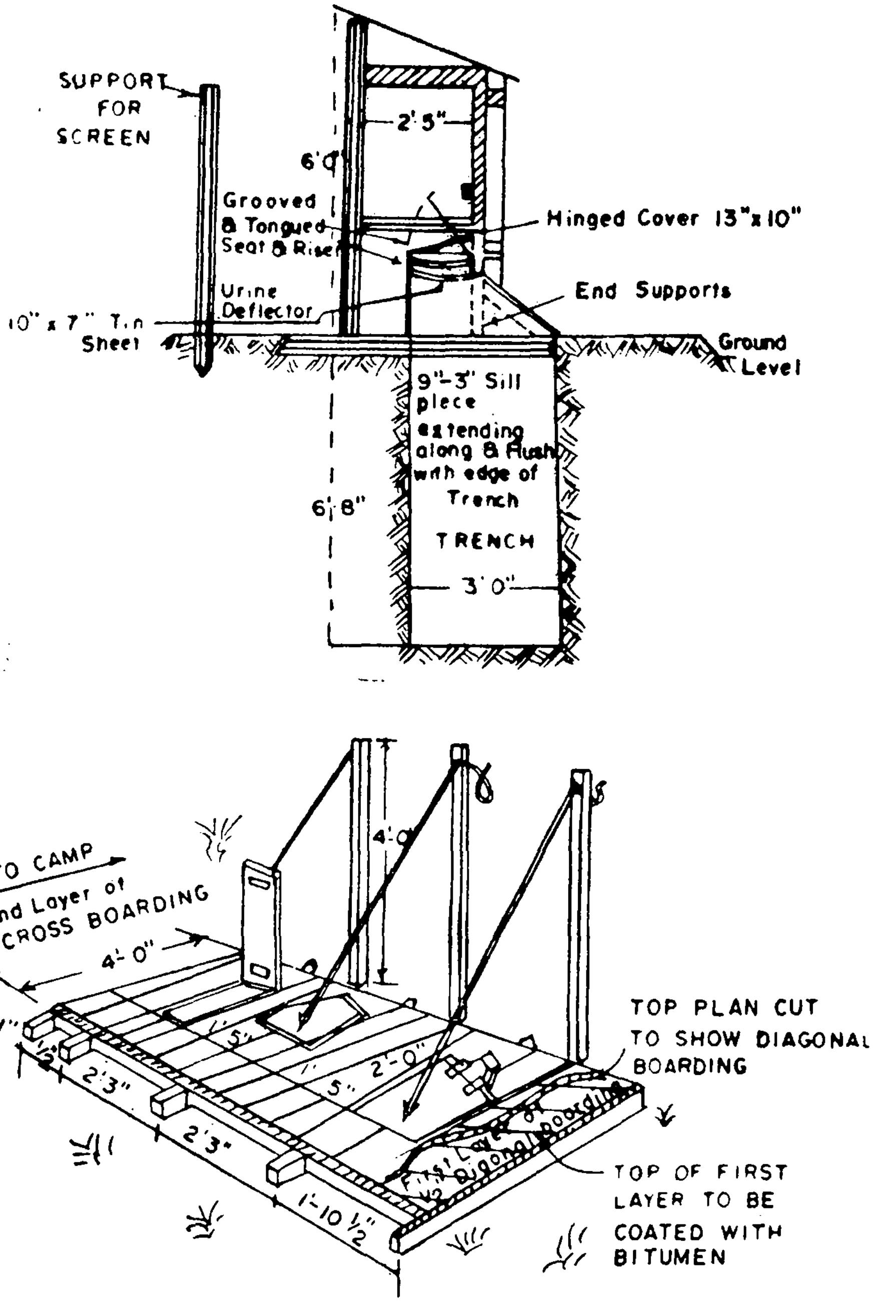

Fig. 1—Deep Trench Latrine

cheap water seal latrine for use in rural areas was evolved as a result of collaborative efforts between various agencies such as, the Research-cum-Action (RCA) Project in Environmental Sanitation of the Ministry of Health; Govt. of India; the Planning, Research and Action Institute of the Govt. of Uttar Pradesh; the Environmental Sanitation Project of the Govt. of Kerala; the American Friends Group in Orissa and the Indian Council of Medical Research. The latrine (PRAI) developed by the Planning, Research and Action Institute of the Govt. of Uttar Pradesh was ultimately adopted for introduction in the villages through the Community Development Programme.

A detailed study carried out on the adoption of this latrine for disposal of excreta in semi-permanent camps was carried out in the early 1960s and a decision in principle was taken to introduce this latrine in semi-permanent camps as the next best alternative to waterborne sanitation which, for obvious reasons, cannot be used in field areas. Extensive field trials were carried out to assess the suitability of this latrine for adoption in the services.

(a) *Design of the Latrine*

It is a pour-flush, lateral pit, water seal latrine. The design is illustrated in Fig. 2. The latrine consists of: (i) a pan; (ii) a P-type trap incorporating a ½ in water-seal; (iii) a lead-off pipe connecting the trap to the pit; it is given a curved shape so as to facilitate the use of a second pit, without having to shift the pan, when the first pit is filled; (iv) a squatting plate or floor, 3 ft x 2 ft 6 in with foot rests; and (v) a pit, 2 ft 9 in in diameter and 6 ft to 8 ft deep, situated behind and slightly to the side of the pan; it is a "kacha", unlined covered pit;

(b) *Location*

(i) Choose a site not flooded by rain. Avoid location of pit near drains or roof drains, as the water may cause collapse of pit.

(ii) Site the latrine as near to house as possible.

(iii) Do not site the pit nearer than 25 ft from a drinking water well.

(c) *Notes on the Use of Latrine*

(i) The latrine is not sanitary unless it is kept clean and flushed periodically by hand. Sanitary staff should make repeated visits to the latrine to ensure cleanliness.

(ii) One or two "lotas" of water used for ablution purposes are usually sufficient to flush the faecal matter into the pit. It is a good practice to flush each latrine seat with a bucket of water, morning and evening. Flushing should be done by throwing the water into the pan with a quick movement of the hand; gentle pouring will not be effective. Wetting the pan with a little water before use will assist in keeping the pan clean.

(iii) When the pit is full of solids, swing the curved pipe to discharge into the second pit. The material in the full pit will disintegrate and become suitable for use as manure within about six months. After removal of the manure the pit will again be ready for use. Pits can also be cleaned when full and then put to use while the contents of the other are aging.

(d) *Field Trials*

The field trials brought out the following salient points on their working:

(i) The latrines worked satisfactorily through out the trial period varying from 15-20 months.

(ii) There was no clogging of the latrines

(iii) There was no smell nuisance, either from the pans or traps or from the pits.

(iv) There was no fly breeding in any part of the latrines.

(v) One extra "lota" of water is required in addition to water used for ablution, for flushing the latrine.

(vi) Maintenance was easy and pan and squatting plate, were washed and cleaned, once a day.

(vii) Washing with plain water was enough; no need was felt for disinfecting or deodorising the latrines.

This latrine fully satisfies almost all the 7 criteria of a satisfactory latrine. It is cheap, sanitary, easy to install, operate and maintain. It, however, has certain limitations; it is difficult to use in places where the soil is impermeable and it cannot work at high altitudes in freezing temperature, for obvious reasons.

This latrine is ideal for a small unit consisting of 5 or 6 persons and in fact, it was designed primarily for the use of families.

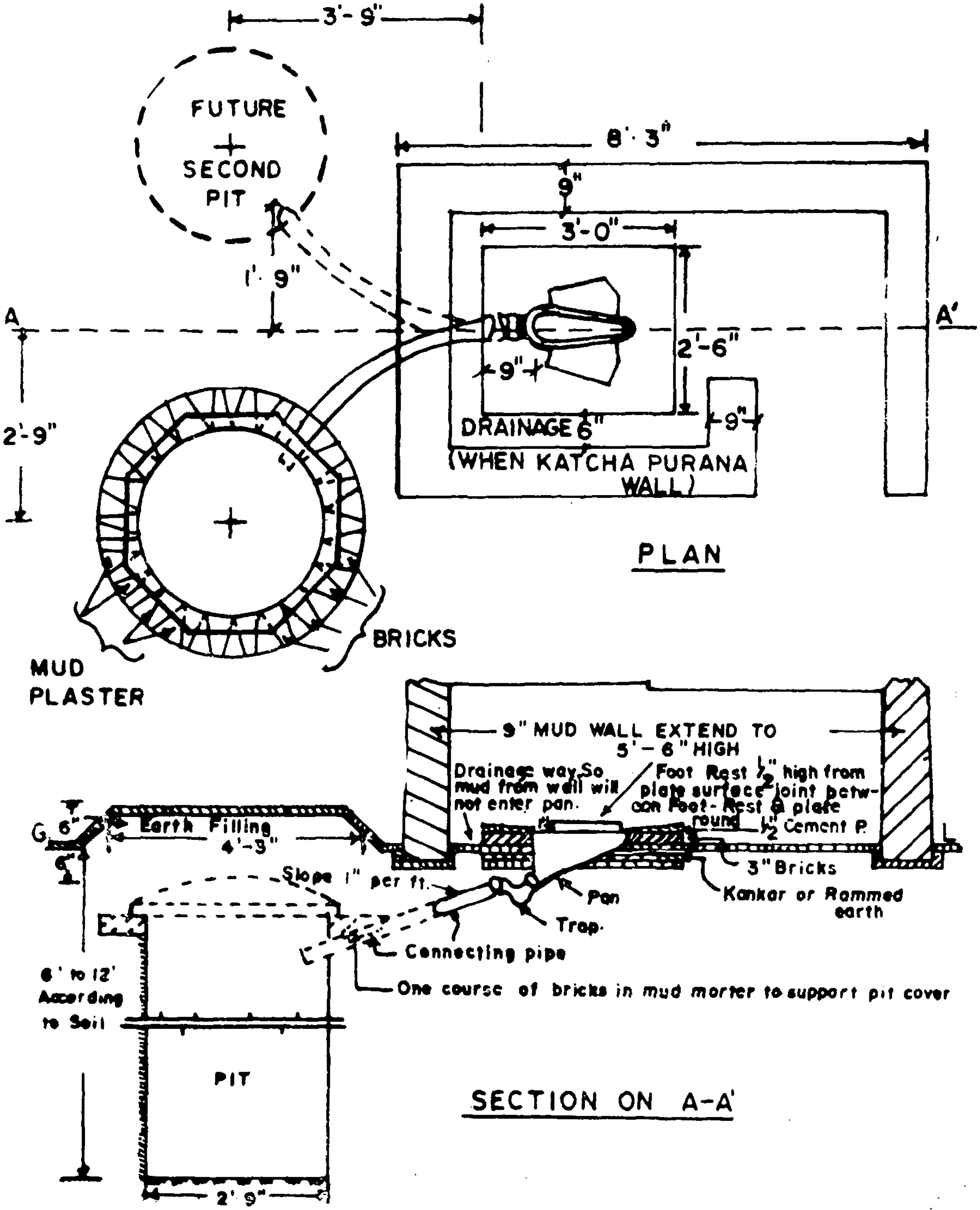

Fig. 2—P.R.A.I. Design Lateral Pit Water Seal Latrine

With suitable modifications in the design, this latrine has now been adopted for use in Garrison Stations where water borne sanitation cannot yet be installed due to prohibitive cost and shortage of water as in field areas. To meet the army requirements the latrine need to be a block of 5 seats connected by lead off pipes to a common pit with provision of an extra pit for alternative use to ensure efficient functioning for a longer period.

Development of a Field Flush Latrine

Another project entitled "Development of a Field Flush Latrine" was sponsored by the DG AFMS in collaboration with CSIR/CPHERI, Nagpur for designing a water sealed single unit superstructure for use over a deep trench latrine. The object of the superstructure with built-in water seal is to replace the bulky wooden seats, by lighter and more durable seats to obviate fly and smell nuisance as also to ensure easy transportation by units during moves in field areas/training/exercise camps.

The prototype superstructure incorporating the above specific service requirements consists of two pieces: (i) A squatting platform, and (ii) A pan—which fits into the squatting platform.

The drawings of the superstructure are shown in Fig. 3. The unit is prepared from fibre glass reinforced material known as GRP; the plastic material being used is polyester resin which is impervious and easily washable. It is also claimed to be strong enough to withstand rough usage by troops under strenuous field service conditions.

The squatting platform is 5 ft x 2½ ft having an opening in its middle for fitting the detachable pan. The platform is provided with two footrests, one on either side of the opening, each being 4 in high, 4 in wide at the anterior end and 2½ in at the posterior end; and are 12 in. apart. The opening for the pan has an alround edge or flang 2 in. wide and is not at level with the surface of the platform but is 1½ in. lower. The pan rests on this edge. The platform is strengthened by three longitudinal ribs each (approx) 18 in. x 1½ in. fixed on the underface, on either side of the pan. No rib runs through the entire length of the platform. The outer edge of the platform is curved upwards (approx) 3 in. all round to give it more strength and toughness. The platform has ½ in. slope from either end towards the central opening for the pan. Due to this slope and upward curve of outer edge, any water falling on the platform is drained into the pan.

The size recommended as per qualitative requirement is considered bare minimum for giving proper strength to the platform and providing adequate elbow space to the users. A length of 1 ft of the platform on either side will rest on the edges of 3 ft wide trench (of DTL). This is for maximum bearing, taking into account the different soil conditions met with in the field.

The pan is 18 in. x 8 in. It has ½ in. water seal, and a 2 in. wide flange which rests on the 2 in. wide edge of the opening in the platform. The slope of the pan in the front and in the rest of the platform is 15° and 40° respectively.

The weight of the platform is 14 kg; of the pan 1.677 kg; total weight of a single seat superstructure being 15.677 kg. For connecting two or more platforms placed side by side, a connecting plate is also provided. It is a rectangular type channel of 4 ft-10 in x 9 in. 3 in. in size. It is placed inverted over the adjoining edges of the two platforms. It is, however, short by about 1 in. on either side (of the length of platform) for ease in placing and removal.

The thickness of the material used in the three pieces is: platform—4 mm; pan—3.5 mm and the interconnecting plate—3 mm.

The material used in the superstructure is not affected by light, chemicals like acids and alkalis and can withstand rough weather conditions of heat, cold and rain. It is fairly light; the total weight being not more than 15 kg, and therefore, easy of carriage.

The initial prototypes manufactured according to the above description were found

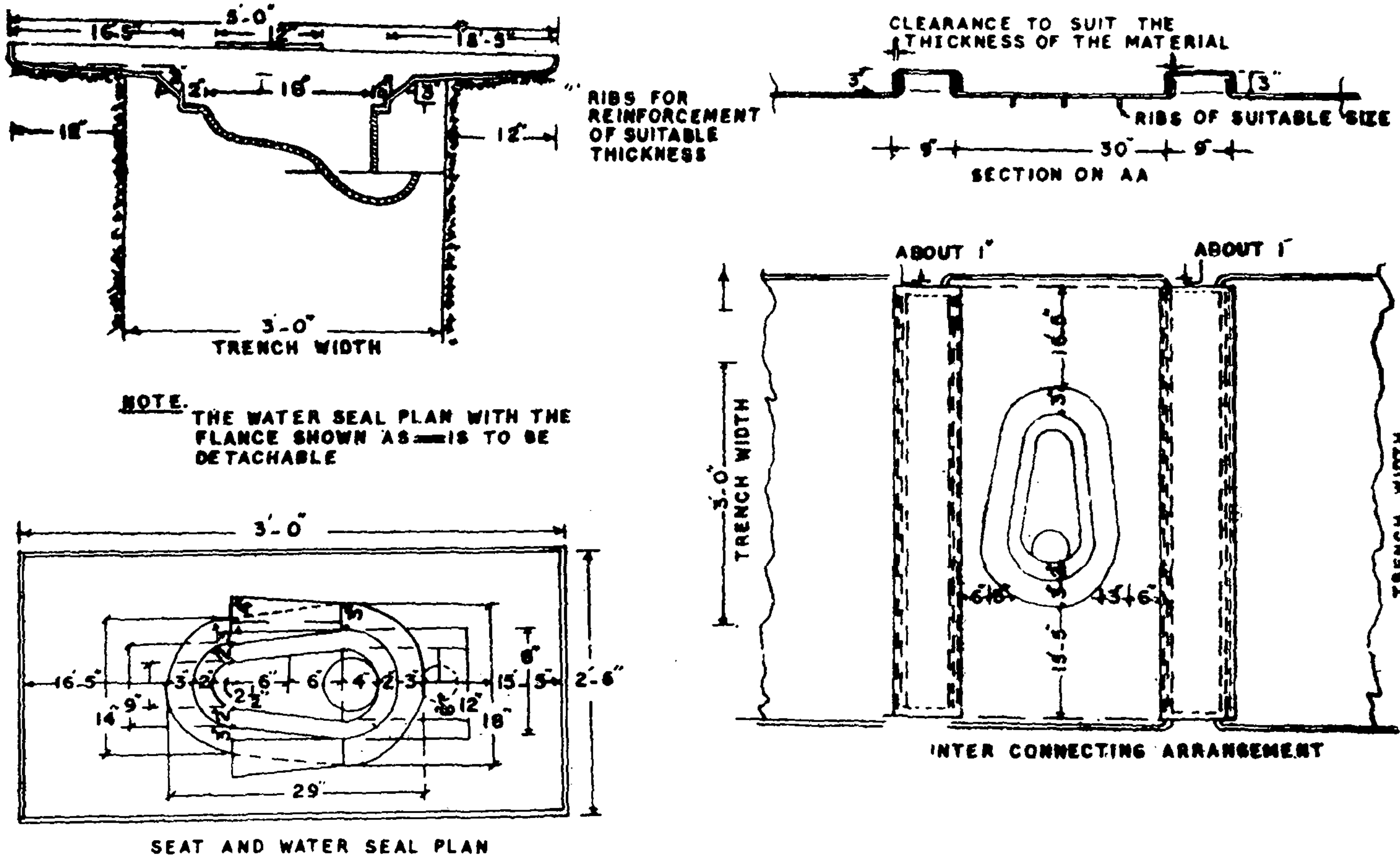

Fig. 3—Portable Flush Latrine Unit

to have some deficiencies and the following further modifications are being incorporated to suit defence requirements:

1. The overall length of the superstructure should be reduced to 4 ft, but the two longitudinal ribs, one on each side of the pan beneath the platform, be extended 6 in. on either side to facilitate hand grip, thus bring the overall length to 5 ft.

2. The distance between the two footrests should be reduced to 9½ in. only in the rear; in the front the distance being 12 in. The length, width and the height of each footrest should be 10 in. 4 in. and 1 in. respectively. The width of the foot rest (i.e. 4 in. should be uniform all along.

3. The width of the flange of the opening (for pan) in the platform should be 3/4 in. instead of 2 in. This will be required to shift the foot rests inwards as in (2) above. The flange should be made 6 mm instead of 4 mm to make it stronger.

4. The flange of the pan should also be about 3-4 in. wide and 6 mm thick. Its lower surface which is rough at present should be made smooth for proper fitting on the smooth upper surface of the flange of the opening in the platform.

5. The lower curve of the water seal is not smooth. It should have a unifotm smooth curve so that excreta does not get obstructed when flushed. The height of the water seal should be increased to ½ in. (instead of ¼ in. at present).

6. Two other ribs on the under surface of the platform should run throughout the length of the platform (one on either side of the pan). At present, there is no rib in the pan portion of the platform, which will bear maximum weight when in use. The proposed modification will give enough rigidity. However, placing the ribs near the outer edges and through the entire length of the platform will further improve the rigidity and the stability of the platform. The depth of the depression in the platform should be reduced to ½ in. from the existing depression of 1½ in.

7. The surface of the front portion of the platform which is smooth and will be used for approaching the pan is slippery. With a view to avoid slipping by users, the surface should have slight corrugated finish.

8. The connecting plate presently designed for connecting two or more platforms appears to be unnecessary, adding to the cost. Instead, one side-edge of the platform should be lipped in such a manner as to take in the edge of the other seat without any play.

9. The height of the edge of the platform should be reduced to 1 in. only except at the centre where it should be 1½ in.

The advantages and disadvantages of the water seal latrine/deep trench latrine/Pan Type Latrine are summarised in Appendix-I.

Summary

Sanitary disposal of human excreta in field areas is a problem to be reckoned with. Faulty disposal carries a number of hidden dangers which sap the health and vitality of the soldier. The deep trench latrine has been the method of choice till today for disposal of human waste in field areas, but this latrine has certain inherent disadvantages. Suitable substitutes for this latrine have been evolved over the last few years in active collaboration with the Civil Research Institutes in the Country. The water seal latrine and the field flush latrine which have been described and discussed in this paper have now been taken into use in the services for disposal of human excreta in the field areas.

APPENDIX-I

DIFFERENT TYPES OF LATRINES FOR USE IN FIELD AREAS ADVANTAGES AND DISADVANTAGES

Item	Hand flushed Water Seal Latrine	Deep Trench Latrine	Pan Type Latrine
Water Seal	Present	Not present	Not present
Fly nuisance	No fly nuisance. The water seal allows the excreta to be flushed through it and prevents access of flies into the latrine pit	The danger of fly nuisance is ever present. Constant supervision and high standard of maintenance is necessary to prevent access of flies and their breading in the trench. Inspite of best efforts, the risk of flies gaining access to the exereta is always present if the flap is left open due to the prejudice / carelessness , ignorance of the user/ sweeper.	It is very difficult to prevent access of flies to the excreta in the pans unless the latrines are properly fly proofed and maintenance is of a high standard. Inspite of best efforts the risk of flies gaining access to excreta is always present if the fly proofed doors are left open due to carelessness/ ignorance of the user/ sweeper.
Bad Smell	The water seal prevents emanation of bad smell from the pit.	Bad smell is usually present inspite of proper maintenance due to decomposing excreta in the latrine and fouling of the adjacent soil by urine.	Bad smell is present because the excreta remains exposed and urine soils the floor of the latrines.
Water Supply	It is suitable for use in areas where only a small quantity of water is available for use in latrines and where water borne system is not possible.	No additional water apart from ablution water is necessary.	Large quantity of water is necessary for clearing the pans and washing the floor and latrine seats.
Final disposal of faeces	No handling of excreta is involved for the final disposal of faeces. The excreta is disposed off directly into the pit behind the latrine seats through the water seal.	The faeces are disposed off direct into the pit under the latrine seats.	Handling of excreta is involved before it is finally disposed off either by incineration or by trenching. The danger of spillage of and soiling the ground is always present.
Location of pits	The latrine can be sited near or inside the place of residence/work. The pit is not directly under the latrine seats but is behind it. There is no danger if the pit were to fall in.	This has to be at least 50 to 100 yards away from living/working place. The pit is directly under the latrine. If the ground is soft/sandy, there is danger of an unlined pit falling in.	To be located at least 50 yards away from living/ working place.

Item	Hand flushed Water Seal Latrine	Deep Trench Latrine	Pan Type Latrine
Shifting of pits	The latrine does not need to be shifted. When one pit gets filled up, the excreta is diverted into the alternate pit by changing the direction of the connecting pipe. By the time the second one gets filled up the first is again ready for use. This will avoid frequent digging of new trenches which is usually difficult due to rocky nature of soil in mountainous areas and limited space available.	The site has to be shifted when the trench gets filled up. Normally, the site needs to be shifted every six months. After some time it becomes a problem to find place for digging trenches due to the limited land available in the vicinity of the unit. During the process of shifting the wooden superstructure often gets damaged and invariably needs replacement every year.	**Not involved.**
Aesthetic aspect	Presents the appearance and cleanliness of a good waterborne latrine	Squatting over the trench full of faecal matter and smell is not conducive to health and hygiene and to good living.	Smell of faecal matter and the sight of pens full of faeces are repulsive for the users.

References

1. Ehlers, V. M. and Steel, E. W., "Municipal and Rural Sanitation" 4th Edn. (1960).

2. Wagner, B. G., "Excreta Disposal for Rural Areas and Small Communities", W.H.O. Monograph, Series No. 39 (1958).

DISCUSSION

Prof. S. V. Patwardhan: The slope of the pan proposed in the drawing seems to be very flat. Were these latrines used in field?

Maj. Gen. M. S. Boparai: The design of the detachable Pan which fits into the squatting platform, conforms to the general layout of the whole superstructure. The size of the Pan is 13" x 8" and it has a ½" water seal. The opening for the Pan has an alround edge or flange 2" wide and is not at level with the surface of the platform but is 1½" lower. The Pan rests on this edge. The slope of the Pan in the front is 15° and in the rest of the platform 40°. The superstructure has not yet been tried under field conditions. The prototypes are being manufactured by the collaborating firm and are likely to be ready in the near future.

PROC. SYMP. ON ENVIRONMENTAL POLLUTION (1973)

Silicon Tetrachloride from Rice Hulls: A Novel Solution for A Solid Waste Disposal Problem

P. K. BASU* C. J. KING+ and S. LYNN+

Rice hulls, a waste from milling of rice, offer a very pure source of silica. Hence, experiments were carried out to assess feasibility of manufacture of $SiCl_4$ which is the most important halosilane commercially manufactured from these rice hulls.

The optimum conditions for pyrolysis and chlorination in the process of manufacture were worked out. Results indicate that the chlorination of rice hulls requires a considerably lower temperature for near complete conversions than required for mixtures of sand and coke.

A conceptual process for the commercial scale manufacture of $SiCl_4$ from rice hulls has been developed and the economic advantages of the process have been compared with the existing process. The proposed process is found to be economically much more attractive.

Introduction

Rice hulls, a by-product of the milling of rice, are the outermost covering of the rice kernels. About one-fifth of the weight of the harvested crop consists of hulls. The composition of rice hulls varies somewhat depending on soil composition, climate, etc. Numerous analyses have been reported in the literature (1). The likely range of composition is given in the following Table:

TABLE I—COMPOSITION OF RICE HULLS

Constituent	Weight (%)
H_2O	2.5—11
Crude protein	1.7—7.3
Crude fat	0.4—3
Nitrogen-free extract	24.7—38.8
Crude fiber	31.7—49.9
Pentosans	17—22
Cellulose	34.3—44
Ash	13.2—29
Lignin	21.4—47

The rice hull ash is primarily silica. Houston(1) has reported a number of analyses of rice hull ash. Table II shows the range of values of the different metallic and non-metallic impurities which may be present in rice hull ash.

TABLE II—AVERAGE COMPOSITION OF RICE HULL ASH

Constituent	Weight % (Dry Basis)
SiO_2	86.9—97.3
K_2O	0.58— 2.5
Na_2O	0.9— 1.75
CaO	0.2— 1.5
MgO	0.12— 1.96
Fe_2O_3	trace— 0.54
P_2O_5	0.2— 2.85
SO_3	0.1— 1.13
Cl	trace— 0.42

The hulls are valueless animal food, not only because of their low nutritive value,

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* Engineers India Ltd., 4, Parliament Street, New Delhi-1.

+ University of California, Berkeley, California, U.S.A.

but also because their high silica content renders them harmful to the digestive and respiratory organs of animals. Their disposal is difficult because of their very abrasive and tough nature. Burning the hulls is getting more and more difficult due to its subsequent air pollution problems. In California, U.S.A., burning of rice hulls is totally prohibited by the air pollution regulations.

Silicon tetrachloride ($SiCl_4$) is the most important halosilane commercially manufactured. It is made by the high temperature reductive chlorination of mixtures of sand and coke. Basu(2) has discussed the different existing methods for the manufacture of $SiCl_4$. Commercially, chlorinations of a mixture of sand and coke are carried out at temperatures of the order of 1300-1400°C. Rice hulls offer a very pure source of both silica and carbon. The latter can be formed by the pyrolysis of the cellulosic material in the rice hulls. The silica and the carbon obtained after pyrolysis are much more intimately dispersed than could readily be accomplished by physical mixing. So the chlorination of the silica in the hulls will proceed more readily than that of a mixture of sand and coke.

Fig. 1 shows the logical sequence of steps for the manufacture of $SiCl_4$ starting from rice hulls as the raw material.

Stoicheiometry

When $SiCl_4$ is made by chlorinating silica in the presence of carbon, the two probable overall reactions are :

$$SiO_2\,(s) + 2C(s) + 2Cl_2(g) \rightleftarrows SiCl_4(g) + 2CO(g) \qquad \ldots\ldots(1)$$

$$\Delta H^\circ_{1300^\circ K} = -\ 2.46 \text{ kcal/mole}$$

$$\Delta G^\circ_{1300^\circ K} = -70.12 \text{ kcal/mole}$$

$$SiO_2\,(s) + C(s) + 2Cl_2(g) \rightleftarrows SiCl_4(g) + CO_2\,(g) \qquad \ldots\ldots(2)$$

$$\Delta\ {}_{\circ}H_{1300^\circ K} = -42.45 \text{ kcal°mole}$$

$$\Delta G^\circ_{1300^\circ K} = -\ 56.53 \text{ kcal/mole}$$

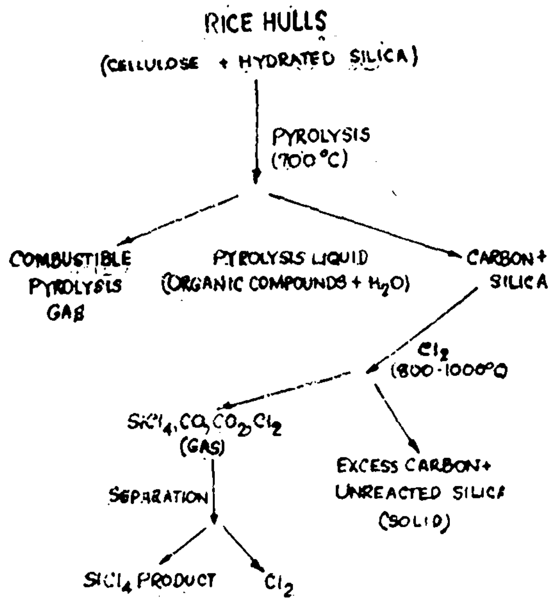

Fig. 1—Steps and Products in the Manufacture of $SiCl_4$ from Rice Hulls

At temperature below 600°C reaction (1) has the greater negative value of Δ G while at temperatures above 600 °C, (2) is a more probable reaction.

Since carbon content in the rice hulls is about 40% by weight of the cellulose, fibre and carbohydrates, the $C:SiO_2$ ratio is equal to 1.54 : 1.0. It may be mentioned here that stoicheiometric ratio required for complete reaction is $C : SiO_2 = 1.0 : 2.5$. Thus, there is about a four-fold excess of carbon present in the hulls over the amount required for stoicheiometric reaction.

Experimental Techniques and Results

Pyrolysis

The first major step in the process for the manufacture of $SiCl_4$ from rice hulls is to obtain an intimate mixture of carbon and silica. This is done by pyrolysis or carbonisation of the hulls. Pyrolysis may be defined as a process of heating an organic material in the absence of oxygen, whereupon the organic matter decomposes in steps to give compounds of lower molecular weight and a residuum of carbon. When rice hulls are heated in an inert atmosphere to a sufficiently high temperature, the lignocellulosic matter decomposes in stages to produce combustible non-condensable gases, containing H_2 CO, CO_2 CH_4, etc., some liquid tarry material and a solid residue containing the carbon, intimately mixed with the ash.

In this work a batch pyrolysis apparatus was set up to pyrolyze the rice hulls. Pyrolyses were carried out at different temperatures to find the effect of temperature on the total volume of gas evolved and on the weight of solid residue. The details of the experimental set up is discussed by Basu (2). Some of the important results are discussed here. Fig. 2 shows the total volume of gas evolved during pyrolysis at different pyrolysis temperatures. It can be seen that the total volume of non-condensable gases evolved increases markedly with temperature. This is due to the fact that at higher temperatures more of the higher-molecular-weight hydrocarbons crack to form lower-molecular-weight compounds.

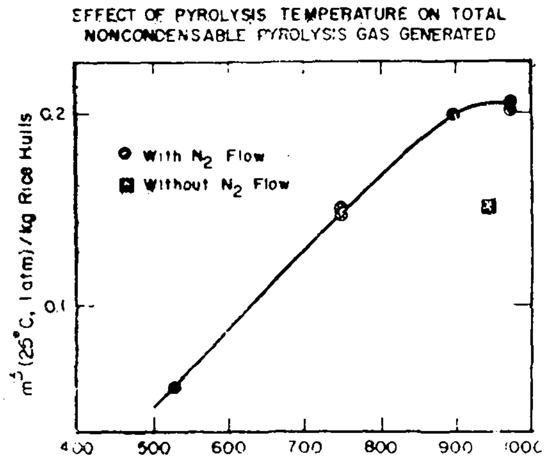

Fig. 2

Fig. 3 shows the variation of the fraction of the solid residue remaining after pyrolysis with the final temperature of pyrolysis. The fraction remained almost constant for temperatures exceeding 650°C. This suggests that by 650°C, all the hydrocarbons have been disintegrated and the volatiles have escaped. So this would be the highest temperature that would be required for pyrolysis.

In this work no attempt was made to analyze the pyrolysis gas. McElhinney *et al.* (3) have reported the destructive distillation of corncobs in the range of 200°—540°C. The H_2 and CH_4 content of the non-condensable gas increased with increasing temperature while the CO_2 content descreased. The heating value of the gas also increased with temperature. They report a heating value of 2700 kcal/cu m. for the gases obtained from pyrolysis at 538°C. A higher heating value of the gases can be expected if the pyrolysis is con

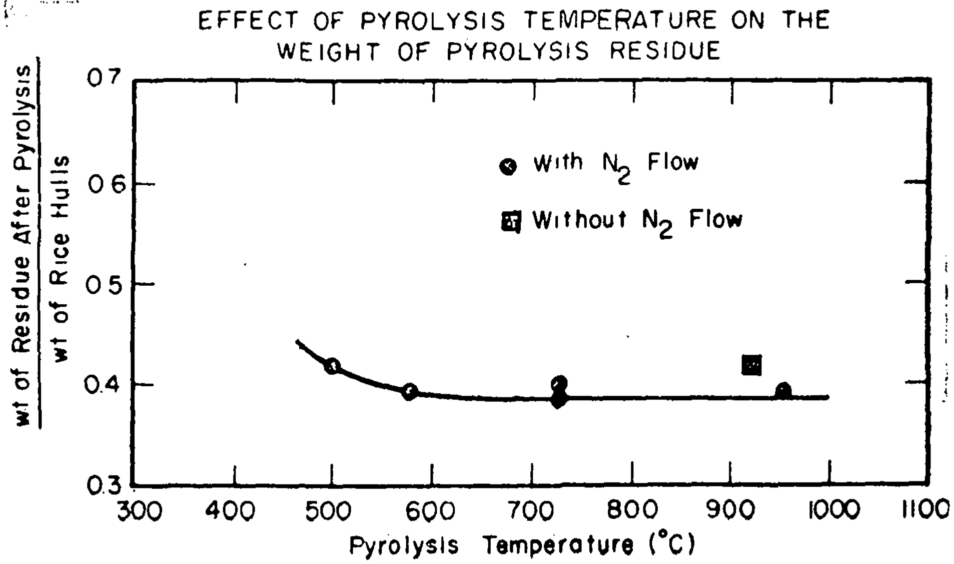

Fig. 3

ducted at a higher temperature because more of the organic compounds in the liquid would be cracked to form combustible gases such as CH_4 and H_2.

Chlorination

The chlorination experiments were carried out in fixed bed tubular flow reactors. Pyrolysed rice hulls were charged in the reactors heated up to the temperature of chlorination in an inert atmosphere and then chlorinated by passing chlorine gas. The details of the chlorination apparatus and the results of the experiments have been discussed elsewhere (2, 4). The results are summarized as follows :

1. Two reactors of inside diam of 9.5 mm and 44.5 mm were used.
2. In the 9.5 *mm* reactor, conversions of the rice hull silica at different temperatures were determined, and it was found that the conversion was independent of both the time of chlorination and the prior chlorination conditions.

   Fig. 4 shows the effect of duration of chlorination on the conversion of rice hull silica. One thing was conclusively proved that the conversion of the silica in the rice hulls was much higher than compared to those of mixtures of coke and sand under the similar conditions of reaction. From Fig. 4. it can be readily seen that at 1050°C, about 67% of the rice hull ash was chlorinated in about 15 min. Under the same conditions of chlorination only 2% conversion of the silica was obtained for a mixture of -80 mesh sand and coke.
3. Electron micrographs of chlorinated rice hulls were taken to study the mechanism of chlorination. The microscopic investigation (2, 5) leads to the conclusion that silica in the rice hulls is much more reactive than ordinary sand, because of its amorphous nature and very fine particle size. The observations show that the rate of chlorination depends on the particle size of the silica. The proximity of the carbon to the surface of the silica may also be an important factor in the chlorination.
4. Chlorination experiments were also carried out in a scaled-up reactor having an I.D. of 44.5 mm. The conversions in this

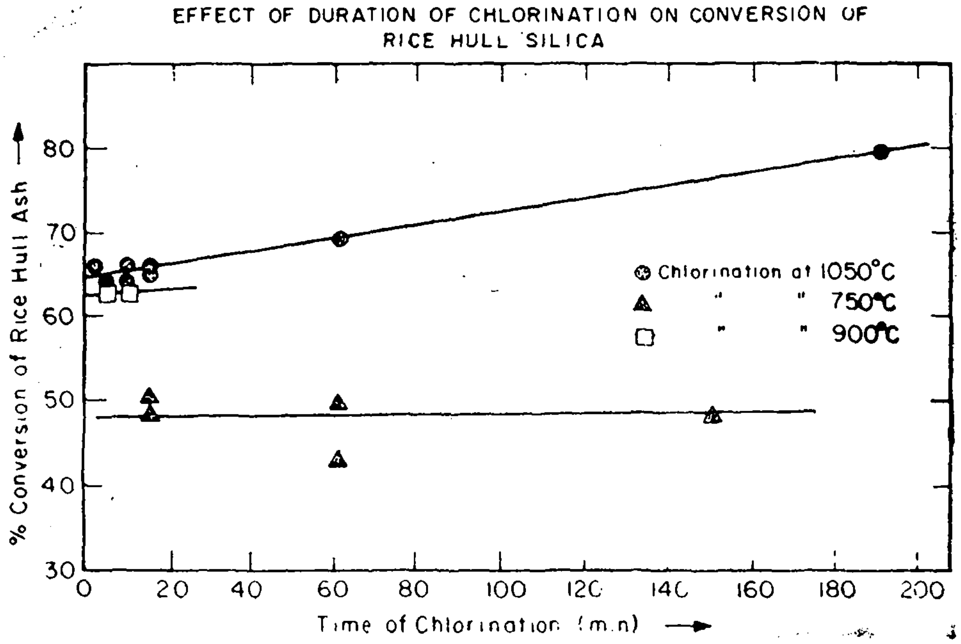

Fig. 4

reactor were found to be larger than those obtained in the 9.5 mm reactor. The gaseous reaction products were analysed by taking intermittent samples at the exist of the reactor. The analytical procedure employed has been discussed by Basu(6). Conversion was a strong function of the superficial gas velocity and the concentration of Cl_2 in the feed chlorine stream. Analysis of the gaseous reaction products showed that CO_2 was formed as a reaction product. The gas analysis data also showed that chlorine was retained by the solids during the initial period of chlorination. This was further verified by analysis of the chlorinated residue, which was found to contain verious amounts of chlorine, depending upon the chlorine partial pressure, temperature and duration of chlorination. Fig. 5 shows the effect of diameter of the reactor and concentration of chlorine on the conversion of rice hull ash.

EFFECT OF DIAMETER OF REACTOR AND CONCENTRATION OF Cl_2 ON THE CONVERSION OF RICE HULL ASH

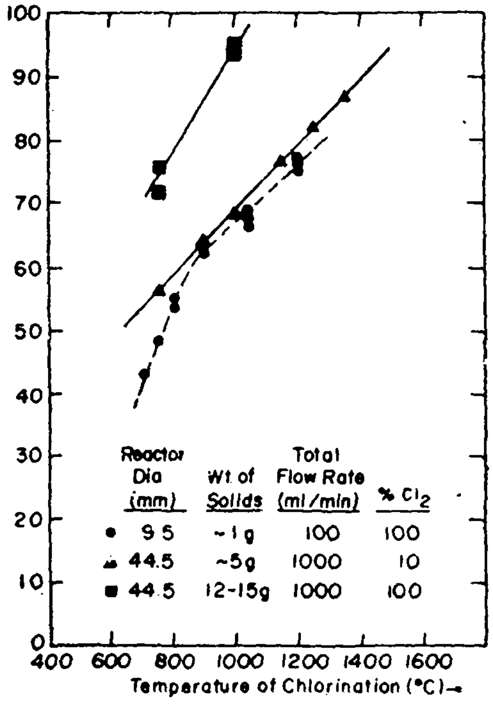

Fig. 5

In spite of the thermodynamics being highly unfavourable, a substantial quantity of CO_2 was present in the gaseous reaction products of the chlorination experiments even at 1000°C. This suggests that CO_2 is the primary product of the chlorination reaction. It has been hypothesised that the chlorination of silica proceeds **via** reaction 2 and later the CO_2 is reduced to CO by carbon in the bed.

$$SiO_2 + C + 2Cl_2 \rightleftarrows SiCl_4 + CO_2 \quad \text{.........(2)}$$

$$\Delta \ H^\circ_{1300^\circ K} = 42.54 \text{ kcal/mole}$$

$$C + CO_2 \longrightarrow 2\,CO \quad \text{............(3)}$$

$$\Delta \ H^\circ_{1300^\circ K} = +\ 40 \text{ kcal/mole}$$

Since reaction 2 is highly exothermic, a temperature wave is generated which moves through the bed with gradual chlorination of the bed. A mathematical model of the temperature wave is discussed by Basu (2) and the peak of this temperature wave is calculated to be several times the steady state temperature of the bed. The model can also explain the higher conversions obtained in the larger diameter reactor, the effects of gas velocity and the effect of chlorine concentration on the conversion of the rice hull silica.

Process Design

Starting from rice hulls, four major unit operations are involved in producing SiCl

1. Pyrolysis of rice hulls.
2. Chlorination of the pyrolyzed hulls.
3. Removal of the chlorinated residue from the reactor.
4. a) Separation and purification of the product $SiCl_4$ from the gaseous product of the chlorination reaction.
   b) Separation of the unreacted chlorine and phosgene from the product gases from recycle back to the reactors.

Basu (2) has developed a conceptual process for the manufacture of $SiCl_4$ from rice hulls. Complete material and energy balance calculations have been worked out and design of the major equipments have been made.

It is suggested that in the process for the manufacture of $SiCl_4$ from rice hulls, advantage should be taken of the temperature wave generated in a fixed bed to yield high conversions. Multiple reactors will be used and cycled in such a manner that the process can be maintained more or less continuous. Fig. 6 shows the major processing steps.

Fresh rice hulls are charged to one of the three reactors and pyrolysed *in situ* with the hot gases obtained by the controlled combustion of the chlorinated residue in one of the other three.

After the pyrolysis is over, the hulls are chlorinated. A chlorination temperature of 1000°C is recommended for near complete conversion of the hulls.

The gaseous reaction products of chlorination will contain unreacted Cl_2, $COCl_2$, CO and CO_2 The gases will go through a separation train to separate pure $SiCl_4$ (as product) and Cl_2 and $COCl_2$ (To be recycled to the reactor) from the non-condensables. This separation scheme could be essentially the same as in the conventional $SiCl_4$ manufacture.

Economic Analysis

Raw rice hulls at a rice mill have negative value since they present a disposal problem to the mill. However, they are quite bulky and hence can not be shipped an appreciable distance economically. They provide not only carbon and the silica for the reaction but also the fuel for operating a $SiCl_4$ plant. If the location of the mill were suitable with regard to both a source of chlorine and a market for $SiCl_4$ a significant economic advantage should result from the utilization of rice hulls because of their low cost.

Although detailed operating data for the current $SiCl_4$ processes are not available, it is believed that an electric furnace is used to obtain the high temperature necessary for the reductive chlorination of sand. The lower chlorination temperature possible, when rice hulls are used, does not require an electric furnace, making an additional important economy for this process.

The separation train for recovering $SiCl_4$ made from rice hulls is also expected to be

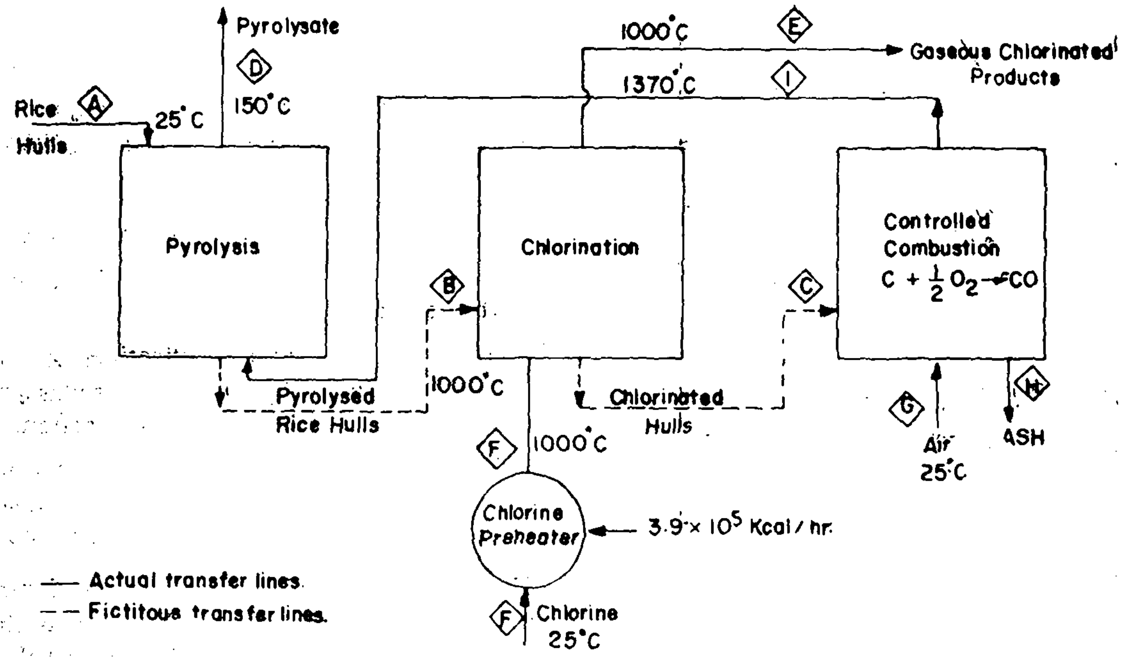

Fig. 6—Schematic Diagram of the Three Reactor System

simpler than that of a conventional plant since the silica in the rice hulls is expected to be purer than any natural source of sand.

The pyrolysis gas from rice hulls may contain some components of economic value. Projects investigating pyrolysis of rice hulls have been reported incompletely in the technical press. This evaluation is outside the scope of this work. Patent rights to this process have been assigned to the University of California.

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DISCUSSION

Shri G. C. Gupta: What is the source of chlorine to be employed in this method ?

Dr. P. K. Basu: Gaseous chlorine from brine electrolysis plants could be used.

Shri J. J. Dave (Bhavnagar): Phosgene is an intermediate product in the method suggested by the author for silicon tetrachloride production, Could the author suggest some method for detection of quantities of phosgene around 0.1 ppm which are hazardous to health on exposure ?

Dr. P. K. Basu: As far as my knowledge goes phosgene should not be hazardous below 1 ppm We have developed a gas chromatographic method of analysis (ref. 7 of text) for the effluent gases from the reactor which can detect phosgene to concentrations as low as 0.01 per cent. I do not know how to detect phosgene below that concentration level. In the process, developed by us, the unreacted phosgene and chlorine are recovered and recycled back to the reactor. Hence, danger of exposure to phosgene is not expected.

Shri B. N. Patil: What is the yield of silicon tetrachloride from 1 kg. of rice hulls ? Is silicon tetrachloride a reactive compound ? Whether it undergoes polymerization while formation at high temperature or not ? What precautions are taken to prevent polymerization of silicon tetrachloride at higher temperatures ?

Dr. P. K. Basu: Yield of silicon tetrachloride from 1 kg of rice hulls is about 500 g. Silicon tetrachloride is an extremely reactive compound and reacts explosively with O_2 and H_2O. But it does not undergo polymerization even at high temperatures.

Shri C. M. Ketkar (Poona): The rice hulls (husk) are valueless as food for cattle provided it is not treated with anhydrous ammonia.

In USA, husks are used as admixture of feeds with a new process of manufacturing protein feed by combining ground husks and anhydrous ammonia under tremendous heat and pressure.

'Rice Mill Feed' consisting of 61% rice husk, 35% of rice bran and 4% rice polish has now established a firm place in U. S. animal feeds and quantity of husks used is estimated at 15,000 tons.

A recent study undertaken in Phillippines reveals that finely ground husks can be a satisfactory substitute. For rice bran in concentrate feed for lactating murrah buffalo, cows and production, cost of such concentrate mixture is about half the normal fine rice bran concentrate.

Rice husk or hulls has a value as fertilizer and compost, soil conditioner and also as Mulch.

In India, where there is shortage of cattle feeds, the use of rice husk (hull) as cattle feed, manure is essential.

Dr. P. K. Basu: I have not come across this process myself. But anyway, the questioner himself states that the process for manufacturing protein feed from rice husks is by combining ground husk and **anhydrous ammonia** under **tremendous heat and pressure.** Anhydrous ammonia is not cheap, and a process which requires "tremendous heat and pressure" can never be a very simple and inexpensive process either. So, I shall not recommend even to make an attempt to make cattle feed from rice hulls by this method in India. Moreover, I believe that the silica in the rice hulls is going to be harmful to the cattle. $SiCl_4$ is not manufactured in India at all. It will also take only a fraction of the total rice hull production of the country to meet the country's $SiCl_4$ demand. The process is inexpensive and has wide prospects of import substitution.

Dr. K. L. Saxena: The composition of hulls as given by author is H_2O, 2.5 and ash content, 20 per cent. The author also states that $SiCl_4$ production is 20 g per 100 g of rice hulls. I would request the author to explain this discrepancy in the light of whether all the silica gets converted into $SiCl_4$.

Dr. P. K. Basu: Ash content of the hulls is about 18-20% of the weight of the hulls. Conversion of silica to $SiCl_4$ is about 97-99 per cent. Therefore, the $SiCl_4$ production is about 50 g per 100 g of rice hulls.

PROC. SYMP. ON ENVIRONMENTAL POLLUTION (1973)

Sanitary Landfill Practices in North America With Special Reference to Canada

T. VIRARAGHAVAN*

The per capita solid waste generation in Canada was observed to be 4.3 lb/day in 1970. Paper and paperboards constituted 40-60% of the municipal solid waste.

Federal legislation on Solid Waste Management does not exist in Canada, though some provinces like Ontario, Alberta and British Columbia have quite comprehensive legislation.

Many Canadian provinces "except those in extreme North" are practising sanitary landfilling after taking some special precautions to account for the cold weather there. This method has been observed to result in most economical refuse disposal.

Introduction

Knowledge of the characteristics and quantities of solid waste produced in the towns, is a pre-requisite to evaluate the most suitable method of disposal and to design such a disposal system. The average per capita production of solid waste in Canada in 1970 is reported to be about 4.3 lb/day. The amount of solid waste generated in Canada during 1970 would be sufficient to build a four lane highway raised three feet above ground level stretching from Toronto to Vancouver. The composition of municipal solid waste in Canadian and U. S. towns generally indicates that paper and paper boards constitute the single large percentage (40-60%) of the municipal solid wastes, with food wastes next in order. ASCE's definition of "sanitary landfill" has helped to resolve inconsistencies in technical literature to a great extent, but confusion still persists due to indiscriminate use by some. APWA's criteria for a sanitary landfill calls for the control of water and air pollution, prevention of vector breeding and all nuisances and the elimination of fire hazards.

Land Requirements and Site Selection

The U. S. Public Health Service estimates that a population of 10,000 would require 15 acre-ft of space per year, using a waste generation rate of 5.3 lb/capita/year, solid waste density of 1000 lb/cu yd and one part earth cover to four parts waste. The factors generally considered in site selection are: (i) zoning restrictions, (ii) accessibility, (iii) haul distance, (iv) availability of cover material, (v) hydrogeological implications, (vi) climatic conditions, and (vii) fire control and other facilities.

Hydrogeological Aspects

Solid wastes ordinarily contain many contaminants and often infectious materials. Serious health hazards or nuisances may result if these pollutants are permitted to enter water supplies. Site selection should include a geological investigation of the site, location of the groundwater table and

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* Doctoral Student, Deptt. of Civil Engg., University of Ottawa, Ottawa, Canada (on leave from the Ministry of Health, Govt. of India, New Delhi).

information on the highest groundwater level ever reached and the general movement of groundwater

The major investigations of the production and movement of dissolved solids and gases from solid waste disposal sites have been made in California and Great Britain. Other investigations have been carried out in New York, Illinois, Pennsylvania, South Dakota, West Virginia and Wisconsin. An excellent review of the problem has been made by Hughes and others in a publication of the Canadian Department of Environment. The research studies generally indicate :

1. A polluting leachate can be produced by refuse in contact with water. The water may be groundwater or surface water from precipitation.

2. Studies in Illinois and in Britain showed that dissolved solids in refuse leachate travel relatively short distances and are rapidly attenuated in fine textured soils with relatively low permeability, but may travel great distances without any significant change in fractured rocks.

3. Gases, as well as dissolved solids, are produced by the decomposition of the refuse. These gases are predominantly methane and carbondioxide. Methane may create explosion problems and carbondioxide may increase the hardness of the groundwater.

4. The length of time required for refuse to stabilize and stop producing contaminants cannot be readily predicted. Some landfills stabilize in three years; others still produce methane after 30 years

The leaching of the landfill would depend upon its location and the nature of interactions between the landfill, rainfall and groundwater flow systems. The leachate in the unattenuated form is potential contaminant. For example, the leachate from a 6 year old landfill in Illinois, had a total dissolved solids of about 7000 mg/l; that from one 18 years old, had still about 1200 mg/l total dissolved solids. The 20-day BOD of leachate from the 18 year old fill, was 225 mg/l; the 5 day BOD of raw domestic sewage in the area was around 100 mg/l.

Considerations of hydrology in site selection are required by law in several states of USA. Attempts are being made in Canada to assess the hydrogeological implications of sanitary landfill sites and evaluate the pollution potential of existing ones in certain provinces.

Winter Operations

Experience has proved that with good planning and proper operating techniques, a sanitary landfill can be operated even in the severe winters of northern states of USA and in many provinces of Canada, other than the extreme north. The trenches are to be excavated before the cold weather, as well as the cover material has to be stockpiled and covered with straw, leaves or other material to prevent freezing.

Settlement and Future use of Landfill Site

The effective planning and operation of a sanitary landfill should include its eventual use. In such planning, it is necessary to recognize that decomposition occuring in a landfill is a long term process. Information available on settlement, indicates that sanitary fills of mixed composition typically settle from 10 to 30% of their original thickness under their own weight, depending on their initial composition. Most of the settlement takes place in the first year or two, but settlement continues indefinitely at a much decreased rate. Future uses of completed fills are generally directed towards their development as recreation areas, parks, playing fields and the like, where surface drainage, gases and differential settlement problems can be corrected with the minimum of effort and hazard.

Recent Developments

Bailing and shredding as auxiliary processes to sanitary landfills are two recent developments currently under investigation. Pulverizers are in operation at Montreal and St. Catharines in Canada. The acceleration of the stabilization procedure in which compacted refuse is aerobically (air is forced by mechanical means) decomposed before final disposal, is a new process under investigation. The aerobic landfill stabilization process shows good promise as a feasible alternative—it conserves land, destroys all pathogenic organisms and odour nuisances are minimized.

Cost

The cost capacity figures developed for Canadian conditions for various disposal units, generally indicate that sanitary landfill is the most economical over a wide range and incineration is generally the costliest.

Legislations, Regulations and Practices

USA enacted "Solid Wastes Disposal Act" in 1965. Many of the states in USA have comprehensive legislations on solid waste management and have regulations and standards, with chapters on sanitary landfill method. In Canada, there is little federal legislation on solid waste management. Canada has lagged the USA both in terms of legislation and the investigation of the problem. Many provincial acts deal with solid wastes in each province. A few provinces like Ontario, Alberta, British Columbia have comprehensive legislation on waste management, with regulations and standards for landfill operations.

Sanitary Landfill Practices in Canadian Towns

A recent sample survey of landfill practices in Canadian towns across the country, generally indicated the following pattern.

1. A significant number of fills in Canada do not have any restrictions on the types of refuse that can be disposed at the landfill, contrary to the practice in USA.

2. Compared to other facilities like telephone or electricity, water supply under pressure is available in lesser number of fills both in USA and Canada.

3. Many of the landfills in Canada are located in rural or suburban zones and are usually beyond 250 feet from the nearest dwelling.

4. The future land use for recreation purposes is quite popular both in Canada and USA.

5. Problems with blowing paper is more common in Canada, while fires are a problem in a large number of fills in USA.

6. An earch cover of 6" after each day's operation appears to be quite popular both in Canada and USA.

Conclusion

Proper investigation and site selection would to a great extent, limit the potential for ground water contamination, would enhance better land conservation and purposeful utilization and would reduce, though not eliminate altogether, many of the operating problems.

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CHAPTER-VII

AIR POLLUTION

PROC. SYMP. ON ENVIRONMENTAL POLLUTION (1973)

Monitoring Air Quality in New Bombay and its Environs

K. V. RAMACHANDRAN,[*]

Monitoring air quality, when developed on the right lines, can be made to serve the dual role of controlling emissions from existing sources and that of providing a means of intelligently locating new industrial units so that their harmful effects are minimised. It may even serve as an aid to overall urban planning both at the city and the regional levels.

In the present paper, the author has discussed the problems encountered in developing a system of air monitoring suitable to the needs of the New Bombay project and described some of the simple techniques which can be used to organise, analyse and interprete data being compiled while waiting for more sophisticated tools to be perfected and applied.

These simpler techniques are often useful also for organizing the sampling operations in such a way that the right data are collected at the right time and the right place.

Introduction

The City and Industrial Development Corporation of Maharashtra Ltd., (CIDCO) has been declared by the State Government as the New Town Development Authority for New Bombay and is vested with powers necessary for planning and implementing the project and for controlling the development with the following main objectives :

1. To reduce the rate of growth of population in Greater Bombay by creating an attractive urban area in the land across the Bombay harbour which will,
    - (a) absorb immigrants who would otherwise come to Bombay, and
    - (b) attract some of Bombays' present population.
2. To support State-wise location policies which lead eventually to an efficient and rational distribution of industries over the State, and to balanced development of urban centres in the hinterland.
3. To provide physical and social services which raise living standards, and reduce the disparities in amenities available to different sections of the population.
4. To provide training and all possible facilities to the existing local population in the project area, enable them to adopt to the new urban setting and participate full in the economic and social life of the new city, and last but not the least :
5. To provide an **environment** which permits the new city's citizens to live fuller and richer lives.

The author does not wish to elaborate on various objectives and the ways of imple-

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[*] City and Industrial Development Corporation of Maharashtra Ltd., Tenth Floor, "Nirmal", Nariman Point, Bombay-1 (M.S.).

menting the same and wishes to restrict to the last said objective, i.e. 'to provide a clean environment' by reducing pollution to the minimum.

Need for Planning

Those concerned do not seem able to even react when problems are foreseen. The response crops in only when the problems are massive and less easily managed. It is obvious that the environmental problems are most actute in urbanised and industrialised pockets of the world. The pollution levels existing in various cities of the world are summarised in Table I. The hue and cry now being made at almost all the major cities of the world should serve as a warning.

The picture is not very much different in many of the Indian cities. A recent short-term survey carried out by the Central Public Health Engineering Research Institute at 4 major centres, **viz.**, Bombay, Calcutta, Delhi and Kanpur revealed that the problem of air pollution exists in all the cities surveyed. Some of the areas can be easily compared to the most polluted cities in the world. In the great surge towards 'progress' the congestion has increasingly fouled the air and water. This is not a welcome sign. It is high time that all those concerned sit back and think in terms of saving the Indian cities before the things get out of control. Early planning is necessary.

CIDCO Plans for New Bombay

As mentioned earlier, one of the important aspects of planning New Bombay, as any other big city, is pollution control. Preparation of land use plan requires a thorough knowledge of the existing environmental conditions. This involves collection of micro-meteorological data and air quality in the area. The project area of New Bombay (Fig. 1) lies in between the main city of Bombay and the mainland area. It is spread out from North to South, occupying an area of 35,000 acres of land. Thana creek is in between the West Coast of the project area and Bombay island. On the eastern side of the project area, there is almost a wall of hills extending up to a height of 250 ft North to South with a pass in between.

The existance of this hill range is a barrier to the natural winds which blow most of the time from North-West or from South-West directions, which may cause some stagnations.

(i) Climatological and Air Quality Surveys:

A preliminary climatological survey regarding the wind patterns and air quality was entrusted to CPHERI. This survey carried out for about 6 months (November-April, 1970-71) at some selected stations throughout the length and breadth of the project area revealed the following:

The preliminary study gave a good insight about the existing climatological conditions

TABLE I—TYPICAL AIR QUALITY IN SOME CITIES OF THE WORLD

Air Pollutant	London	Chicago	Cincinnati	San Francisco	Tokyo	Bombay	Calcutta	Kanpur	Delhi
Sulfur dioxide (ppm) summer	.087	0.135	0.029	0.008	0.059	0.039	0.022	0.041	0.015
winter	0.177								
Nitrogen dioxide (ppm)	0.029	0.042	0.030	0.042	0.062	0.011	0.012	0.04	0.011
Oxidants	—	0.004	0.014	0.018	—	0.006	0.015	0.048	0.009
Suspended particulates μ g/m^3)	221	280	176	104	261	238	527	488	700

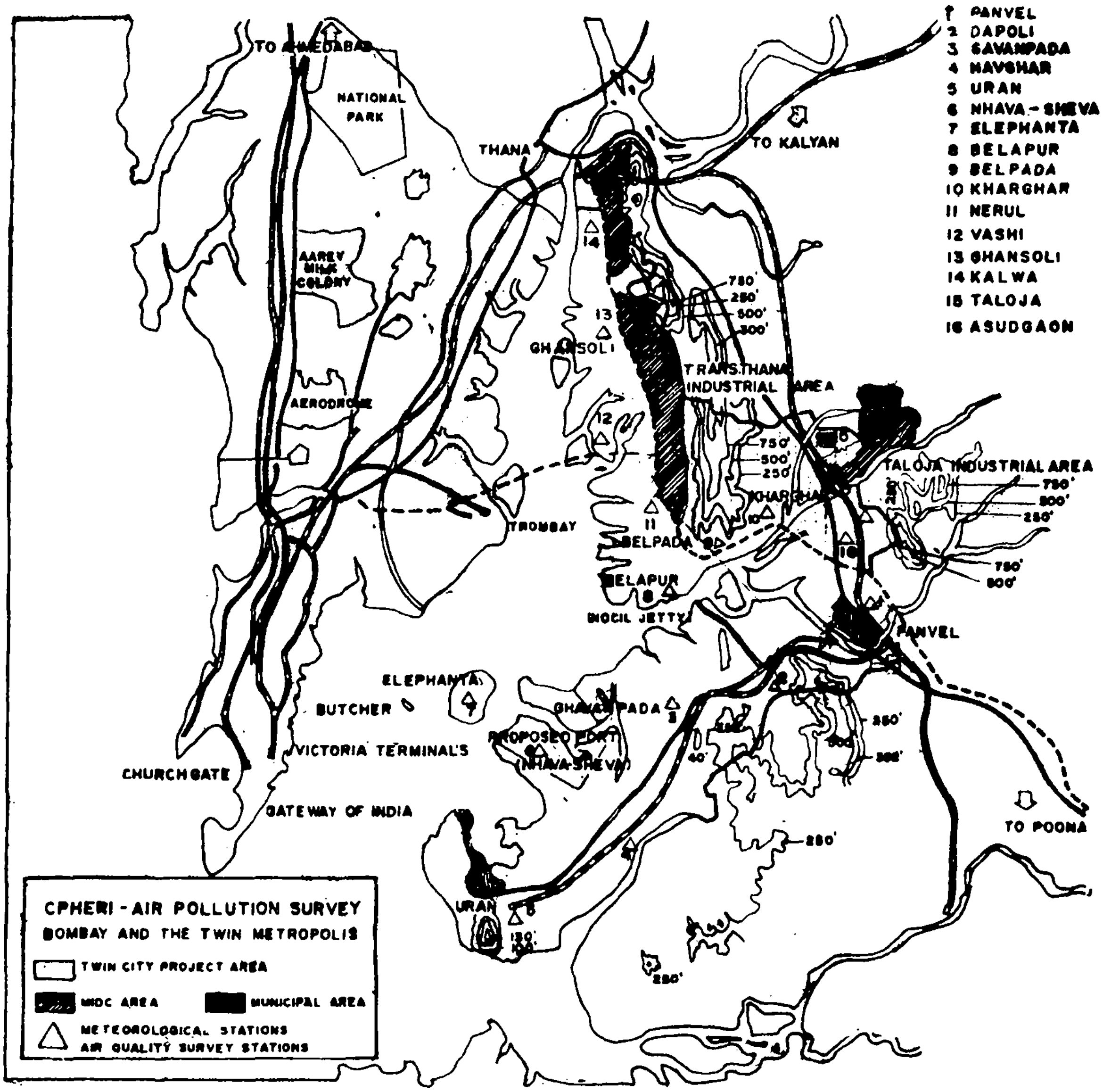

FIG.1 : MAP SHOWING THE AIR MONITORING STATIONS IN THE TWIN CITY AREA

via general wind patterns (Figs 2-6) existing levels of pollution etc. However, it was felt that this data was not sufficient enough in zoning the New Bombay region for different activities. Accordingly, a long term survey extending over a period of 2-3 years was entrusted to CPHERI. The main objectives of the study were:

1. To determine the existing environmental conditions both with regards to factors affecting climate (such as temperature, humidity, wind direction and velocities) and those important from the point of view of public health (such as present levels of pollution and anticipated increases).
2. To help define areas which are favourable or otherwise for various types of development from air pollution point of view.
3. To assist CIDCO in establishing a permanent Cell for environmental pollution study to monitor the existing level and its control.

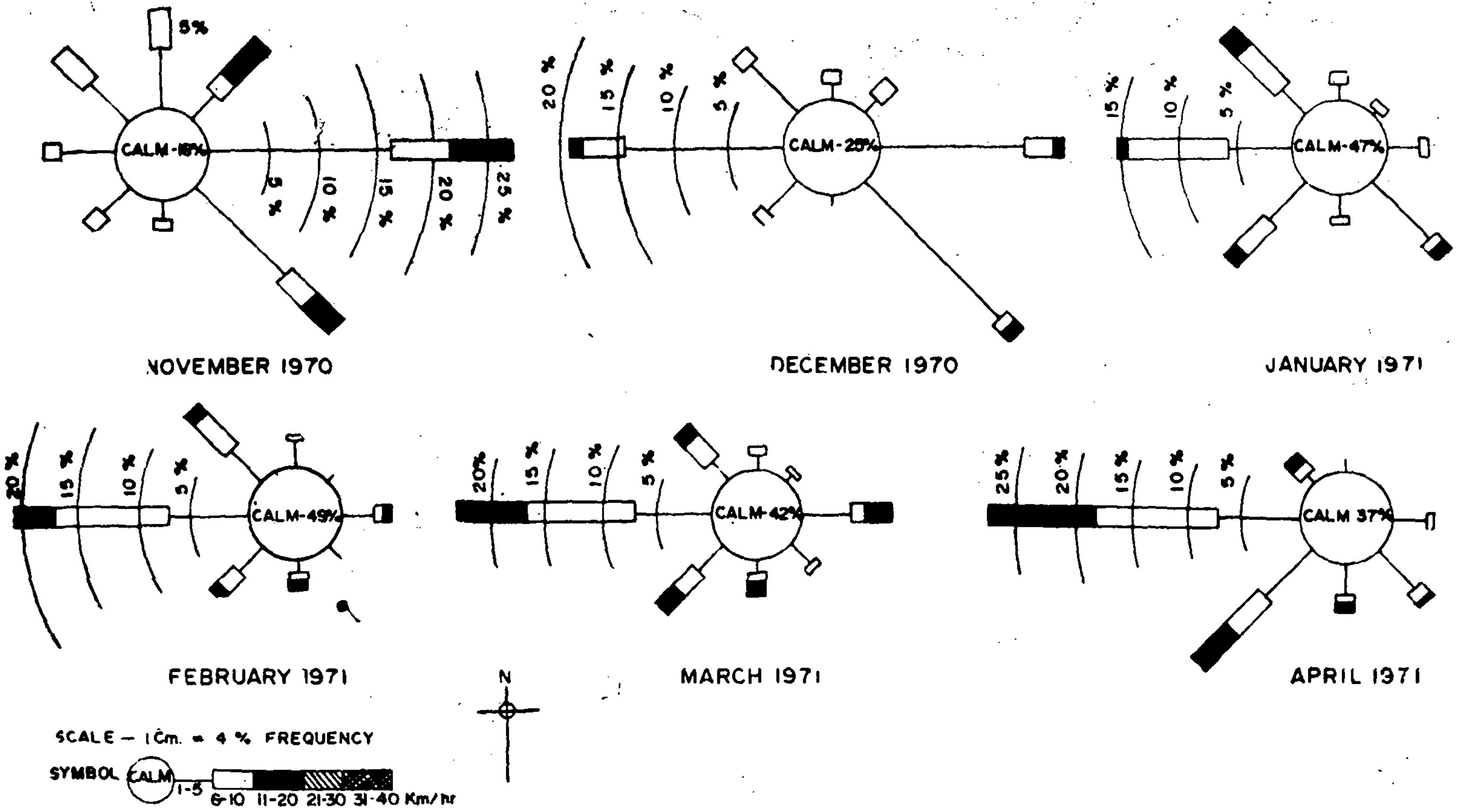

Fig. 2—Wind Roses for Panvel

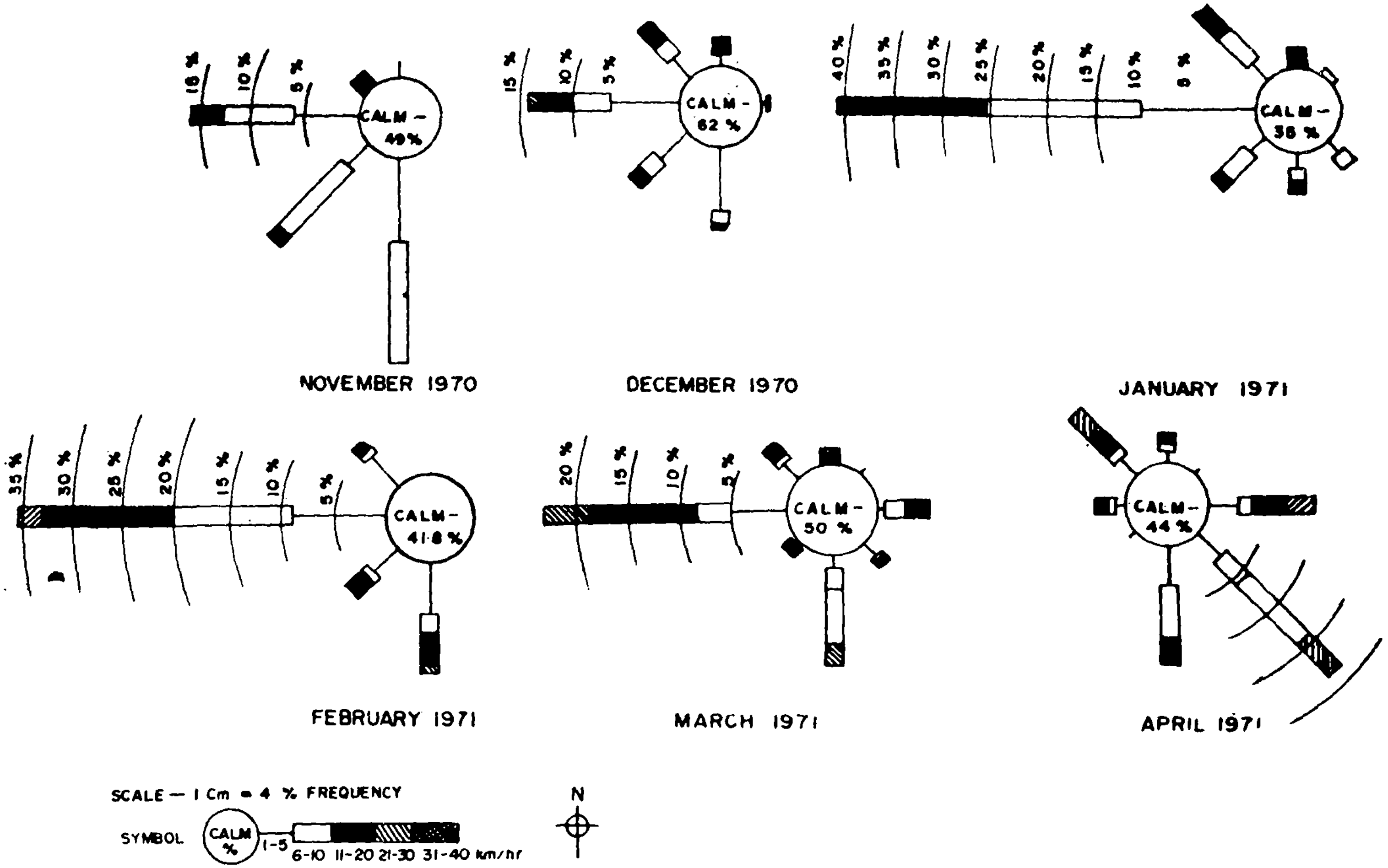

Fig. 3—Wind Roses for Ghansoli

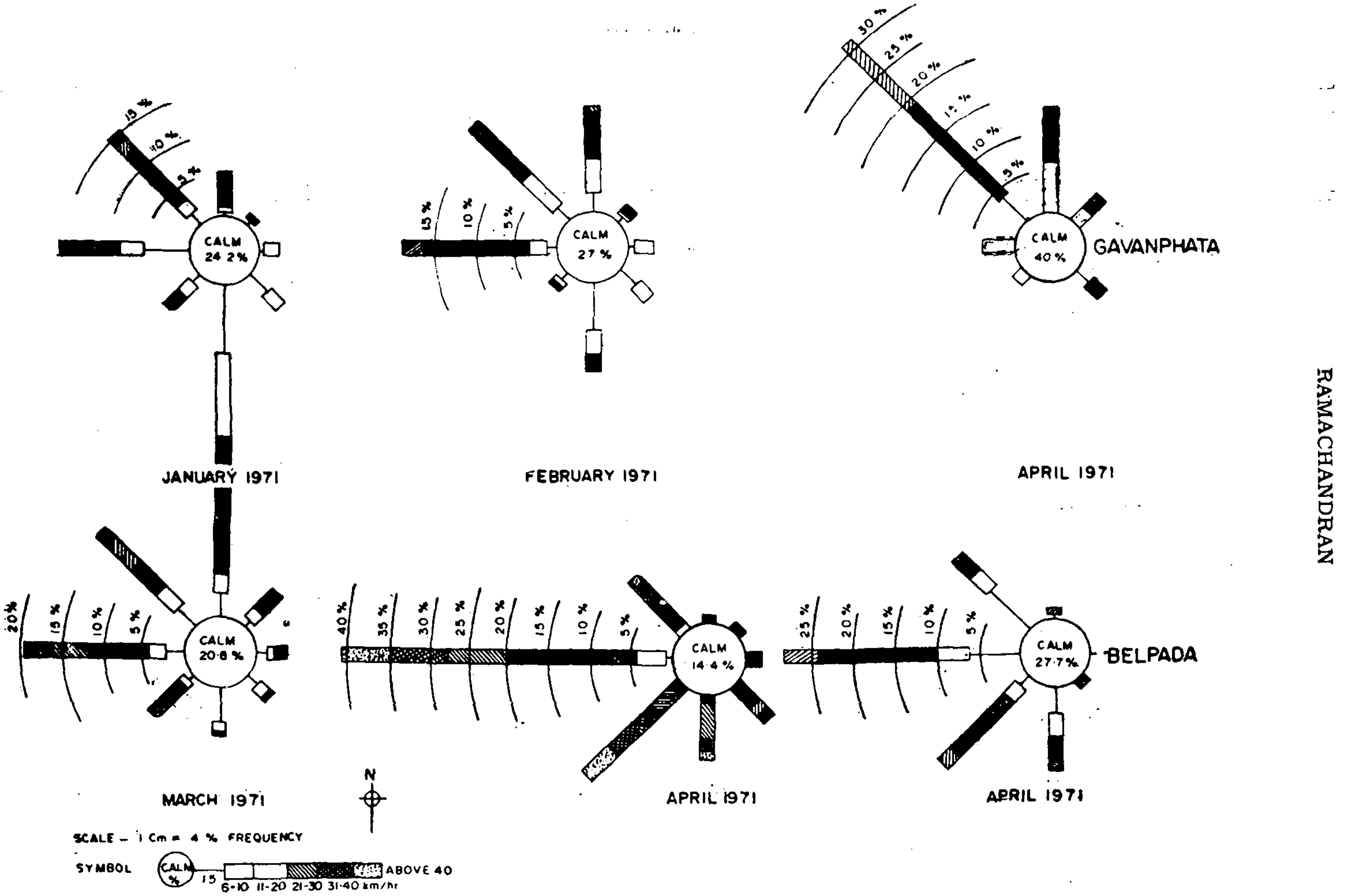

Fig. 4—Wind Roses for Uran

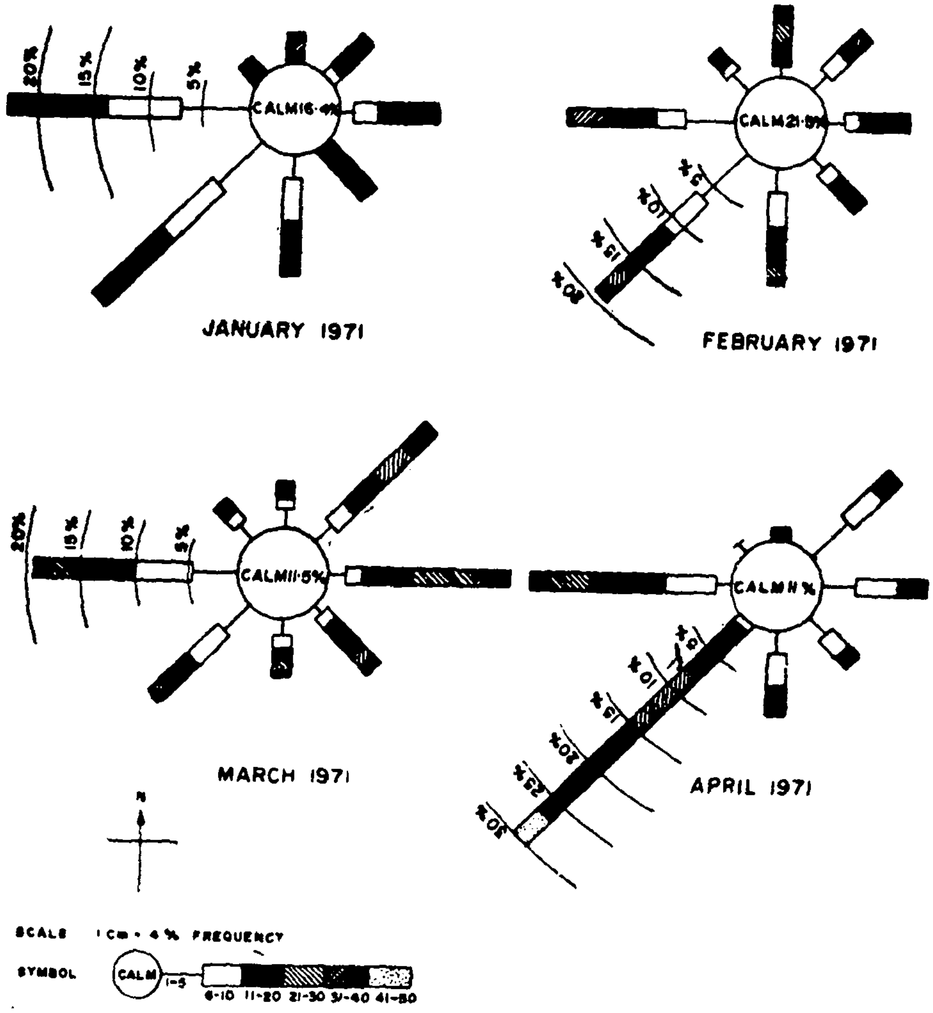

Fig. 5—Wind Roses for NOCIL Jetty

(ii) **Grid Pattern for Monitoring**

It is proposed to set up a grid covering 16 meteorological stations within the CIDCO and also cover the fringes. The set of the grid has been illustrated in the map attached.

(iii) **Protected Zone**

Apart from this study, the CIDCO is already corresponding with the State Government UDPH Department to declare the New Bombay area as "protected zone" as per the Maharashtra Prevention of Water Pollution Act 1969. This will help a great deal in protecting the Water Courses (Thana Creek) from indiscriminate dumping of industrial wastes.

(iv) **Landscape**

Ecologists and city planners have time and again emphasised upon the importance of parks and natural open space vegetations in an urban environment. CIDCO intends that every standing tree is preserved and forests given a fair chance to revive and flourish. CIDCO has prepared an afforestation programme to restore a large tract of forest land.

Trees have already started arriving at the first nucleus development being established

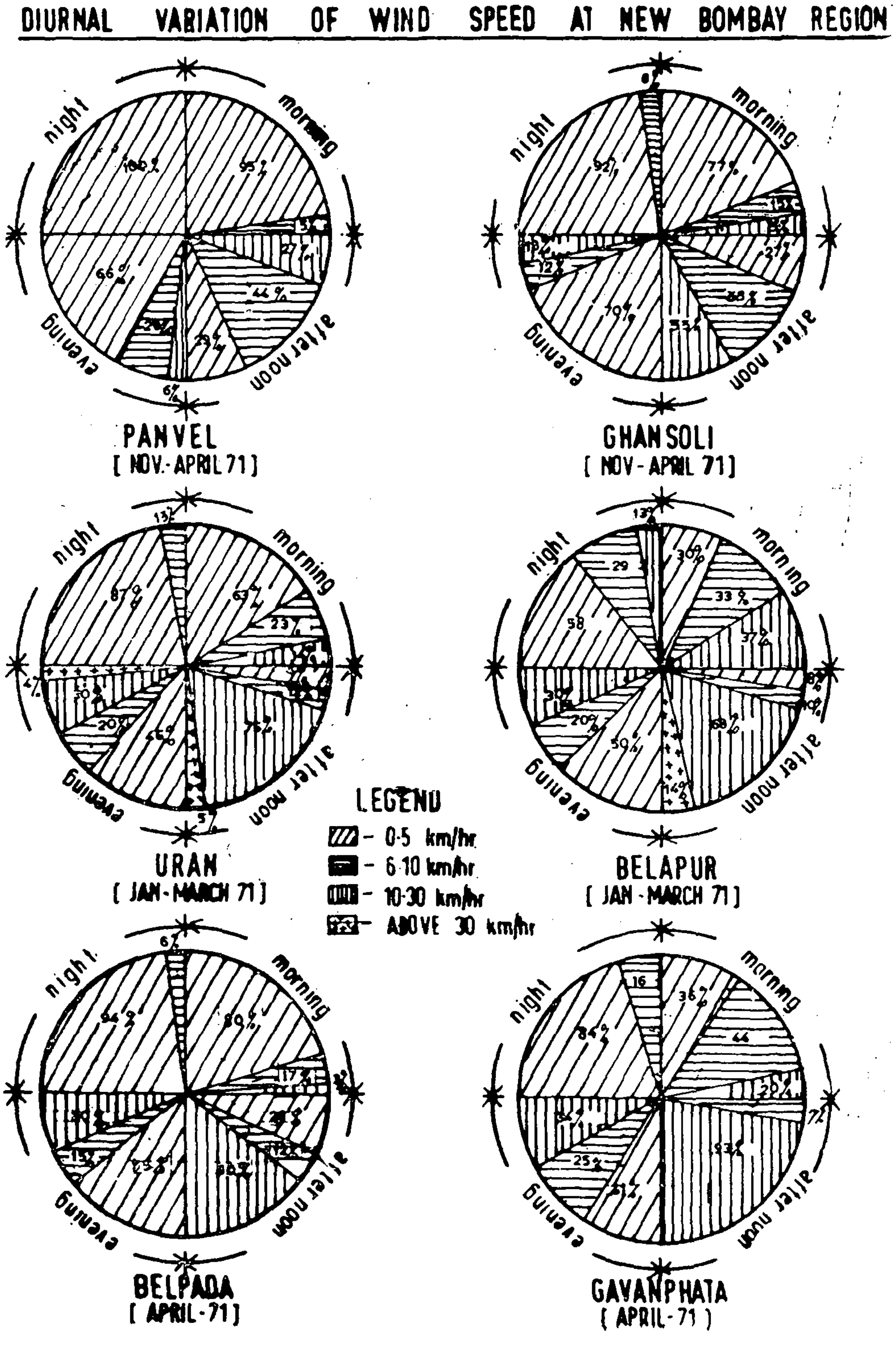
DIURNAL VARIATION OF WIND SPEED AT NEW BOMBAY REGION
night
morning
after noon
evening
PANVEL
[NOV.-APRIL 71]
100%
95%
66%
44%
27%
33%
29%
6%
GHANSOLI
[NOV-APRIL 71]
92%
77%
79%
53%
38%
27%
12%
URAN
[JAN-MARCH 71]
13%
87%
63%
23%
75%
65%
20%
30%
4%
5%
BELAPUR
[JAN-MARCH 71]
13%
29
30%
33%
58
37%
68%
50%
20%
30%
14%
LEGEND
0-5 km/hr
6-10 km/hr
10-30 km/hr
ABOVE 30 km/hr
BELPADA
[APRIL-71]
6%
94%
89%
17%
29%
13%
75%
88%
GAVANPHATA
[APRIL-71]
16
36%
84%
44
29%
7%
93%
25%
51%

Fig. 6

at Vashi where the New Thana Creek bridge joins Vashi.

(v) Cluster Development

Another important tool in protecting the congestion and other pit falls of urban centres is the cluster development. Each cluster is separated from the other by green belts. Each cluster is self-sufficient in the sense that it provides for all the basic amenities (social, educational, etc.) for a healthy and tension-free life.

The first phase of development at Vashi called as Early Development Area (EDA) is planned with the above considerations. EDA has a number of clusters with a lot of greeneries (Fig. 7).

First cluster (cluster– α) has already out of cluster — α (Fig. 8) if examined criti- gone into the construction phase. The lay cally will reveal many interesting features. Apart from the greeneries and open spaces, the roads, for instance, are peripherial to the area covered by the sector. The roads have no tie-ups with each other. By this arrangements the central area is free from congestion and allows enough scope for landscaping.

Pollution respects no boundaries—district, state or national. This points to the failings of the more or less simpliastic solutions intended to adopt as a means of correcting the environmental problems. If self-enhancing surroundings are to be created in cities, the first requirement is to plan and implement programmes which encompass the problems of the metropolitan regions ***in toto.***

From the climatological data collected so far in the New Bombay region it is found that conditions in New Bombay are governed to a great extent by the controls enforced in the Greater Bombay area.

Legislation and Standards

CIDCO believes that effective steps in ensuring a clean environment lies not only in planning/zoning but also in checking and controlling the present sources. Contaminants from non-regulated areas may make local efforts futile. Zoning may not provide protection for an urban area against air pollution, unless provision is made for area-wide control measures. Throughout the world legal means of air pollution control have been newly created or improved. Many countries have set up their own air quality and emission standards. Table II summarises the air quality standards set up by some countries in the world.

Presently, there are no such legislations or standards in India. Now, it is a must that country-wide air pollution legislation is provided. For this purpose, the first step is to have air quality standards. Until such time that enough data are available in the country, some tentative "norms" based on the standards set in other countries, could be adopted provisionally.

There is an urgent need now to set up Central and State Government agencies working in collaboration with the Central team for abatement of pollution. These must be authorised to :

1. Set up air monitoring stations on the regional grid pattern to study movement and carry over of pollutants.
2. Conduct a research programme and collect information relating to air pollution—its control and prevention.
3. Establish air quality and emission standards which may be applicable State-wide or in designated air quality control regions.
4. Consult and cooperate with similar agencies in other States of the country as well as other Nations in procuring the information and execution of the programmes.

CIDCO is already in touch in the "State Vigilance Committee on Air Pollution" to fix some tentative norms. Also efforts are being made with the Bombay Municipal Corporation to have an integrated net-work of monitoring stations for Bombay and New Bombay so that observations are made similtaneously and controls applied effectively.

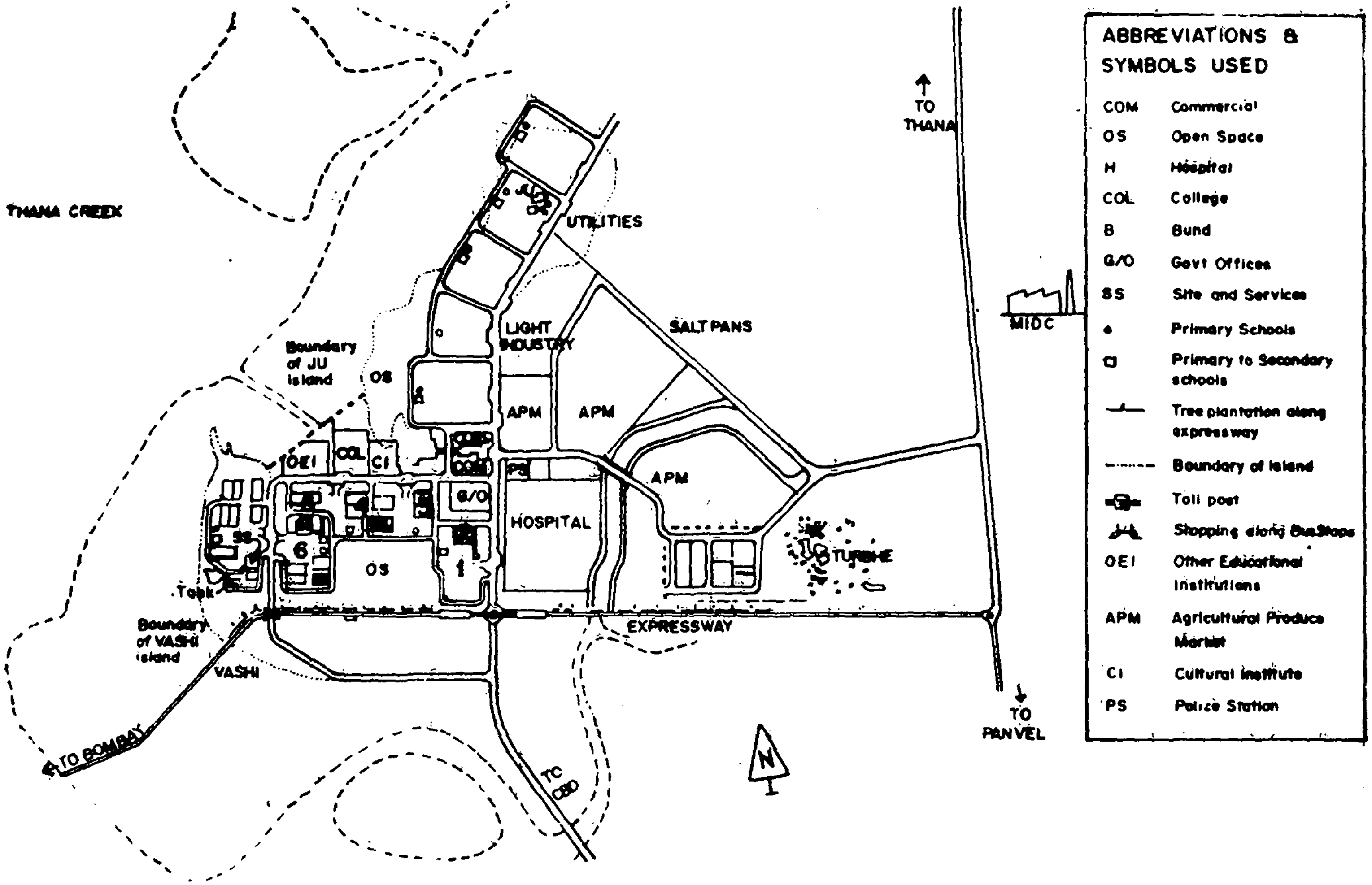

Fig. 7—Vashi Township and Agriculture Product Market (EDA)

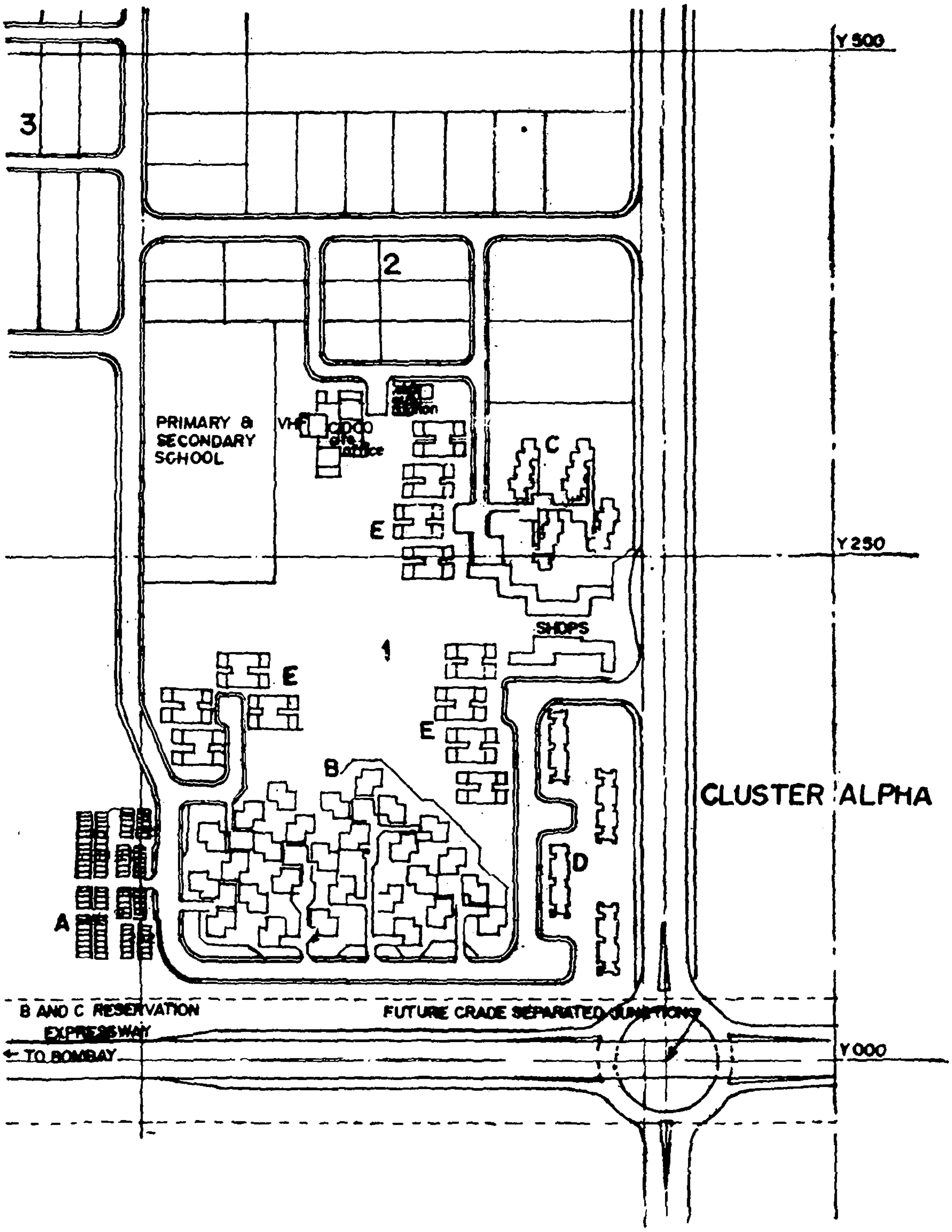

Fig. 8—Cluster— α of the EDA

TABLE II—AIR QUALITY STANDARDS FOR SPECIFIC POLLUTANTS(1)

No. Pollutants	U.S.A. (ppm) 24 hr	U.S.A. (ppm) 1 hr	U.S.A. (ppm) others	U.S.S.R. (ppm) 24 hr	Poland (ppm) 24 hr	Germany (ppm) 24 hr	Czechoslovak (ppm) 24 hr	Canada (ppm) 24 hr
1. Sulphur—dioxide	0.1 (residential)	0.25	—	0.058	0.13	0.30 (2 hours)	0.06	0.2
2. Carbon—monoxide	—	120 (California)	30	0.9	0.45	—	0.9	5
3. Fluoride (HF)	0.002 (urban)	—	—	0.01 mg/cu m	—	—	0.01 mg/cu m	0.004 ppm
4. Hydrogen-sulphide	—	0.1 (California)	—	0.005	0.005	0.2 (8 hr)	0.005	0.03 (30 min)
5. Nitrogen-dioxide	—	0.25 (California)	—	0.045	0.11	1 (8 hr)	0.06	0.1
6. Oxidants (by KI)	—	0.15	—	—	—	—	—	—
7. Lead (Pb)	—	—	0.005 mg/cu m (30 days)	0.0007 mg/cu m	—	—	—	0.02 mg/cu m (30 min)
8. Sulphates (H_2SO_4) suspended	—	—	0.01 mg/cu m (30 days)	0.1 mg/cu m	—	—	—	—
9. Suspended particulate matter (dust)	0.125 mg/cu m (Industrial)	—	—	0.15 mg/cu m	0.2 mg/cu m	—	0.15 mg/cu m	0.175 mg/cu m

Note— (1) Ref. "Industrial Pollution Handbook" by Herbert F. Lund.

(2) grams of gal/cu m x 24.2 x 10^3/mol. wt. = ppm by volume
or μg of gas/cu m x 0.0242/mol. wt. = ppm by volume

Summary

From the above discussions, it is evident that monitoring air quality is going to be quite commonplace in years to come. When developed on the right lines it can serve the dual role of controlling emissions from the existing sources and that of providing a means of intelligently locating new industrial units so that their harmful effects are minimised. It may even serve as an aid to overall urban planning both at city and regional levels.

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PROC. SYMP. ON ENVIRONMENTAL POLLUTION (1973)

Air Pollution Problems Pertaining to Aluminium Industry

S. K. MEHROTRA* and S. P. MENE*

The main pollutants of aluminium industry are hydrogen fluoride, sulphur dioxide, carbon dioxide, dust, etc. At present there are no standards for maximum allowable discharge to atmosphere available for the aluminium industry. The gaseous pollutants after treatment could be utilised for the recovery of important materials like cryolite or aluminium fluoride. This country is without the know-how of the two important methods available for reducing the concentration of the pollutants, *viz.*, wet scrubbing and dry scrubbing. The paper describes in detail the merits of the two processes mentioned above. It also emphasises where further efforts could be concentrated for the development of indigenous technology.

Introduction

The problem of human environment, although it is by no means new, has suddenly cropped up like a nightmare. It is acommunity alone which has to be responsible to maintain the ecological balance and clean environment of the surroundings. The rapid industrial growth has magnified the problems for disposing industrial wastes which are found in solid, liquid as well as gaseous form. It is, therefore, imperative that effective steps should be taken well in time for any eventuality in future.

Generally, in metallurgical plants where chemical reactions are involved, one compound is converted into another and the gases are liberated during the process. These waste gases like SO_2, HF, CO, CF_4 etc. may contain recoverable elements and in turn could be processed further if desired or let off to the atmosphere. It is these unprocessed gases which are the pollutants of the environment.

If human beings, wild life and vegetation around is exposed to such an environment for a prolonged period, this could have harmful effects on human health, animal life and surrounding nature. The industrial growth increases pollution problems and, therefore, should be tackled at the initial planning and design stage of a new industry to safeguard any future hazards. The paper deals mainly with the problems arising due to gaseous waste of an aluminium industry.

Present Method of Aluminium Production

The metal 'aluminium' is produced by the electrolytic reduction of alumina, which is generally carried out in the electrolytic cells having a cathode and the anode. At present there appears to be no other commercial method available to replace the same.

The commercial electrolytic reduction cells are mainly classified with the types of anodes as follows:

(a) Horizontal stud design (Soderberg type)

(b) Vertical stud design (Soderberg type)

(c) Prebaked design.

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* Bharat Aluminium Co. Ltd., Korba (M.P.).

In the first two types of design the anode is continuously baking during operation while in the third, it is a baked type. The chemical reaction usually takes place in the molten alumina which is adequately fluxed with cryolite. The reaction is as follows:

$$2\ Al_2O_3 + 4C \rightarrow 4\ Al + 2CO + 2CO_2 \ldots \quad (1)$$

The liquid aluminium is deposited at the bottom of the cathode and sucked out of the cells. It is then sent to the foundry for casting into various forms of ingots and pigs.

During the regular operation, dissolved alumina in the cryolite is depleted continuously. The gases like CO, CO_2, HF, CF_4, SO_2 are liberated continuously alongwith dust, alumina, tar fumes, etc. These are taken out from the gas burners provided at the side of electrolytic cell where CO is burnt into CO_2. These gases pass through the central duct line provided for this purpose and could be let off to the atmosphere with or without treatment. The gases liberted at the anode consists primarily of CO and CO_2, as already mentioned, and carbon monoxide burns when reaching the surface of the electrolyte. Thus, the hazard of CO is reduced to minimum, but the gases still contain undesirable impurities primarily of fluorine compounds resulting from the break down of fluroides in the cell both entrained cryolite and alumina dust, and tarry constituents from the anode.

In modern aluminium plants, therefore, the gas is cleaned before it is released to the atmosphere. This serves three purposes **viz.** (i) it allows the recovery of alumina, cryolite and aluminium fluoride, (ii) it also ensures better working conditions for the workmen, and (iii) it protects the vegetation around.

The gases can be collected and cleaned by several methods which are described in detail in this paper.

These gases when let off to the atmosphere without any treatment constitute the main source of air pollution from aluminium industry. In general, these gases have been found to have the following composition:

Type of gas	Concentration Gm/NM^3
HF	0.126
SO_2	0.217
Dust	0.800
Tar	0.010

At present there are no standards (i.e. maximum allowable discharge to the atmosphere) available in India for these pollutants.

The waste gases containing fluorine compounds are the only source for the recovery of raw materials. The recovery of the important materials like aluminium fluoride and cryolite becomes essential because these items are scarce. At present, the indigenous production of cryolite and aluminium fluoride cannot meet the demand of the increased aluminium production. Since the imports are becoming difficult, recovery of the above valuable materials through chemical treatment of these gases will result in considerable saving of valuable foreign exchange.

There are two important methods available for reducing the concentration of harmful gases generated during production of aluminium before they are let out to the atmosphere. The methods are: (a) Wet Srubbing, and (b) Dry Scrubbing.

Wet Scrubbing

This method is common and found to be working satisfactorily in the plants. The working principle of this is shown in the flowsheet (Fig. 1).

In this method the gases are passed through the electrostatic precipitators where dust, tar, alumina particles etc. are removed. The gases then pass through the scrubbers where they are washed with soda solution. The HF is dissolved and the solution is recirculated to achieve the desired concentration.

The solution is then sent to the cryolite regeneration plant for further treatment. In cryolite regeneration shop it is treated with

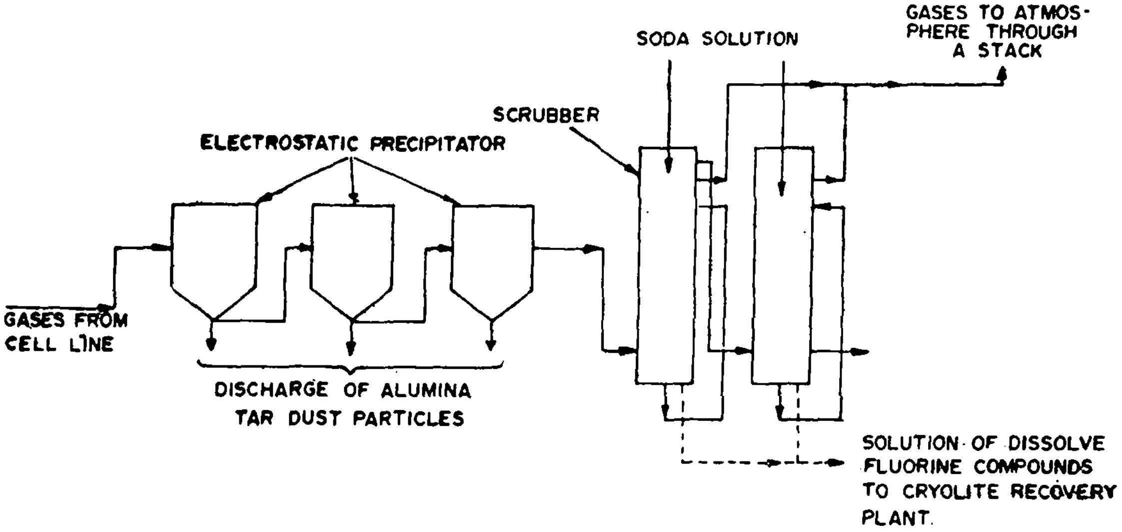

Fig. 1—Flow Sheet for Wet Scrubbing Process

sodium aluminate solution to precipitate out cryolite which is filtered, dried and sent back for reuse in the cells. Main chemical reactions taking place in scrubbers and cryolite regeneration unit respectively are given below:

$$Na_2CO_3+HF+SO_2 \rightarrow NaF+Na_2SO_4+NaHCO_3 \quad \ldots (2)$$

$$NaF+NaHCO_3+Na_2O\ Al_2O_3 \rightarrow Na_3AlF_6+Na_2CO_3+H_2O \quad \ldots (3)$$

The gases after passing through the scrubbers are left to the atmosphere through a stack. The concentration of harmful gases is thus reduced to traces. The recovery of HF is about 98 percent.

Dry Scrubbing

In the second method the principle is that the aluminium fluoride is recovered finally instead of cryolite. The method is divided into two classes:

(a) Dry Scrubbing with ammonia

(b) Dry Scrubbing without ammonia.

The process flow sheet is given in Fig. 2.

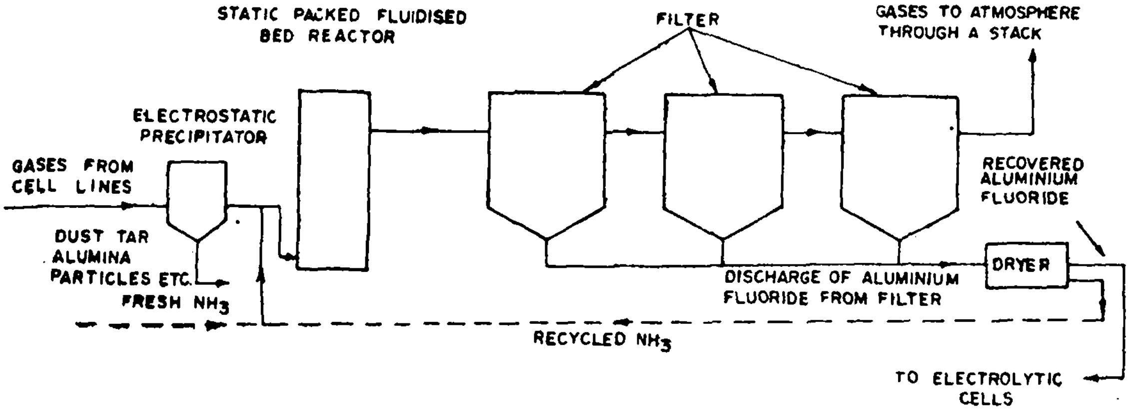

Fig. 2 -Flow Sheet for Scrubbing with/without Ammonia Process.

(a) *Dry Scrubbing with Ammonia*

In this method, gases are first passed through electrostatic precipitators and then reacted in a reactor with dry alumina where preliminary reaction takes place between HF and Al_2O_3 as follows:

$$HF + Al_2O_3 \rightarrow AlF_3 + H_2O \quad \dots (4)$$

The reaction is partially complete and the gases are subsequently passed through the filters where HF further reacts with dry alumina and ammonia, producing NH_4F_2 and AlF_3. The reaction is made complete by increasing the retention time of gases in the filters and subsequently the material is removed through a conveyor at the bottom of the filters. The material then passes through the calciner. The ammonia is evaporated and recycled back into the system. The gases after passing through the filters are left to the atmosphere through a stack. The concentration of harmful gases is thus reduced to traces. The recovery of HF is about 99 percent.

(b) *Dry Scrubbing without Ammonia*

In this process the ammonia gas is not used. The gases coming from the electrostatic precipitators are passed through a fluidized reactor where dry Al_2O acts as a carrier agent. The reaction is mainly as follows:

$$HF + Al_2O_3 \rightarrow AlF_3 + H_2O \quad \dots (5)$$

The reaction rate is enhanced here because of high temperature and the recovery of HF is about 99.5 percent. The final product, however, is the same in dry scrubbing with/without ammonia. In both dry and wet scrubbing processes it is possible to recharge the material directly to the cells.

The distinct advantage of the dry scrubbing process is that it produces aluminium fluoride contrary to wet scrubbing process, which produces cryolite salt.

In the routine electrolytic cell operation aluminium fluoride is one of the most important raw materials. If aluminium fluoride is used it is possible to manufacture cryolite *insitu* in the cells using the available sodium content of the alumina. The Na_2O content in the alumina is generally 0.3 to 0.4 per cent. In the event, more electrolyte generation is desired, it is possible to add excess soda ash and aluminium fluoride.

New Process for Aluminium Production

It may be possible in future to replace the available commercial method by a direct reduction process. In this process, in short, bauxite is reduced with carbon in electric furnace to an alloy of aluminium and the other reduction products of other constituents of the bauxite such as iron, silicon and titanium. This alloy is further treated at high temperature and pressure with aluminium trichloride gas, whereby the aluminium content of the alloy is volatilised as aluminium subchloride. The gaseous aluminium subchloride is further decomposed by changing temperature and pressure to aluminium and gaseous aluminium trichloride. This gaseous aluminium trichloride is further recycled into the system.

Although the method has been successful in the laboratory tests, to date no research organisation in the world has been able to transmute it into a commercial process. The distinct advantage of this process is that it is a close process. It not only replaces the use of fluxing media (mainly cryolite, aluminium fluoride etc.) but also eliminates the conventional use of alumina in the extraction of aluminium from bauxite. This process, therefore, eliminates the air pollution problems posed by the existing commercial method. The research, however, is still continuing and a breakthrough may come in near future.

BALCO Plans Ahead

It will be interesting to note that at present Bharat Aluminium Company, a Government of India Undertaking, is engaged in the construction of the biggest aluminium Smelter of 100,000 ton/yr capacity at Korba in Madhya Pradesh.

The importance of the air pollution and recovery (cryolite salt) problems have been analysed in detail and appropriate measures have been envisaged for the coming plants at Korba in Madhya Pradesh and Ratnagiri in Maharashtra.

At Korba, Bharat Aluminium Co. will be installing a complete gas cleaning installation consisting of electrostatic precipitators, scrubbers which will be supplemented by a full-fledged cryolite recovery plant. These units take advantage of the technology developed by the collaborators in the USSR. We hope to reduce the concentration of the pollutant gases to traces before they are left to the atmosphere and provide better surroundings and cleaner working conditions.

At present the technology of neither of the processes mentioned above is known in the country. Only a few aluminium plants have the facilities for the recovery of these gases and arrangements for reducing the concentration of pollutants below harmful levels before they are left to the atmosphere. All the plants appear to have bought these technologies from their collaborators who have patent rights for the same.

The technology of the wet scrubbing process is complicated and the equipments required are mostly not of standard type and are rather of special designs. The use of wet scrubbing for the recovery of waste gases and also for the reduction of concentration of pollutant gases have problems for disposing waste gases and waste liquors also.

The reaction mechanism for the dry scrubbing process is complicated although it is more sophisticated and simpler to operate. It is these two areas where further efforts need be concentrated for obtaining the knowhow of these processes. The laboratory efforts when transplanted to full scale plant will have many problems associated with scaling and model studies.

It need not be said that problems associated with model studies can be analysed using similarity principles and dimensional analysis

Summary

The problem of air pollution is an important one and with the rapid industrial growth of the country, the need for developing indigenous technology for self reliance could hardly be over emphasized. If no timely efforts are made for the development of technology, indigenous will have to be imported the same from advanced nations and this may be an expensive proposition. At times, it may not even be possible.

It is a matter of pride to mention that Bharat Aluminiums' initiative in the field of air pollution control will create interest among the scientists to explore the new horizons in the field.

DISCUSSION

Shri P. K. Yennawar (Nagpur): Are there full scale recovery plants in India for fluorine as cryolite?

Shri S. P. Mene: As far as we know, there are no full scale plants for the recovery of fluorine as cryolite in India.

Shri K. V. Muthukrishnan (Tiruchirapalli): (i) The author mentioned that the cost of electrostatic precipitator is higher than scrubbers. I would like to point out that even though the initial cost is higher, operating cost of electrostatic precipitator is less. (ii) Regarding particulate sizes, electrostatic precipitators are efficient in collecting particulates right from sub-micron size.

Shri S. P. Mene: (i) No comments. (ii) We agree.

Shri K. S. Misra (Ranchi): (i) Paper does not deal with all the aspects of the aluminium industry. (ii) Have the authors assessed technoeconomic feasibility and recommendation of the processes, namely, wet method, dry method, NH_3 method and fixed bed reduction methods? (iii) What are the limits of noxious gases let to atmosphere? (iv) I would like to point out that the technology of gas cleaning is available in this country.

Shri S. P. Mene: (i) It deals with only the Smelter portion of aluminium industry, since we believe that there will not be any recovery from the foundry, anode paste plant, sheet rolling shop departments, etc. (ii) The technologies of other methods, viz., dry scrubbing, dry scrubbing with ammonia, fludized bed, etc. are not available with us. If technologies are to be imported the technoeconomics would be different than if the technology is available indigenously. It is not possible to work out the technoeconomics at the present time. (iii) These should be as low as possible. The limits used are based on the experience of our collaborators. We have accepted the same, since we do not have the Indian Standards as yet. (iv) We are of the opinion that the technology is not available to the requisite depth.

Shri N. G. Ashar (Bombay): (i) What is the design criteria for collection of gases? How could it be applied to the existing plant? (ii) What is the amount of loss per ton of aluminium before and after F_2 recovery?

Shri S. P. Mene: (i) This is dealt with in detail in the paper. Gases are collected through a central duct system by creating an appropriate suction at the processing point. The gases are then fed to the various units like electrostatic precipitators, scrubbers, etc. and left to the atmosphere through a chimney. The method of collection is dependent on the design of the electrolytic cell. (ii) Recovery is dependent on the plant design and the operation technique. In general, recovery of fluorine as F is about more than half of gases collected at the gas cleaning end.

Shri S. Mukherjee: (i) What is the cost associated with the suggested process? (ii) What is the range of particle size removed? (iii) Is it economical with respect to other methods for removing suspended impurities of this particle size range?

Shri S. P. Mene: (i) The plant is yet to be commissioned and, therefore, the cost figures are not available. (ii) In electrostatic precipitator, sizes upto sub-micron level are easily removed. (iii) If the recovery of fluorine gases is used for the generation of cryolite, this method has been found to be more economical than other methods.

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Recent Trends in Sampling and Assessment of Stack Effluents

N. KURMAIAH* and M. N. RAO*

An important problem associated with air pollution control is to obtain a representative sample and to analyse it properly. The *sampling techniques of stack effluents (gases as well as particulates)* are still *unexplored fully*. A continuous analysis of the stack effluents is desirable in order to control pollution of the air effectively and efficiently.

The present state of knowledge in this vital field of sampling and analysis of stack effluents along with some critical comments *forms the basis of this paper. This field is particularly challenging* to the manufacturers of equipment for sampling and assessing pollutants.

Introduction

Air Pollution is a subject that covers a number of problems and several branches of science are involved in its investigation. Its direct connection with growing industry was first recognised in England in the 19th century which resulted in the legislation of the socalled "Alkali Act." Much work was done since then in the assessment and abatement of air pollution by industrial discharges in general and stack effluents in particular.

An attempt has been made in this paper to review the recent trends in the development of equipment for sampling and continuous monitoring of stack effluents. The aim of the paper is to introduce the recent technology to the manufacturers of equipment and induce them to think of indigenous manufacture of such equipment.

Pollution control depends much on the knowledge of what is coming out of the stacks. Representative samples and their proper analysis is necessary. If a pollutant can not be measured, it can not be controlled.

Sampling—A Major Problem

Sampling techniques have been described in detail in literature (1-5). The stack sample methodology published by the "Environmental Protection Agency" (6) is directed towards specific industries, but can be modified to suit other requirements as well. In combustion process, the SO_2 emission rate can often be determined most easily by measuring the sulphur content of the fuel. But most of the cases are not so simple. Many complex chemical operations include both very simple and very complicated emission measurement problems, and so each source must be approached as a new problem. That is to say, **effluent characteristics are critical and are not subject to generalization.** For example, one system consisted of particulates and acid gas (acid: low concentration) In this case, reduction of particulate matter by 99.5% did not have a significant effect on opacity i.e. the problem was in dealing with the acid gas. The answer wagged to install a nucleator, which reduced opacity to less than 5 percent (7).

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* Regional Engineering College, Durgapur (W.B.)

The selection of sampling site and the number of sampling points needed are based on attempts to get representative samples. In order to achieve this, the sampling site should be at least eight stack or duct diameters downstream and two upstream from any bend, expansion, contraction, valve, fitting, or visible flame. For rectangular duct, the equipment diameter can be calculated from the expression,

Equivalent diameter=2 (length x width)/(length+width)

After determining the sampling locations, provision must be made to "traverse" the stack. That is, the actual sampling must be performed at a number of traverse points in the stack. These multiple samples are necessary because of the extreme gradient flow and concentration that occur in some stacks. The concentrations of even relatively inert gases (i.e. CO_2, CH_4) have been found to vary greatly within a stack. The above considerations along with gas flow measurements and sampling strategy have been discussed in detail by Morrow, *et al.* (8).

Gas Sampling

A knowledge of the temperature variation acorss the stack is important. This is done as part of the velocity traverse and indicates variation in gas distribution. The sampling rate and time of sampling at each point are often kept the same to simplify calculations. Stainless steel is usually an acceptable probe material.

Extended flushing with stack gas should precede sample collection. This flushing is important if losses to the walls of the probe and sample collector are to be avoided often the entire sampling system must be heated to prevent condensation of water, heavy hydrocarbons and sulphur compounds.

Sampling of Particulates

A representative sampling is obtained only if the velocity of stack gas stream entering the probe nozzle is the same as the velocity of the stream passing the nozzle. If the sampling velocity is too high (super-isokinetic sampling), there will be a smaller concentration of particles collected (because the inertia of the larger particles prevents them from following the stream lines into the nozzle). Alternatively, in sub isokinetic sampling), where the gas sampling velocity is below that of the following gas stream, the gas samples would contain a higher than the actual particulate concentration because heavier acrosol particles will enter the nozzle, but light particles will be diverted.

The sequence of components in a sampling train may be represented as: nozzle, probe, particulate collector, cooling and/or gas collector; flow measurement devices; vacuum source. The general methods of assembly and operation of this system are already known to a sufficiently thqrough extent (8).

Assessment of Stack Effluents

Fixed gases

It is essential to know the average molecular weight of the flowing gases to determine the actual velocity or volumetric flow in a stack. In stacks where air is present or where combustive gases are emitted, fixed gas (N_2, CO_2, O_2) concentration data are required for this calculation. In addition, these gases are indicators of equipment operation and hence their measurement is often desirable as a process control tool. The well known Orsat analyzer and Gas chromatographic analyzers can be successfully employed.

O_2 and CO_2

Continuous monitoring of O_2 and CO_2 is possible using electrometric and non-dispersive infra-red (NDIR) analyzers respectively.

Carbon Monoxide

The major source of CO is automotive emissions, but significant emissions also occur from stationary source fuel combustion and a myriad of industrial processes. Continuous monitoring of CO is usually performed by non-dispersive infra-red (NDIR) analyzers. Frequent zeroing and calibration of the equipment is necessary due to drift.

Sulphur compounds

(SO_2, SO_3, H_2S and mercaptans) :— In many stacks only one type of sulphur compounds is present. In the flame photometric analyzer the sample is burnt in a hydrogen flame and the intensity of the sulphur emission line is measured by a photomultiplier. This equipment is sensitive and it does not drift but small variations in pressures and flows affect the operation. Refinement is desirable.

SO_2

Of the various types of SO_2 monitors the following are worthy of mention: U. V. absorption, correlation spectrometry, NDIR, titrimetry, conductometric, electrochemical etc.

Oxides of Nitrogen

The following methods can be used for monitoring:

U. V. Photometric (NO_2, NO); correlation spectrometry (NO); electrochemical (NO_3 NO_2, NO); chemiluminescence (NO); NDIR (NO_2, NO) etc.

Hydrocarbons

These can be monitored by chromatographic methods, spectroscopic methods or by using Flame-Ionization Detectors.

Particulates

Particulates are defined as all airborne solid and liquid matter. They include solid particles and liquid aerosols. Particle diameters can vary from a few hundred Angstrom units to larger than 50 μ (50,000 A°). Particulate estimations fall into two categories i.e. opacity measurements and mass measurements. No general correlation is found between these two estimations.

Opacity measurements are carried out using a transmission photometer but these measurements are beset with many disadvantages and drastic modifications are desirable. Opacity measurements are useful for controlling particularly bad (and nuisance type) emissions, especially black particles, such as found in incinerators and power plant stacks. The assessment of total mass of emissions is preferable because one can estimate day and night, regardless of colour (8). In order to estimate mass two factors must be known: (i) Particulate concentration in terms of weight, and (ii) the gas flow rate. If it is assumed that gas flow rate has been determined and that isokinetic sampling is used, it is necessary only to determine particulate concentration to know the mass emitted. Two monitors useful for this purpose are described below:

(i) *Piezoelectric Monitor*

In this device, particles in the sample stream are electrostatically deposited on to a piezoelectric sensor. The added weight of particulate changes the oscillation frequency of the sensor in a characteristic way. This instrument can not handle very high particulate loadings found in many stacks without dilution of the sample. The dilution step greatly complicates the sampling problems associated with use of the device since two iso-kinetic samples are required, one of the stack and another of the diluted stack sample. A piezoelectric microbalance system consists of the components shown in Fig. 1. The output signal can be conditioned so that it becomes directly proportional to particulate mass concentration. It can then be recorded either by digital or analog recorder (9, 10).

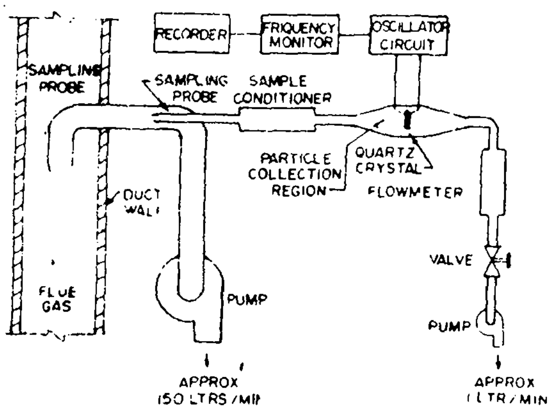

Fig. 1—Piezoelectric Microbalance Instrument

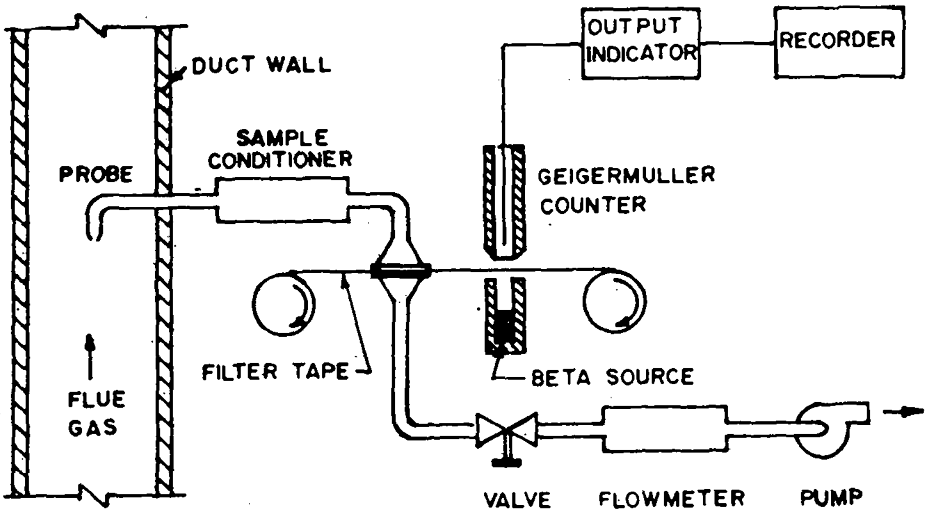

Fig. 2—Beta Radiation Attenuation Instrument

(ii) Beta *Attenuation Monitor*

In this type of device (Fig. 2) the particulate sample is filtered using a continuous filter tape and the mass of particulates filtered out is determined by measuring its attenuation of beta radiation. Since beta attenuation characteristics are not very different for a wide variety of stack particulate matter compositions, a direct mass measurement is possible. Carbon-14 with a half life of 5,568 yr is a typical beta radiation source, thallium-204, cerium-137 and promethium-147 have also been used. Geiger-Muller (GM) counters are the most common detectors, but proportional and scintillation counters have also been used. The difference in count rate of the GM detector before and after the particles are collected is a measure of the mass of particles on the filter (10).

Conclusion

A review of recent trends in sampling and continuous monitoring of stack effluents suggests that collection of representative samples is the most important aspect of the air pollution control programmes. There is a lot of scope for improving upon the present-day methods of sampling and analysis. It is, in fact, a challenge to the manufacturers of equipment to produce suitable indigenous equipment for sampling and continuous monitoring of stack effluents.

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Pollution from Cement Industry

J. K. SINHA*

An investigation into the particulate pollution from ten cement factories all over the country was taken up between the period Feb. '68 to July '72. The work included the estimation of: (i) dust which was discharged into the atmosphere from cement kiln, coal drier and cement mill chimnies, (ii) airborne dust concentration at working places during different operations, (iii) airborne dust around the factories, (iv) variation in airborne dust concentration along the plums, and (v) dust exposure for different classes of workers in the cement industry.

All the results are summarised in the paper. It was found that the average dust discharged into the atmosphere through several cement kiln chimnies amounted to 9.75% of the clinker produced, which amounted to 1.25 million tonnes of valuable dust discharged per year into the atmosphere.

Introduction

The cement industry is one of the most basic industries on which the industrial development of a country depends. The first cement kiln with a capacity of 1000 tonnes of portland cement was installed at Porbunder as early as 1914. However, in 1947, India had 18 cement factories in the country producing one and a half million tonnes of cement. Today India has 46 cement factories producing about 14 million tonnes of different kinds of cement and the target of production during the Fourth Five Year Plan is expected to be 18 million tonnes during 1973-74. This clearly shows the rapid growth of the cement industry in the country. Today India ranks ninth as a cement producing country of the world but as a consumer it still ranks low. In India, the per capita consumption of cement has increased from 5 kg in 1947 to 27 kg in 1970. However, the per capita consumption of cement in advanced countries of the world is about 15 to 20 times higher than in India.

Cement Manufacture

In the process of manufacture of cement, cement industry handles very fine pulverised material (fine powders) both as raw material and feed to the kiln and the finished product. The feed to the kiln is 85-90 percent minus 170 mesh sieve size (about 89 μ, 1 μ $=10^{-4}$ cm). The finished product, i.e., the cement is about 86 percent minus 5.66 μ size.

The pulverised coal, used for firing cement kilns is also fine powder; 85 to 90 percent passes through 170 mesh sieve size (B.S. Sieve).

All these indicate the problems associated with handling of such fine powders at different stages of manufacture of cement.

A part of the fine powders as mentioned above finally escapes to the air through chimneys and pollutes the atmosphere. The pollution of atmosphere by particulate matters may have the following effects: (i) reduced visibility, (ii) general dustiness of

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* Scientist. Central Mining Research Station, Barwa Road, Dhanbad (Bihar)

the area, (iii) retards the growth of the vegetation, (iv) nuisance to the inhabitants, (v) loss of valuable raw material, (vi) affects the security of State during the period of war, (vii) thermal pollution of atmosphere, and (viii) health hazards to the workers and inhabitants. A lot of controversy exists as to the ill effects of cement dust on human beings (1, 2).

In view of the above effects, the pollution of atmosphere due to cement industry is a severe menace and scientists, engineers and technologists need to pool all the possible resources to ameliorate the hazards.

Effects of Silica

The major compounds constituting cement are: CaO 62% and SiO_2 22%. The proportion of free silica is about 1% in the finished product but may be anything upto 6.5% in material handled in the crusher house, raw mill and stone house.

Silicon is distributed in inorganic forms in nature in the same way as carbon is distributed in organic matters. Silicon is next to oxygen in abundance and constitutes about 28 percent of the lithosphere. Free silica (silicon-dioxide) occurs in nature in three forms: (i) crystalline, e.g., quartz, (ii) amorphous, e.g., opal, and (iii) crystocrystalline, e.g., flint. The dusts produced by silicon dioxide are pathogenic.

Materials and Methods

The following experiments were conducted in the selected cement factories with a view to estimate the dust concentration in various units.

Dust Loading of Gases

Gases were drawn isokinetically from the duct at sampling spot by a high pressure exhaust blower through a stack sampler containing tarred paper thimble (sixlet thimble of size 22 x 80 mm) of known weight, making sure that the nozzle of the sampler was facing the incoming gas. The volume of the gases sampled was measured by rotameter. The duration of sampling varied from one minute to thirty minutes. The paper thimble, after sampling, was dried in an air-oven and weighed. The difference of weight gave the weight of dust obtained from the measured volume of gases (recorded by rotameter)..

Measurement of Quantity of Gases Flowing in Duct

A standard pitot tube was used to measure the velocity of gases flowing in the duct. The following formula was used:

$$v = 243 \sqrt{h}$$

where h = velocity pressure in mm of water.

The cross-sectional area of the duct at the place of measurement of the velocity was taken diametrically. The quantity of the gases flowing in the duct was calculated using the data.

$$Q = v \times A$$

where v = velocity of gases flowing, and

A = mean area of cross-section of the duct.

Airborne Dust Sampling

The samples of airborne dust were collected in impinger flask (sampling tube) in liquid medium (distilled water with about 5% alcohol) by impingement with the help of M.S.A. Midget Impinger. The impinger pump was manually operated and which sucked dust laden air through the liquid at a rate of 2.8 l/min under a pressure of 30.48 cm of water gauge. The diameter of nozzle through which the air was sucked was 1 mm. Velocity of the impingement was 4.2 km/min.

Counting of Dust Particles

The liquid containing the dust particles was mixed thoroughly in the impinger flask and was poured in a counting cell (wipple disc) of 1 mm depth and a glass slide was placed on it. The dust particles were allowed to settle for 20 min before counting. The counting of the dust particles was carried out by an optical microscope under light field technique at a magnification of 10 x 10. The concentration of the airborne dust at a sampling spot were calculated from the counting results, the time of sampling and the volume of liquid sampled in the impinger flask.

Results and Discussion

Estimation of Dust Losses to the Atmosphere

The dust losses to the atmosphere through the chimneys of the cement kiln was investigated. The results are given in Table I. Taking the average dust loss from the kiln as 9.75% of clinker on the basis of the results, the total loss from the cement industry at a production of 13 million tonnes of clinker per year, comes to about 1.25 million tonnes of dust per year. Ultra fine (sub-micronic) particles of this dust remain in air for ever, whereas the larger particles settle to the ground with a lapse of time. A good percentage (about 90% or more) of this dust must be trapped by appropriate gas cleaning devices to avoid pollution of atmosphere. This is a very valuable raw material and would be a profitable feed back to the kilns for the manufacture of cement. The gas cleaning device or the dust trapping machine will pay for itself.

TABLE I—RAW MATERIAL LOSS IN TONNES PER YEAR THROUGH CEMENT KILN CHIMNEY STACKS.

Cement works No.	Clinker production tonnes/ year	Dust loss through chimney stacks tonnes/ year	Percentage loss of clinker	Rupee equivalent @Rs. 50/- per tonne
4	261600	15478	5.90	7,73,900
5	180000	6750	3.75	3,37,500
6	90000	17370	19.30	8,68,500
7	180000	3186	1.77	1,59,300
8	530000	64005	13.16	32,00,250
9	270000	20826	7.76	10,41,300
10	90000	10890	12.10	5,44,500
Total	16,01,600	1,38,505	—	69,25,250

Airborne Dust Concentration

Average airborne dust concentrations in particles per cu cm of air (ppcc) at different spots during different operations in ten cement factories are given in Table II. The minimum and maximum concentrations are also given in brackets. The average concentration of airborne dust for all the factories taken together, during different operations, are also included in Table II. These observations are discussed below:

Lime Stone Crushing Plant

The pathogenesis of limestone dust has been summarised in Zaidi's "Experimental pneumoconiosis" (1).

The average concentration during normal working of the limestone crushing plant varied from 2167 to a maximum of 2835 ppcc though the minimum and maximum recorded concentrations were 957 ppcc and 6905 ppcc respectively. The average concentration of airborne dust at factory number 9 was only 423 ppcc. This was due to very erratic working of the crusher. The average concentration during crushing of the limestone includes the average concentration at factory No. 9 and was 2367 ppcc. The concentration during crushing plant was higher and had a great nuisance value and measures must be taken to reduce the concentration so that working atmosphere in the crushing plant would be improved.

Kiln Firing End

The average airborne dust concentration at the kiln firing varied from 352 to 1308 ppcc. Since the particles were coal dust, the TLV was taken for coal dust as 650 ppcc. Out of 7 cement factories, only one cement factory showed the concentration at kiln firing end above the TLV of 650 ppcc. The average for all the factories was below the TLV and it was 580 ppcc. However, the maximum concentration at the kiln firing end for four cement factories was above the TLV.

Clinker Cooler Area

The threshold limit value for clinker dust is taken as that for the cement dust, i.e., 1750 ppcc. The average airborne dust concentration in the clinker cooler area varied from 986 ppcc in factory number 8 to 2765 ppcc in factory number 2. Out of 6 factories, the concentration of airborne dust in the clinker cooler area was above the TLV (1750 ppcc) at only one factory (No. 2). However, the average airborne dust concentration at the clinker cooler area for the cement industry as a whole was 1394 ppcc which was below the TLV.

Cement Mill

Out of ten factories the average airborne dust concentration at cement mill for three factories (No. 1, 4 & 5) was above the TLV of 1750 ppcc. The average lowest concentration was 2417 ppcc for factory No. 1. The higher concentration at the cement mill was recorded where there were leakages of cement dust from the transport pipe, the area was not cleaned regularly and the floor was covered with fine dust and the area was so covered that at times gust of wind from outside used to come in raising most of the floor dust in the atmosphere.

However, the average airborne dust at the cement mill for all the factories, i.e., cement industry as a whole, was 1214 ppcc which was much below the TLV of 1750 ppcc.

Packing House

The average airborne dust concentration at the packers during packing of cement for seven factories varied from 1915 to 4915 ppcc with a maximum of 8480 ppcc and were above the TLV and was 1600 ppcc, though the highest concentration even at this factory (No. 10) was 2673 ppcc. The average airborne dust concentration at the cement packers during packing of cement in gunny bags for all the cement factories (i.e., for cement industry) was 3330 ppcc far above the TLV of 1750 ppcc. Some of the reasons for the high concentration at the cement packers during packing of cement were as follows:

(i) No ventilation system at the packers,

(ii) Leakage from the packing machine,

(iii) Dust got airborne when the full cement bags had even a little fall,

(iv) Dust produced during transportation and packing of full cement bags in the yard and in the wagon. This dust raised the general airborne dust concentration in the packing house, and

(v) Lack of cleaning the cement dust accumulated on the floor around the packing machine. At places there were several inches of dust on the floor.

Wagon Loading

The average airborne dust concentration in the closed wagons during loading of cement bags were very high and varied from 5231 to 16500 ppcc far above the TLV of 1750 ppcc. The maximum was still higher and, it was 18000 ppcc. The average airborne dust concentration in the wagons during loading of cement bags for four factories was 6723 ppcc about four times the TLV.

Some of the reasons for the high concentration in the wagons during loading of cement bags were as follows:

(i) Drop of cement bags during packing in the wagon produced enough dust which got airborne and filled the small closed space of the wagon.

(ii) There was no arrangement of ventilation which could have removed the high concentration of the airborne dust in the wagon.

Coal Crushing Plant

The average airborne dust concentration around the coal crushing plant was above the TLV of 650 ppcc and varied from 877 ppcc for factory No. 8 to 2673 ppcc for factory No. 7. The average airborne dust concentration in the area was about three times the TLV for factory No. 9 and four times for factory No. 7. The average airborne dust concentration around the coal crushing plant for all the three factories was 1843 ppcc which was about three times the TLV (650 ppcc). However, the maximum concentration was as high as 4180 ppcc. This indicated that the concentration of airborne dust around the coal crushing plant was exessively high and some of the reasons for this were as follows:

TABLE II—AIRBORNE DUST CONCENTRATION AT DIFFERENT OPERATIONS IN TEN CEMENT WORKS

Operations	Airborne dust concentration in ppcc with mean, maximum & minimum										Mean ppcc for all the works	TLV in ppcc
	1	2	3	4	5	6	7	8	9	10		
1. Lime stone crushing plant	2635 (2240-3500)	2685 (1175-6905)			3515 (2505-4640)	2167	2580 (957-5213)		423 (239-957)		2367 (957-6905)	
2. At the kiln firing end	—	545 (110-1800)	556 (385-930)	—	—	435 (319-638)	352 (160-691)	1308 (931-1596)	348 (223-638)	519 —	580 (110-1496)	650
3. Klinker cooler plant.	1000 (880-1236)	2765 (935-6430)	1430 (1380-1515)	1273 (1120-1490)	—	886 (611-1542)	1012 (430-1596)	—	—	—	1394 (430-6430)	1750
4. Cement mill inside	2105 (1296-3267) 3 Nos.	1590 (426-1970) 4 Nos.	420 (146-1050) 3 Nos.	1960 (1850-2090) —	2417 (1785-3440) 5 Nos.	1706 (1302-2154) 3 Nos.	270 (133-452) 1 No.	657 (318-864) 4 Nos.	446 (252-704) —	570 (492-718) 1 No.	1214 (146-3267) —	1750 —
5. Packing of cement	2945 (2450-3460)	4915 (1550-8480)	3400 (2500-4200)	4258 (2575-5000)	5096 (2775-6130)	800 (532-1409)	—	2513 (2154-2872)	1915 (1702-2128)	1600 (1024-2673)	3330 (1024-8480)	1750
6. Wagon loading	—	16500 (15600-18000)	—	—	—	5231 (3670-7341)	—	8553 (8181-8925)	6384 (6277-6490)	—	6723 (3670-18000)	1750
7. Around coal crushing plant.	—	—	—	—	—	—	2673 (1197-4180)	877 (771-1037)	1980 (1968-1995)	—	1843 (771-4180)	650
8. Around coal drier.	—	—	—	—	2590 (1920-3385)	—	—	—	—	628 (432-718)	1609 (432-3385)	650
9. Around coal mill	—	—	—	—	3957 (3395-4000)	—	378 (385-372)	—	—	971 (325-2068)	1769 (325-4000)	650
10. General atmosphere in the factory area.	714 (612-1357)	180 (145-215)	371 (145-570)	705 (600-810)	855 (760-950)	—	—	—	—	—	567 (145-950)	1750
11. Fixed sampling point. (For 7 days)	—	—	371 (193-918)	—	—	214 (170-310)	118 (53-231)	114 (80-133)	74 (35-119)	—	163 (35-918)	

N.B.: T.L.V. for (1) Cement dust ... 1750 ppcc
(2) Coal dust ... 650 ppcc

(i) Excessive leakage of coal dust at several points,

(ii) Absence of ventilation system in the closed space,

(iii) Poor cleaning of the floor dust, and

(iv) Fall of fine coal during transportation.

Coal Drier

The concentration of airborne dust around coal drier varied from 1920 to 3385 ppcc. The average concentration of the airborne dust was 2590 ppcc, far above the TLV of 650 ppcc.

Around another coal drier chimney, which was a part of a coal grinding mill, the condition was not so serious and the average concentration was 628 ppcc, which was below the TLV.

The high concentration in the four cases was due to the following reasons:

(i) The coal drier cleaning device (cyclone) was not working to its full efficiency and the capacity of the device was too large.

(ii) The coal dumping area was around the coal drier which was adding its share to the airborne dust.

Coal Mill

The average airborne dust concentration around the coal mill was above the TLV of 650 ppcc. In case of factory No. 5, the average airborne dust concentration around the mill was about six times the TLV (650 ppcc). For factory No. 7. only two readings were taken when the mill was not working.

The high concentration of airborne dust around the coal mill could be attributed to the following factors:

(i) Leakage of dust from the transportation,

(ii) Practically there was no system of ventilation for the area around the coal mill. This was important since the area was closed and covered.

General Atmosphere within the Factory Area

The average airborne dust concentration in the general air within the factory area varied from 180 ppcc for factory No. 2 to 855 ppcc for factory No. 5. The maximum concentration of airborne dust in this area was 1357 ppcc. The average airborne dust concentration in the general atmosphere within the factory area for all the five factories was 567 ppcc. Thus, the concentration of airborne dust in this area was always within the TLV of 1750 ppcc. The TLV for this area is taken as that for cement dust, even though the dust in this area would be a mixed one.

Fixed Point

The average airborne dust concentration at a fixed point in front of the general administrative office varied from 74 to 371 ppcc while that in front of the general office for five cement factories was 163 ppcc. These data suggested that the general office is situated in the cleanest area of the factory.

Airborne Dust Concentration in Cement Industry as a Whole

The results given in Table II show that the concentration of airborne dust around kiln firing end, clinker cooler and cement mill were within the permissible limit (TLV). On the other hand, the concentration of airborne dust at limestone crushing, at cement packing machines, in the wagons during loading of cement around coal crushing machines, coal drier and coal mill were above the safe limit (TLV). The industrialists should not get scared from it. Rather this should be taken as an encouragement to take necessary measures to trap the dust which get airborne. This is not merely the dust but a valuable and costly raw and finished material and would perhaps pay for itself.

The airborne dust around the factory area in general atmosphere was within safe limit. It could be said that the cleanest area of the factory was the general office.

Health Hazards to Workers

The health hazards from cement dust is a very controversial issue (1, 2). All the same, the dust cannot be taken as harmless to the workers. The threshold limit value of cement dust exposure was calculated from the TLV (1750 ppcc) and the total shift hours (8 hr). This gives a cement dust exposure threshold limit value of 1400 ppcc—hr for 24 hours. Similarly, the threshold limit value for coal dust exposure has been calculated and it came to 5200 ppcc—hr.

The total dust exposure per shift for workers at different locations are given in Table III.

The workers at kiln firing end, clinker cooler area, cement mill, general atmosphere in the factory area and in the office were exposed to dust within the safe limit, i.e., within the threshold limit value (TLV) of dust exposure.

On the other hand, workers at cement packing, wagon loading with cement bags, around coal crusher, coal drier, coal mill and limestone crusher, exposed to dust exposure above the threshold limit value.

Variation in Concentration of Airborne Dust with distance from Stacks

The investigation into the condition of airborne dust concentration with the distance from the stack was considered essential since this affected the colony and the inhabitants around the factory.

The investigation was carried out along the direction of the wind upto a distance of 2 km. The distance of 2 km was an arbitrary decision depending upon the convenience to take about 10 samples at a stretch along this distance.

TABLE III—AVERAGE DUST EXPOSURE FOR WORKERS IN CEMENT INDUSTRIES

Sl. No.	Workers at different operations	Average for all cement works (ppcc)	Time spent by the workers under different conditions (hr)		Average dust exposure during different operations (ppcc-hr)	TLV of dust exposure (ppcc-hr)
			Working area	General atmosphere		
1.	Lime stone crushing plant	2367	8	—	18936	
2.	At kiln firing end	580	8	—	4640	5200
3.	Clinker cooler area	1394	8	—	11152	14000
4.	Cement mill house	1214	8	—	9712	14000
5.	Packing of cement	3330	4	4	15588	14000
6.	Around wagon loading	6723	4	4	29160	14000
7.	Around coal crushing plant	1843	6	2	12192	5200
8.	Around coal drier area	1609	6	2	10788	5200
9.	Around coal mill area	1769	8	—	14152	5200
10.	General atmosphere (within the factory area)	567				
11.	Fixed point (infront of general office)	181	8	—	1448	

Note— (1) Samples were taken by MSA Midget Impinger

(2) TLV for dust exposure (ppcc-hr) (i) Cement dust—14000
(ii) Coal dust — 5300

(3) TLV for cement dust=17500 ppcc for coal dust = 650 ppcc

(4) The TLV for dust exposure was obtained by multiplying TLV for dust concentration and the shift hours.

(5) Workers in the packing house and wagon loading area, performed their duties for 4 hr per shift of 8 hr and the rest 4 hr they spent in the general atmosphere i.e. in the average dust concentration of 567 ppcc.

The results of the variation in airborne dust concentration in the general atmosphere along the wind upto a distance of 2 km from the source (stacks) are given in Table IV.

On an average, the highest concentration of airborne dust occurred within 1 km from the source though this seemed to depend on meteorological conditions prevailing in the area.

Where there was no obstruction to plume due to topography or tall buildings and the wind was not turbulent, the plume went miles away from the source in the form of a ribbon as in the case of cement factory No. 6.

Diurnal Variation in Concentration of Airborne Dust

Samples of airborne dust were taken at fixed places in front of the general office of the cement factories. The samples were taken at a particular time and for seven days of the work in order to get an idea as to how it varied over a week. The results are given in Table V.

From the Table V, it was clear that the airborne dust concentration did not depend on the days. The highest concentrations occurred on Tuesday, Saturday and Sunday in different factories. In majority of cases the concentration was high on Sunday.

Conclusions

1. The average dust loss from the cement kiln chimneys from cement industry was 9.75% of the clinker produced from the kilns. At an annual production of 13 mil tonnes of clinker, the dust discharged to the atmosphere with kiln gases amounted to 1.25 mil tonnes. This was a very valuable processed raw material and was valued at over Rs. 6 crores at the rate of Rs. 50/- per tonne of the dust.

Out of 14 kilns investigated, only three were incorporated with kiln gas cleaning devices; two with cyclones and one with electro-static precipitator.

2. Leakages of dust from the transporting ducts were responsible for undue rise in the airborne dust concentration at many working places in the factory.

3. At several places, the fall of the material from one conveyer to another or to hopper was excessive and proper design of

TABLE IV—VARIATION OF DUST CONCENTRATION IN THE DIRECTION OF FLOW OF FLUE WITH DISTANCE

Cement Work No.	Distance from stack (m)										Stack height and wind velocity
	200	400	600	800	1000	1200	1400	1600	1800	2000	
	Concentration of airborne dust (ppcc)										
3	171	132	190	—	87	—	—	—	—	—	5 kg/hr
5	—	2215	2275	2400	—	—	—	—	—	—	53 m (160 ft)
6	120	92	80	106	40	40	53	27	19	—	60 m (200 ft)
7	106	178	252	429	655	525	140	108	74	—	41.8 m (150 ft)
8	250	355	409	480	503	446	278	165	313	160	53.34 m (160 ft) 10 km/hr
9	266	518	625	665	758	904	718	280	185	160	53.3 m (175 ft) 10 km/hr
10	213	193	140	140	133	100	106	93	80	66	48 m (160 ft)

TABLE V—DIURNAL VARIATION IN CONCENTRATION OF AIRBORNE DUST

	Cement works number				
Days	3	6	7	8	9
Monday	—	212	53	93	35
Tuesday	918	170	159	119	53
Wednesday	266	160	66	133	72
Thursday	333	210	133	120	80
Friday	146	—	80	80	78
Saturday	193	—	101	120	119
Sunday	—	319	231	133	86
Mean over a week	371	214	118	114	74

Note— Samples were taken at a fixed point consecutively for seven days.

chute was not there. This again unduly raised the airborne dust concentration at several working places.

4. Artificial or mechanical ventilation was not adequate and at many places it was not provided especially in the closed areas of dusty operation. This added to the concentration of dust at these working places.

5. The average airborne dust concentration at the following places with the respective operations were above the threshold limit value for the cement industry as a whole, though it varied from factory to factory and also within the factory.

(i) Limestone crushing plant
(ii) Packing of cement in bags
(iii) Loading of cement bags into wagons
(iv) Around coal crushing plant
(v) Around coal drier
(vi) Around coal mill

The workers at the above places were exposed to dust exposure per shift which was above the threshold limit value.

6. The average airborne dust concentration at the following places with respective operations were within the safe limit (TLV) for the cement industry as a whole though they varied from factory to factory and within the factory:

(i) At the kiln firing end
(ii) Clinker cooler area
(iii) Around cement mill
(iv) General atmosphere within the factory area
(v) General office area

The workers at the above places were exposed to dust exposure per shift which was within the safe limit.

7. The airborne dust concentration increased with the distance initially for about one km and then had a downward trend. In some cases, the maximum concentration down wind occurred before one km or even after one km.

Recommendations

1. Gas cleaning devices should be used with the cement kiln gases. This will trap most of the valuable 1.25 mil tonnes of processed raw material which is discharged into atmosphere. This will serve two important purposes: (i) conserve the valuable raw material and use it for the manufacture of cement, and (ii) reduce to the lowest level the pollution of atmosphere from the cement kiln dusts.

2. The gas cleaning devices must be designed considering all the important factors such as the dust load of the gas, size distribution of the dust, volume and velocity of gas, and other physical, chemical, electrostatic characteristics of the dust and the gases.

3. Leakage of dust from different sources in the cement manufacture must be stopped. This could be achieved by proper inspection and maintenance.

4. Proper ventilation system should be provided for the closed spaces. If necessary, hood and ducting system should be provided to clear away the dust at the source so that the working atmosphere is cleared. This could be particularly useful at transfer points, at crusher and grinding mills.

5. Pressurised cubicles should be provided for the packers packing cement in the bags.

6. Duct ventilation must be provided in coal transport and coal reclamation tunnels.

7. Since the maximum concentration of airborne dust down wind occurred at about 1 km, the residential colony and area should be at least 1 km away from the factory chimney. However, other factors such as general topography of the area and the meteorological conditions must be taken into account before taking final decision.

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Note—The idea and opinion expressed in this paper are those of the author and not necessarily of C.M.R.S., Dhanbad or C.S.I.R., New Delhi.

DISCUSSION

Dr. K. P. R. V. Murty: What were the concentrations of dust inside and outside the factory and in the chimney?

Dr. J. K. Sinha: The concentration of airborne dust inside factory varied with operations as given in the text. However, the average concentration during different operations inside the factory was 2313 ppcc.

The concentrations of airborne dust outside the factory are given in the text. The average concentration outside the factory was 245 ppcc. The concentration outside the factory depends upon several parameters such as weather contitions, the emission characteristics of the dust from the chimneys and the working conditions of the plants and gas cleaning equipments.

The average dust concentration in the kiln chimney stack was 2.26 g/cu ft of air with cyclone gas cleaning equipment.

Shri M. Miakhan: Some manufacturers in the country, especially in the field of sanitation, claim that the emissions from the chimney stacks in the industry are beneficial to plant growth. Please clarify.

Shri P. K. Yennawar: What are the health hazards and vegetation damages due to cement dust?

Dr. J. K. Sinha: The health hazards due to cement dust definitely exist. This is apparant from the results of an investigation carried out by the USPHS. In the present investigation a group of 33 workers in a cement factory were considered. The results revealed that 15 persons (40.6% had pneumoconiosis. These workers were working in the industry for more than 3 years.

Deposition of cement dust on vegetation retards the growth of plants considerably. The question posed by Dr. G. N. Radhakrishna and its answer given, may please be seen in this connection.

Shri M. D. Misra: Regarding the efficacy of electrostatic precipitator in cement industry, the author has stated that none of the precipitators installed by Brain Cement Mills is working. Moisture content in stack gases is an important factor for working of electrostatic precipitator. Will the author please inform what is the optimum moisture content allowed for effective working of these precipitators and what has been actual moisture content in stack gases analysed by the author in different cement factories.

Shri C. P. Tyagi: The author has stated that electrostatic precipitators do not work. Has the author gone into reasons as to whether it is due to variation of coal quality, over which the factory has no control. What other methods can be suggested?

Dr. J. K. Sinha: Execuse me, Sir, what I have said is that "the electrostatic precipitator in the cement industry are working with very poor utilization factor." This is mostly because of the following: (i) The micro CO—Analyser go out of order very frequently and it takes time to put them right. At one place, it had taken about 2 years and still the CO—Analyser is not commissioned; (ii) Poor voltage regulations; (iii) Inadequate maintenance; and (iv) Frequent power failures.

Shri S. C. Kale: What is the extent of effectiveness of mechanical control measures at final bagging point? We feel that atleast in this process when the dust concentrations are very much in excess of the threshold limits, the only measure is to use mechanical filter type respiration.

Shri P. T. Shah: How does the author propose to reduce the pollution load in the cement bagging section?

Dr. J. K. Sinha: The pollution load in the cement bagging section could be reduced by the following methods: (i) Use of automatic bagging machine; (ii) Maintaining the bagging machine in proper order. If any leakage is located the same must be attended to immediately; (iii) Hood and ducting system should be used to clear the dust which may still get airborne at the bagging section; (iv) The fall of cement bags in the transportation system should be avoided. Smoothing stopping slide may prove useful in reducing the dust; and (v) Dust proof cement bags should be used.

As regards the use of filter type respirator, I agree with Shri Kale. Dust mask would help to reduce the ill effects of dust on the workers. This should be introduced in the cement industry, especially at bagging house or wherever the airborne dust concentrations are excessive.

Shri C. K. Kale: The gaseous effluents from a cement factory comprise of solid and gaseous phases, the former is made up of fine dust particles uniformly distributed. The particles contain mineral constituents with potassium and calcium, besides silica. These dust particles settle over the cropped area and the K and Ca is made available to the plants. Besides, the acidic condition of the soil is improved due to the basic nature of the particular components of the aerosol.

The gaseous phase is mainly CO_2 which is beneficial to the plant growth. It may not be out of place to consider insecticidal and larvecidal effects of the traces of sulphur oxides in the gaseous effluents on the crops. The oxides of nitrogen in the gaseous effluents, on hydrolysis, are a source of nitrate—N, beneficial to the plant growth. It is unlikely that concentrations of oxides of N and S, the gaseous effluents, when present in large concentrations of the order of ppm, will be detrimental to the plant growth.

Dr. J. K. Sinha: Shri Kale has not posed a question, but rather made comments. The solid effluents from a cement factory contain potassium and calcium but neither in free state nor as useful chemical components for plant growth. Whatever little be the percentage of oxides of nitrogen and sulphur in the gaseous effluent it is converted into acids which, before being converted to useful chemical components, damage the growing plants. This is to be noted that the concentration of SO_2 even of the order of 0.5 ppm is enough to cause extensive damage to vegetation.

Dr. G. N. Radhakrishna: There may be a controversy on whether the cement dust is harmful to plants. At the Mysore Cement Factory in Mysore State it is, however, observed that the coconut gardens in the vicinity of the factory are ruined due to deposition of cement dust on the leaves. During my visit to the factory, the authorities admitted this and informed that they had to acquire a few gardens in he vicinity of the factory. But, I feel that a systematic study has to be made on the effects of cement dust on vegetation.

Dr. J. K. Sinha: I agree with Dr .G. N. Radhakrishna. Systematic studies on the effect of cement dust on vegetation would reveal many important points which may prove very useful under Indian weather conditions. All the works referred to in different text books are based on experiments under weather conditions other than India.

Shri S. Mukherjee: From the slides shown, it is found that none of the chimneys have been properly designed. Cement industries which pollute air to a great extent should give proper stress on design of chimneys. Any tall chimney will not serve the purpose?

Dr. J. K. Sinha: The design and height of chimney will only help to release the dust laden air at high altitude and thus allow its dispersion before it reaches ground level. Thus, the height of a chimney would allow to reduce the concentration of the pollutants at the ground level.

The pollution from a chimney stack could be reduced by the following methods: (i) Proper design of right kind of gas cleaning equipment and its efficient working; (ii) Proper maintenance and working of the main plant **e.g.** cement kiln. The firing, feeding for the kiln must be regulated; and (iii) The quality and quantity of the coal fired must be as specified.

Shri V. D. Kothiwale: (i) Have you considered the possibility of fabric filters, which are also equally efficient for removing fine dust particles? These have been used for boiler stack cleaning; (ii) The recovered dust will not be pure cement but will contain other impurities: How do you propose to separate the impurities?

Dr. J. K. Sinha: (i) Yes, filters could be efficiently used to clean the kiln gases before these escape to the atmosphere. Important point is the development of high temperature, filter media, since the gases to be cleaned would be at high temperature which an ordinary fabric filter would not stand; and (ii) The dust recovered by the gas cleaning equipment from the kiln gases is not cement at all. However, it could be fed back to the kiln for the manufacture of clinker which subsequently would be pulvarised to cement in the process.

Shri K. V. Muthukrishnan: The author once pronounced that the efficiency of the electrostatic precipitator (ESP) decreases with decrease in gas velocity. But theory on electrostatic precipitators states otherwise.

Dr. J. K. Sinha: I am sorry, Shri K. V. Muthukrishnan has mistaken me. The efficiency of ESP will improve by reducing the gas velocity in the ESP. This will allow more time for the dust particles to be collected at the plates in the ESP chamber.

Dr. P. K. Basu: What is the break cp of cost of an electrostatic precipitator namely the installation, maintenance and the operating costs? Is it true that the finer particles that escape the electrostatic precipitators are more harmful to the respiratory system of human beings?

Dr. J. K. Sinha: Dr. Basu's question on economics of electrostatic precipitator is very interesting. I have not gone through the economics of it, but I would be glad if some delegates could throw light on this.

Fine dusts are more harmful for human beings, since they tend to stay longer in the lungs.

Shri V. I. Pandit: (i) Could you tell about the particle size of the average dust which is discharged to the atmosphere at 9.75%, from the kiln?; (ii) What is the atmospheric concentration of the dus at the breathing zone level both in and out of the factory premises; and (ii) Do you have firm data for the pnemoeoniosis (from cement industry)?

Dr. J. K. Sinha: (i) The size frequency distribution of the dust discharged into the atmosphere through the kiln chimneys are as follows:

(A) **Frequency-size distribution of kiln dust (microscopic)**

Size (μ)	Percentage
< 2.83	55.4
2.83—4.00	14.4
4.00—5.65	15.5
5.65—8.00	7.00
8.00—11.31	4.3
11.31—16.00	2.0
16.00—22.62	0.8
22.62—32.00	0.6
	100.0

(B) **Frequency-size distribution of kiln dust (weight basis)**

Size (μ)	Percentage
< 10	9.29
10—20	19.47
20—30	23.66
30—40	9.20
40—53	27.68
53—76	6.90
76—152	2.40
152	1.40
	100.0

(ii) The answer is already given under question by Dr. K. P. R. V. Murty. (iii) No systematic survey has been carried out so far which could give the incidence of Pneumoconiosis amongst the workers in the cement industry.

PROC. SYMP. ON ENVIRONMENTAL POLLUTION (1973)

Concentration Technique for Determination of Air Pollutants at Sub-micro Level and a New Technique for Concentration of Carbon Monoxide

A. K. GHOSH,* D. P. RAJWAR,* P. K. BANDYOPADHYAY* and S. K. GHOSH*

Determination and control of air pollutants at sub-micro level have been facilitated by supplementing modern instrumental techniques including partition and adsorption gas chromatography, with mass spectrometer, infra-red detector and various ionisation detectors as sensors. Pre-concentration of the pollutants offers new possibilities and the range of the instruments largely limited by the instrumental noises is increased substantially.

The paper presents advantages, scope as well as limitations of the new stage-wise concentration technique which is able to concentrate permanent gases, particularly carbon monoxide, upto 2000 times before it can be fed to either gas chomatographic, spectrometric or mass spectrometric assessment.

Determination of carbon monoxide present in the level of less than 0.01 ppm has been carried out with ± 10% accuracy using Preconcentration technique, G. C. column and catalyst/F.I.D. detector whereas the F.I.D. used alone could not detect less than 1 ppm. With mass spectrometric determination or using helium or cross section ionisation detector the toxic gas may be estimated upto 0.00001 ppm with similar accuracy.

Introduction

The increasing awareness for the necessity of assessment and control of atmospheric pollutants has resulted in significant advancement in development and application of instrumental methods like adsorption and partition chromatography, mass spectrometry, infra-red spectrometry, polarography and many other quality monitoring devices for the determination of trace quantities of toxic elements in respirable air. Although such useful work have in many cases extended the scope and possibilities of micro-analytical work offered by conventional laboratory methods like iodometry, colorimetry etc., the limitations imposed by instrumental noise restrict the use of instruments only to the range covered by them. Situations may, however, warrant determination of gaseous pollutants in amounts much lower than that considered possible by the enumerated methods alone. Concentration of the sample to bring the toxic constituents to analysable level has often been found necessary in such cases and various techniques have been suggested (1-9).

General Technique and Theory

Concentration is normally carried out by fractionation at deeper than ambient temperatures or at ambient temperature without employment of any sorbent or by selec-

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* Scientists, Central Mining Research Station, Barwa Road, Dhanbad (Bihar).

tive adsorption/dissolution of desired constituents on some suitable sorbents/solvent sheathed material. The retained constituents are subsequently desorbed or evaporated at conveniently elevated temperature and assessed qualitatively and quantitatively by suitable analytical methods. The handled volume for concentration, often being large, high efficiency of stripping the sample of its desired constituents is rarely achieved in ordinary fractionation unless very long cooling coils are used. Adsorption (adsorption and solution) methods on the other hand, have high mass transfer efficiency in view of large interacting surfaces of sorbents and a tube filled in with such conveniently selected materials is used to concentrate the desired constituents. Sometimes the chromatographic column is itself used for such purpose (10).

The maximum possible sample volume that can be drawn through concentration tube for quantitative retention of any constituents by the sorbent may be theoretically predetermined from the data obtained from a frontal analysis experiment in which the effluent from the adsorption tube is monitored by a suitable sensing detector (11).

Novak *et al.* (11) found from consideration of chemical potential i.e. application of Gibbs—Duhem equation in the system of elution chromatography that range for using concentration methods is limited by certain maximum concentration of the estimated substance in the sample. However, this value exceeds the normal trace concentration limit considerably. The restriction imposed from such consideration seems hardly of any significance.

Glueckauf's treatment (12) using graphical integration of the breakthrough curve provides a useful method for determining the maximum volume that may be retained Cropper *et al.* (3) arrived at similar figures for his small absorption tube designed to concentrate sample containing various industrial pollutants by assuming approximate Gaussian distribution towards the outlet end of the tube. The method runs as follows:

If a sample volume Vs is equal to the retention volume V_R, the standard deviation σ in retention for two consecutive sections in the absorption column is given by

$$\sigma = \frac{V_R}{\sqrt{n}}$$

Where n is a number of theoretical plates. The distribution of the i^{th} unit of sample volume, the extent to which the particular constituent will not be retained on the tube is given by that fraction of the area under the curve of the probability integral outside the bounds of the tube.

$$\text{i.e.}\quad 0.5-\frac{1}{\sqrt{2\pi}}\int_0^t \exp\left(\frac{-t^2}{2}\right)dt, \quad \left[t=\frac{i}{\sigma}\right]$$

and the percentage of the total sample not retained on the tube is, therefore,

$$\sum_{i=0}^{=100}\left[0.5-\frac{1}{\sqrt{2\pi}}\int_0^t \exp\left(\frac{-t^2}{2}\right)dt\right]$$

Assuming a typical value of $n = 32$ for the small tube and $\sigma = 17.5$, Cropper *et al.* went on to calculate the above expression with the aid of the probability integral curve and found it 7 percent. That is, if the sample volume is equal to retention volume, 93% will be retained by the tube. If the sample volume is reduced to 80% of retention volume, only 1% loss may follow. The maximum possible sample volume with fairly reasonable recovery, therefore, could be:

$Vs^{max} = 0.8\ V_R$, ensuring a sample efficiency of 99 percent.

Values of V_R (and that of $V_{m\ x}$) can be calculated from specific retention volume Vg by means of the simplified expression,

$$V_R = V_g T W_L/273$$

where T is the temperature of the tube during adsorption in Kelvin and W_L is the weight of the stationary phase in the tube.

Literature Review on Concentration Technique

Zocchi (10) determined hydrocarbons at sub-micro level by employing carbowax 20 M on 40-60 mesh alumina as gas liquid partition packings kept in liquid oxygen (-183°C). The concentrated sample was separated by G. C. column (6 m long, 4 mm diam, operating temperature 45°C) by direct elution method using N_2 as carrier gas and flame ionisation detector. Elaborate details of technique are described and the concentration of C_2—C_5 hydrocarbons in this manner permitted estimation in fractions at ppm range with recovery efficiency of 100 percent.

Lower hydrocarbons present as pollutants have also been efficiently concentrated by employing dimethyl sulfolane on C-22 fire brick maintained at ice-water temperature (1), by various traps—adsorbent and gas liquid partition types (2), by active carbon column (5) and by teflon powder coated with apeizon L (6). In all the methods the separation and estimation are effected by G. C. technique, with various types of ionisation detectors.

The exhaustive treatment on concentration technique (3) related to both adsorption and gas-liquid partition types of traps, provides details on theory and practices involved in the technique. The authors with their silicon elastometer E. 301 coated celite traps have been able to concentrate upto 1000 ml of gas sample for the analysis of the aromatic and other cyclic toxic constituents with about 99% recovery efficiency.

La Hue *et al.* (9) estimated atmospheric nitrous oxide by concentration technique with molecular sieve 5A trap to a level of 300 ppb using thermal conductivity as sensor.

Concentration of Permanent Gases

Literature on concentration of gases which are permanent in nature i.e. having very low boiling points are few. Determination of traces of nitrogen in cylinder argon by concentration of 2 l of sample gas in molecular sieve 5A column of G. C. unit followed by subsequent elution with argon and measurement by T.C.D. has been reported (10). The method, however, appears to be hardly suitable for mixtures other than binary applicable only in certain ranges and is likely to have tailing problem when large volumes of sample are handled. Pre-concentration of carbon monoxide, argon, nitrogen, methane, oxygen etc. offers difficulty in view of high retention volume of the normal permanent constituents of atmospheric air from which they are to be concentrated.

By ordinary concentration technique employing molecular sieve 5A as trap material it was found that even by mercury suction only 40% of the total amount of the pollutant could be recovered when the adsorption temperature was kept at —18°C ± 2°C and subsequent desorption was carried out at 80°C.

Elution of the gas with carrier gas resulted in considerable volume of the concentrated gas so much so that concentration beyond twenty times could not be made possible.

Experimental Set up

A single permanent gas, carbon monoxide which is of considerable importance in view of its high toxicity was selected for studying desorption characteristics of the sorbed gas at various desorption temperatures.

Single Stage Concentration

Accurately prepared CO samples were, first dried by passing through two moisture traps ($CaCl_2$ and P_2O_5) and finally stripped of its CO_2 by allowing the sample to be led through a carbosorb tube to a U-tube containing 5 g of molecular sieve 5 A (size —60, +72 B.S.S.) kept in a Dewar flask containing freezing mixture (salt-ice, temp —19°C). The traps were evacuated prior to introduction of the gas to permit assessment of the exact volume passed through the tube for concentration. The adsorbed gas was subsequently desorbed at 100°C and eluted by the carrier gas argon. The samples were periodically analysed with the Pye-Argon chromatograph with a 1.5 m molecular sieve 5A column and F.I.D. sensor preceded by hydrogenation catalyst.

The Figs. 1, 2 and 3 show how the concentration of CO was distributed in the volume

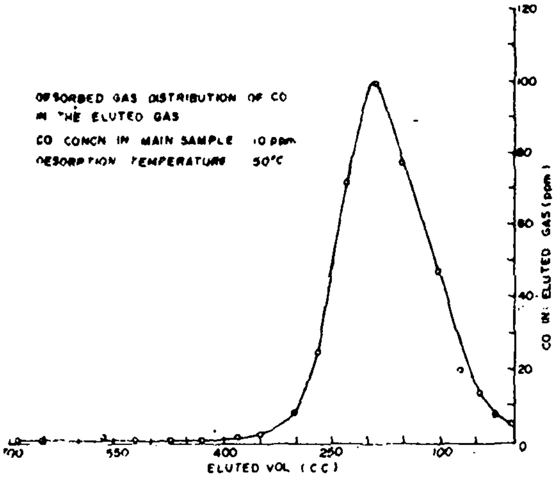


Fig. 1

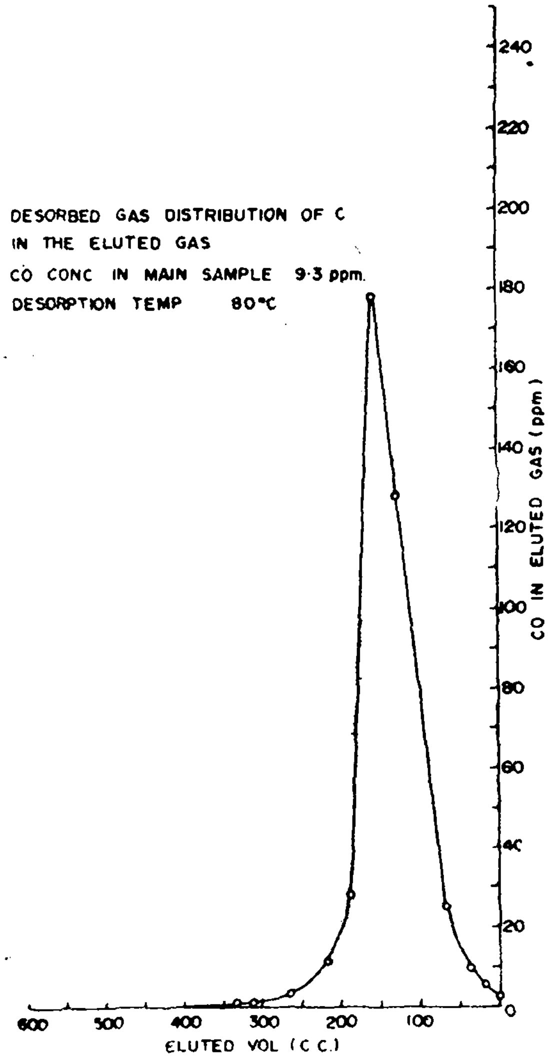


Fig. 2

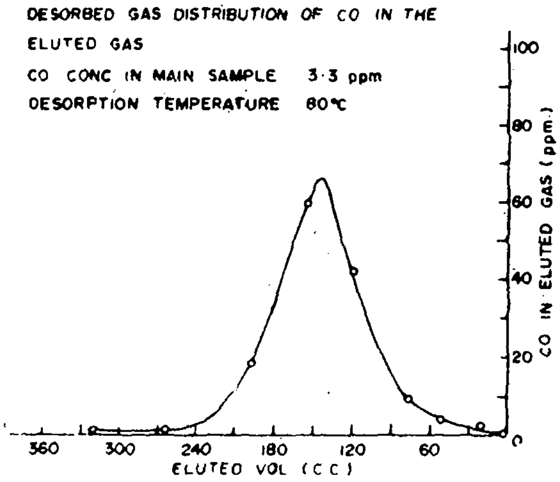
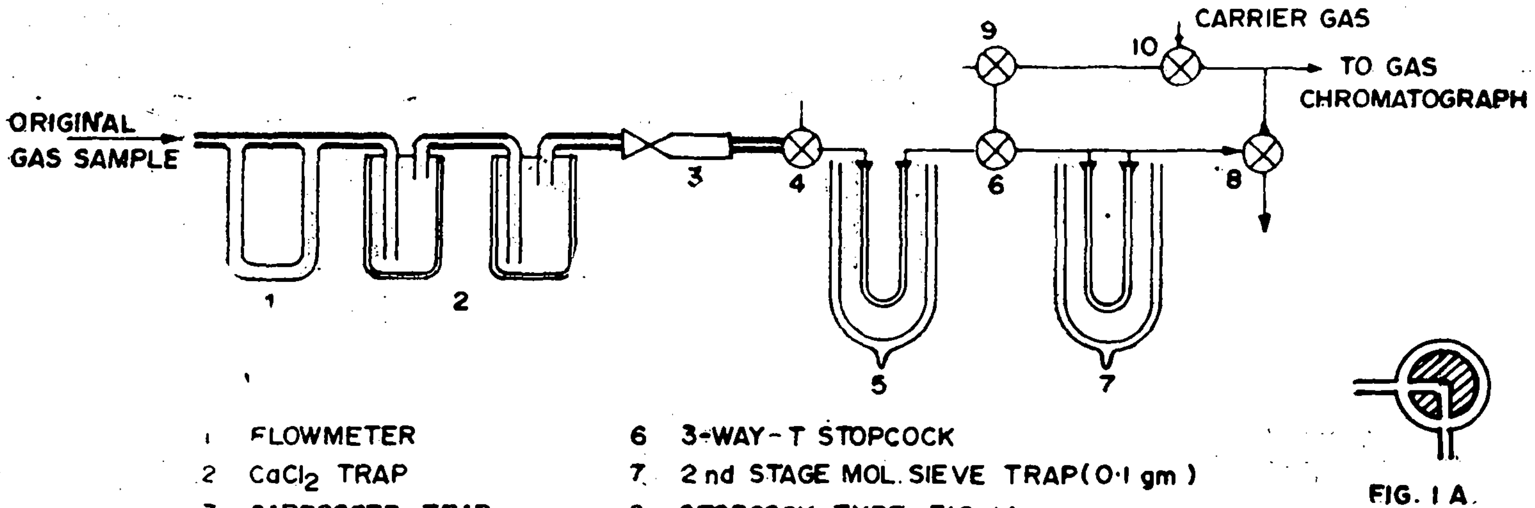


Fig. 3

eluted. Although the recovery is 100% the method of concentration by one stage only uptq a maximum twenty times only is hardly worth the trouble.

Two stage concentration

The set up for two stage concentration is illustrated in the schematic sketch (Fig. 4). Very low concentration of carbon monoxide (<1 ppm) was carefully prepared and led through the flowmeter to traps for removal of moisture and carbon dioxide. The moisture free gas was passed through a U-tube (Ist stage) containing 5 g molecular sieve 5 A activated at 250°C, cooled and kept in freezing (salt-ice temp., —18°C ± 2°C) mixture, at a rate of 120 ml/min to atmosphere. The Dewar was then removed and replaced by a boiling water bath. The held gas desorbed along with the desorbed air and was led through the 2nd stage U-tube containing 0.20 g molecular sieve 5A activated and kept in freezing mixture (salt-ice temp. —18°C ± 2°C) in the previous manner. Fifty ml of cylinder nitrogen gas (checked for nil carbon monoxide) was subsequently flushed through the first stage tube through the stopcock (no. 4, Fig. 4) to purge the tube completely. By turning the stopcocks 7 & 10, after the freezing mixture has been replaced by a water bath (100°C), the carrier gas was allowed to elute and carry the desorbed and concentrated carbon monoxide to the G.C. column containing moleculer sieve. Subsequent to separation, carbon monoxide was catalytically hydrogenated by a nickel ca-



1 FLOWMETER
2 $CaCl_2$ TRAP
3 CARBOSORB TRAP
4 3-WAY-T STOPCOCK
5 1st STAGE MOL. SIEVE TRAP (2 g)
6 3-WAY-T STOPCOCK
7 2nd STAGE MOL. SIEVE TRAP(0·1 gm)
8 STOPCOCK TYPE FIG. 1A
9 3-WAY-T STOPCOCK
10 STOPCOCK TYPE FIG. 1A

FIG. 1 A.

Fig. 4—Scheme for Two Stage Concentration of Carbon Monoxide

talyst (placed in series between the column and F.I.D.) to methane and finally detected by F.I.D.

Operational Data of the G.C. Separation and Estimation :

Length of column — 1.5 m
Ionisation current — 10^{-9} amp
Temp. of the column — 50°C
Flow rate — 60 cu cm/min
Carrier gas — Argon
Recorder — Honeywell; 1 mv Strip chart recorder.

Results and Discussion

The results of analyses of seven samples containing different concentration of carbon monoxide are given in Table I.

Cylinder nitrogen gas was tested by the method and was found to contain no carbon monoxide.

Atmospheric air around the laboratory building sampled and tested for carbon monoxide was found to contain 0.049 ppm on 22-7-72.

The retentivity of carbon monoxide on molecular sieve is appreciably affected in presence of moisture and, therefore, it is imperative to strip the sample of all its moisture content before introducing to the trap. Although it is not provided in the sketch, it is advisable to put a short column of P_2O_5 between the calcium chloride and carbasorb trap.

TABLE I—ANALYSIS OF AIR SAMPLES FOR CARBON MONOXIDE CONCENTRATION

Sl. No.	Total volume of sample passed (ml)	Total volume of eluted gas after final collection (ml)	CO concentration (ppm)			Remarks
			Concentrated sample (G.C. figure)	Prepared sample (Calculation basis)	Prepared sample (Detection basis)	
1	3500	16.75	33.1	0.120	0.15	The sample was diluted with atmospheric air outside the laboratory building.
2	4900	18.60	10.434	0.050	0.040	The sample was diluted by air which was drawn through hopcolite, fused $CaCl_2$ and P_2O_5
3	5950	18.79	15.66	—	0.050	The sample was atmospheric air sampled at CMRS which was not analysed otherwise (collected on 22-7-72).
4	5050	18.89	11.27	0.043	0.042	The sample was diluted by cylinder nitrogen gas.
5	4000	18.49	7.321	0.030	0.035	The sample was diluted by hopcolite cleansed air.
6	8000	18.12	2.912	0.018	0.018	The sample was diluted with cylinder nitrogen gas.
7	8000	18.00	0	—	0	The sample was cylinder nitrogen gas.
8	5000	Direct feeding of the concentrated sample to G.C. column		30 cu cm of 12 ppm CO sample was diluted to 10 l CO (computed) = 0.040 ppm	0.033	

In the experiments carried out by the authors during early stages the total gas held was of the order of 10 ml (elute: 16 to 18 ml) and initially small sample volumes were introduced to G.C. column. By proper choice in the amount of adsorbent in two stages it is possible to keep the volume limited to 1.5 to 2 cu cm and thus with 1000 ml of original sample on concentration of 500 times may be effected. The sample in such a case may be directly eluted to the G.C. column with the carrier gas.

A third stage concentration with 20 mg of molecular sieve in a capillary U-tube would permit concentration to an extent of 5000 times but the method would hardly be convenient for normal monitoring purpose.

The first stage trap along with its accessories may be conveniently accommodated in a portable compact box and samples upto 1000 ml may be collected and brought to the laboratory for transferring the adsorbed gas to the second stage trap and finally to G. C. unit for estimation. Normal G.C. units range with catalytic hydrogenation followed by detection by F.I.D. can be bettered to lower limit of 0.5 ppm; with two stage concentration technique the lower limit could be brought down to 0.001 ppm.

With helium detector the extent of estimation could be brought down to an unbelievable 0.00001 ppm for the detector can by itself detect upto 0.005 ppm without concentration.

Conclusion

In very early detection of spontaneous combustion, in studying the trend of distribution of carbon monoxide in the upper atmosphere as well as in the pollutant cycle studies over oceans, the new stagewise concentration technique is likely to open new vistas of investigation apart from its utility for reliable monitoring of permanent pollutants in the respirable atmosphere.

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DISCUSSION

Shri P. K. Yennawar: What are the specific pollutants that can be determined using FID technique?

Dr. A. K. Ghosh: All hydrocarbons and other pollutants that are ionisable by hydrogen flame can be determined with FID technique when present in micro-quantities.

Shri J. J. Dave: Could you suggest some method for detection of quantities around 0.1 ppm of phosgene and phosphine which are hazardous to health on exposure?

Dr. A. K. Ghosh: ACGIH recommended TLV values for phosgene and phosphine as 0.1 and 0.3 ppm respectively. Colorimetric methods employing Harrison's reagents (diphenylamine and p-dimethyl-amino benzaldehyde) or nitroso reagents can determine phosgene in microquantities, i.e., upto 0.2 ppm. Iodide-Acetone method permit iodometric estimation of the gas present in sub-microquantities if the gases capable of liberating iodine from iodide are absent. Phosphine can be determined in sub-microquantities stated using suitable concentration technique and phosphorous detector developed by M/s Aerograph, USA or by sodium flame ionisation detector.

Shri B. N. Patil: How to estimate sub-micro level of sulphate in a monolith of dam which causes bad odour? How to concentrate sulphur in minute concentrations? And further, how to remove the sulphur pollution when sulphur is in the gaseous form like H_2S and complex compounds of organic origin like cystine, etc.?

Dr. A. K. Ghosh: H_2S, SO_2 and Mercaptans may be determined successfully by sampling in liquid media and subsequent conductometric (micro-coulometric) titration. Iodometric estimations are also convenient provided suitable technique is applied to remove H_2S when both H_2S and SO_2 are present. Spot detector tubes are good enough for determination of all the three gases in the ppm range. They can also be detected and estimated by G. C. technique using coulometric detector (Ref: *Analyt. Chem.*, **37**, 6, 644 (1965)).

Shri T. H. Venkitachalam: The development of a new concentration technique for air pollutants present in micro-quantities will no doubt be appreciated by the analysts. However, I would like to ask the authors if they think that this rather sophisticated procedure can be coupled with field sampling survey in practice.

Dr. A. K. Ghosh: For field survey where distribution of CO with respect to distance of emission points are to be studied, a portable sampling kit containing the first stage concentration trap (s) dipped in freezing mixtures contained in thermos flasks may be used. Subsequent second stage concentration and chromatographic analysis may follow conveniently in the laboratory. With a simple G.C. apparatus and FID detector, analysis of CO in the range 0.001 ppm to 1 ppm can be carried out with ± 10% accuracy.

Dr. C. Narain: (i) With the molecular sieve trap method, is it possible to retain the higher concentrates of the normal pollutants in the atmosphere? (ii) It is the FID/Catalyst system and not the FID system alone, as mentioned in the summary, which can be used to measure carbon monoxide. (iii) Can you verify the statement made in the summary that carbon monoxide to a level of 0.00001 ppm can be measured? (iv) The reduced hydrogen flame phometose detector can be used to measure gases in the atmosphere.

Dr. A. K. Ghosh: (i) In the concentration of sub-micro level of gases, large volumes of sample are involved and whether higher concentrates can be retained completely is determinable only through frontal analysis and knowledge of break-through volume for the concentration of the higher concentrates. However, as the retention time of normal hydrocarbon pollutants or oxides of sulphur and nitrogen is pretty high in molecular sieve material, the presented method is suitable only for permanent gaseous pollutants present in sub-micro level. (ii) It is needless to mention that CO must be reformed to methane for its detection and estimation by FID technique. (iii) The helium detector developed by M/s Aerograph claims to have a sensitivity of 0.5 ppb (vide Aerograph Research Notes, Spring—67. p. 3). The possible limit of 0.00001 ppm in determination by concentration has been based on this detector. (iv) No comments.

Shri K. V. Venkatesh (Thana): Why is sub-micro determination of CO necessary? The threshold values (TLV) for CO are in ppm range and a Drager tube should be adequate.

Dr. A. K. Ghosh: Determination of CO in TLV ranges are not only possible with Drager detector tube kit alone but also with detector tubes developed by National Bureau of Standards of USA, Kitagawa of Japan and by authors themselves, the last being leased out and manufactured in India by MSA (Pvt) Ltd., Calcutta. Regarding the necessity of determination of CO in sub-micro ranges the concluding paragraph of the communication is referred to.

Dr. P. K. Basu: H_2S, SO_2 and Mercaptans can be measured at ppm concentrations by micro-coulometric titration.

Dr. A. K. Ghosh: No comments.

PROC. SYMP. ON ENVIRONMENTAL POLLUTION (1973)

Seasonal Variation of Surface Temperature Distribution over Bombay

N. M. PHILIP,* C. E. J. DANIEL* and K. KRISHNAMURTHY*

Early morning mobile temperature surveys were conducted over Bombay City and surroundings on several days suitably selected to represent various seasons. In the cold weather period, the existence of a marked 'heat island' over the City of an intensity of about 6°C has been revealed. In the other seasons, the temperature distribution as modified by the seasons and the prevailing winds have been studied. The usefulness of these surveys in estimating the modification of the low-level temperature profile ovr various parts of the City and in the mapping of the urban boundary layer has been discussed together with their important application in air pollution studies.

Introduction

Of late, the study of man's influence on environment has attained great importance in view of the associated urban problems of pollution. In industrialised urban areas the concentration of atmospheric pollutants and their patterns of dispersion depend on meteorological variables like, airflow, radiation, temperature and precipitation and also on topography, proximity of water masses and the complex urban lay-out. Considering temperature, higher temperatures have been noticed inside towns and cities. There are four main factors contributing to this higher temperature **viz.** changes in the thermal characteristics (like albedo, heat conductivity and thermal capacity) of the surface following the substitution of buildings and roads for farms and fields, changes in the airflow patterns with a reduced diffusion of heat from streets and courtyards, changes in evaporation rates and heat losses and the heat added by human beings and human activity. These factors are of differing importance in different cities. Their combined effect, however, results in the formation of the 'heat island' which varies in intensity from city to city and from season to season. A detailed study of the temperature field over cities will facilitate understanding of the modifications of the urban boundary layer and the consequent effects on the concentration or dispersion of air pollutants. In this paper, the early morning temperature distribution over Bombay city and suburbs obtained by mobile temperature surveys conducted on 4 days covering 3 seasons is presented.

Data and Analysis

The heat island effect is most prominantly noticed around the minimum temperature epoch when the temperature curve is more or less 'flat'. Generally, the time between 0100 hr IST and sunrise will indicate very little variation in temperature. The best possible way to measure the temperature field over a city will be to establish a close network of observing stations and to take observations simultaneously. As this requires

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* India Meteorological Department, Poona-5.

considerable manpower and equipment a mobile survey is considered a suitable alternative. The surveys made at Bombay were conducted by one team on 29-2-1972 and 1-3-1972 and working jointly by three teams on 15-5-1972 and 31-8-1972. When only one team conducted the survey, the team started and ended the surveys at the Colaba Observatory covering the length and breadth of Bombay city and portions of Greater Bombay upto Kurla and Powai in the north and Trombay towards the east. Observations were taken at approximately 60 points during each of the surveys. When three teams participated in the survey, one team started and ended the circuit at Colaba Observatory while the other two started and ended their trips at the Santa Cruz Airport Observatory. Fig. 1 shows the routes followed by the three teams during the survey on 15-5-1972. The total number of points of observation was 140 on each of these days and the area covered was Bombay city, Greater Bombay and portions of the area on the adjoining mainland proposed to be developed as the twin city. At each point of observation, temperature observations were taken with calibrated Assman psychrometers and the time of observation noted with the help of synchronised watches. The wind speed and direction were also estimated at each observation point. The psychrometers were exposed for about 2 to 3 min at each point before being taken in the vehicles to the next point on the survey route. The points were pre-determined and chosen in such a way as to ensure adequate coverage of the main urban area and portions of the suburbs. In order to make corrections for the small temperature trend during the period of survey, recording thermographs were installed at suitable representative locations. At the end of the survey the observations taken at each of the points were reduced to a particular time by applying the trend correction so as to render them quasi-simultaneous. The reduced temperatures were then plotted on maps and analysed taking the topography and wind into account. Figs. 2 to 5 show the temperature distribution obtained after the analysis.

Discussion

The surveys made at Bombay on the 4 dates mentioned could be taken to represent 3 seasons **viz.** the cold weather period (29-2-1972 and 1-3-1972), the hot weather period (15-5-1972) and the monsoon period (31-8-1972).

The surface temperature distributions during the cold weather period are the most important as far as air pollution is concerned. Low level temperature (as detected by radiosonde ascents) in the early hours of the morning are a common daily feature during the period and such inversions create conditions that favour the accumulation of air pollutants close to the ground and prevent their dispersion. The vertical extent of the heat dome or the urban boundary layer over various parts of the city can be determined by the surface temperature distribution. Usually, marked temperature inversions are associated with the absence of wind and the 'heat island' intensity is the maximum during this season.

In the hot weather period the ground inversions are not marked and there is reasonably good mixing at low levels in vast portions of the city. This reduces the intensity of the 'heat island' to a certain extent. In the monsoon season, the mixing at lower levels attains a maximum with a moderate to strong steady wind from the southwest to west. Temperature contrasts consequently decrease and the 'heat island' intensity falls sharply. It is significant that there is still a difference of about 2°C between the urban temperature and the rural surroundings in the monsoon season which is perhaps due to the permanent contribution of heat by the population, buildings and industry in the urban complex.

Cold Weather Period

Fig. 3 can be taken to represent a day in the cold weather period with a marked inversion. The wind was less than 5 kmph, skies were clear and radiative cooling was prominent. It may be noticed that the difference in temperature between the warmest part of the city (24.5°C) over Malabar Hill

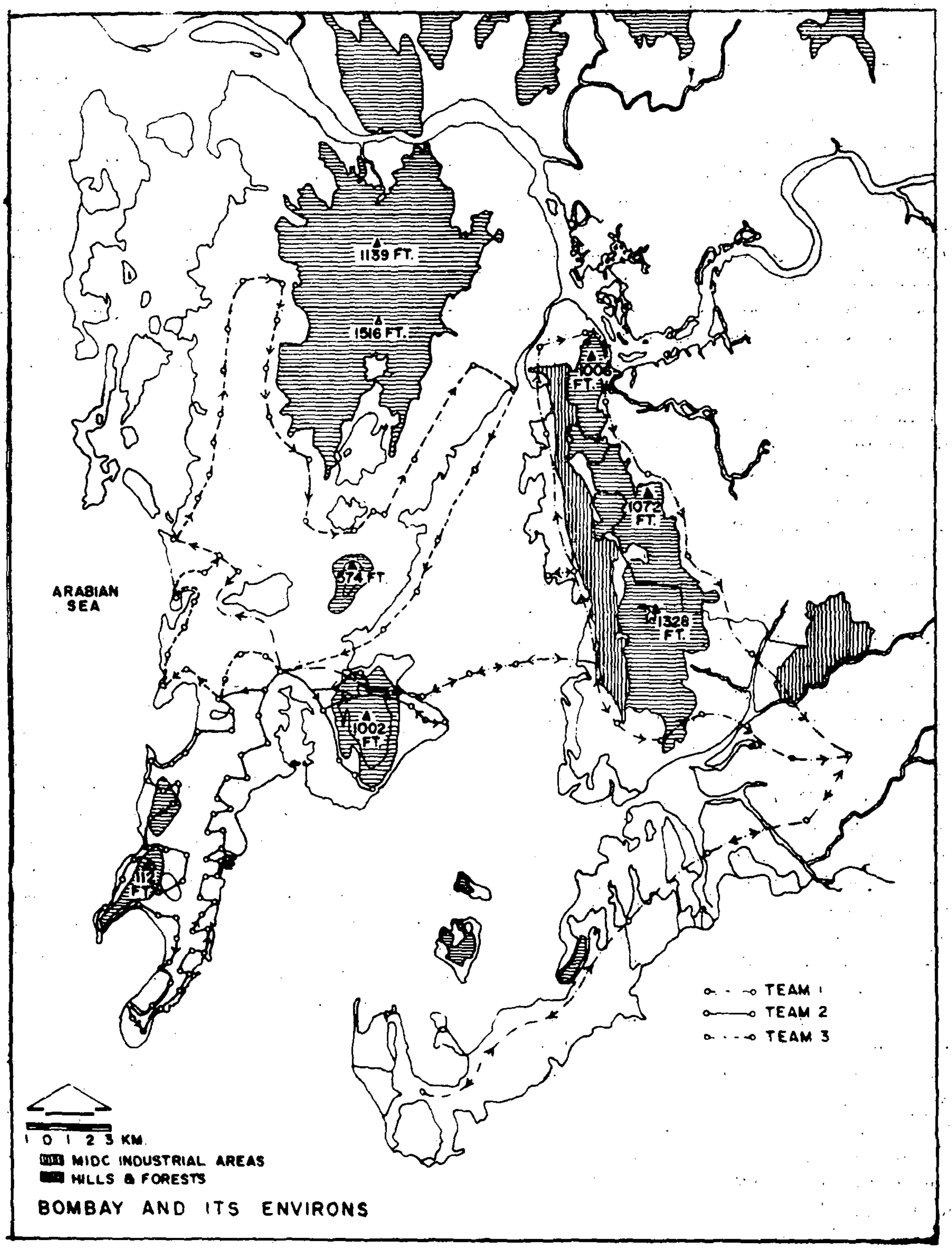

Fig. 1—Routes followed by the Survey Teams on 15-5-1972.

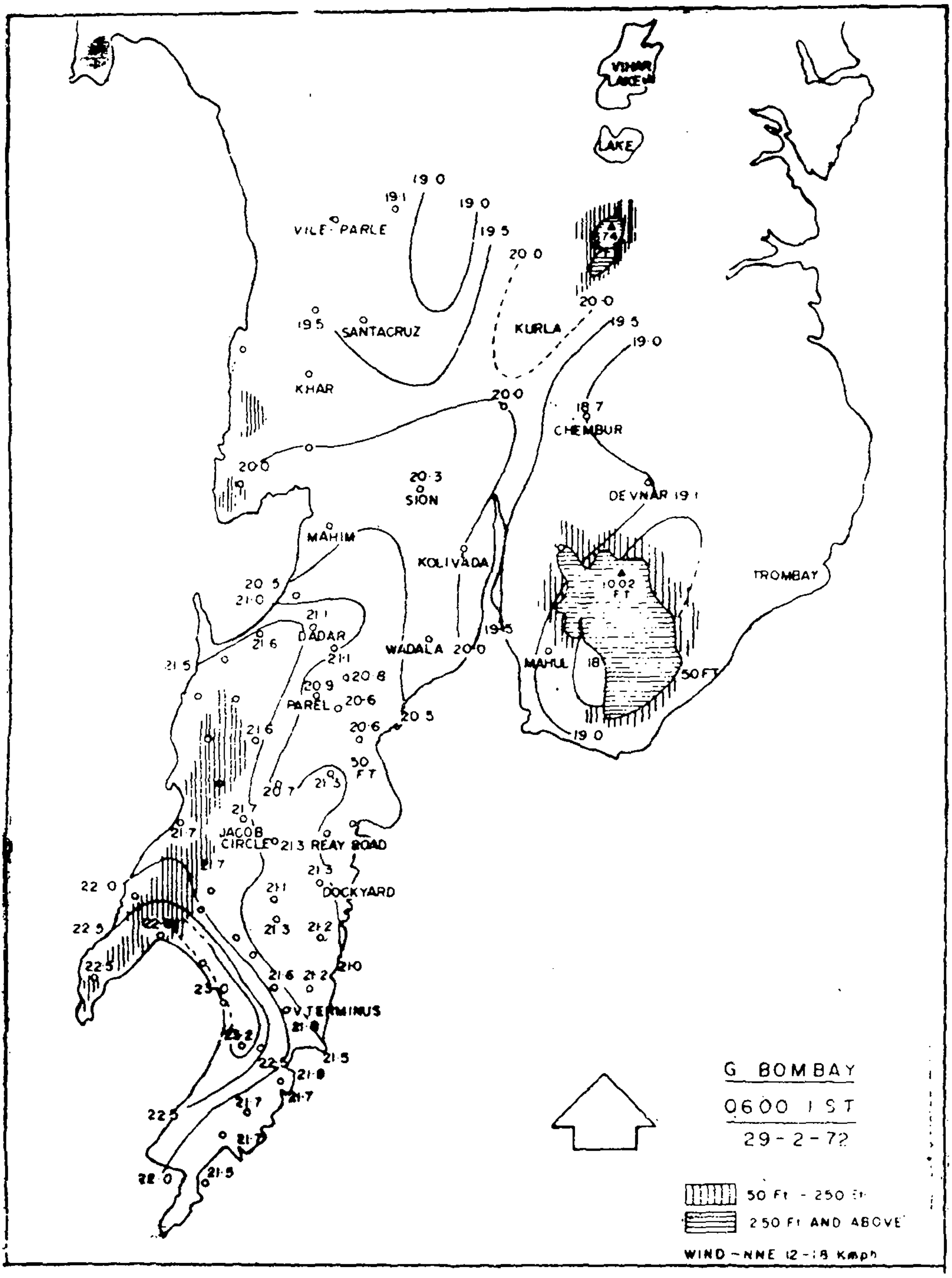

Fig. 2—Temperature Distribution
(Cold Weather Period)

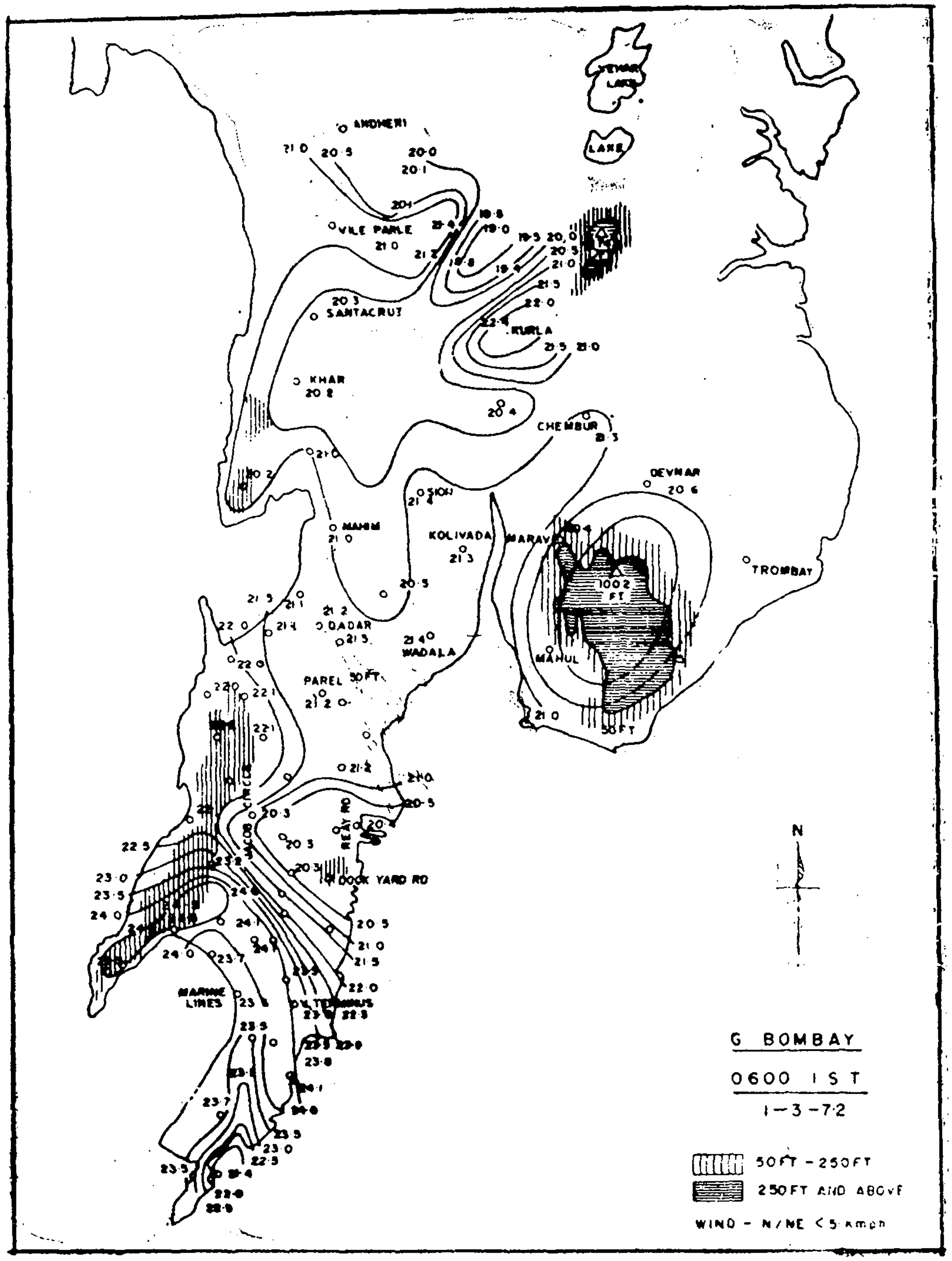

Fig. 3—Temperature Distribution
(Cold Weather Period)

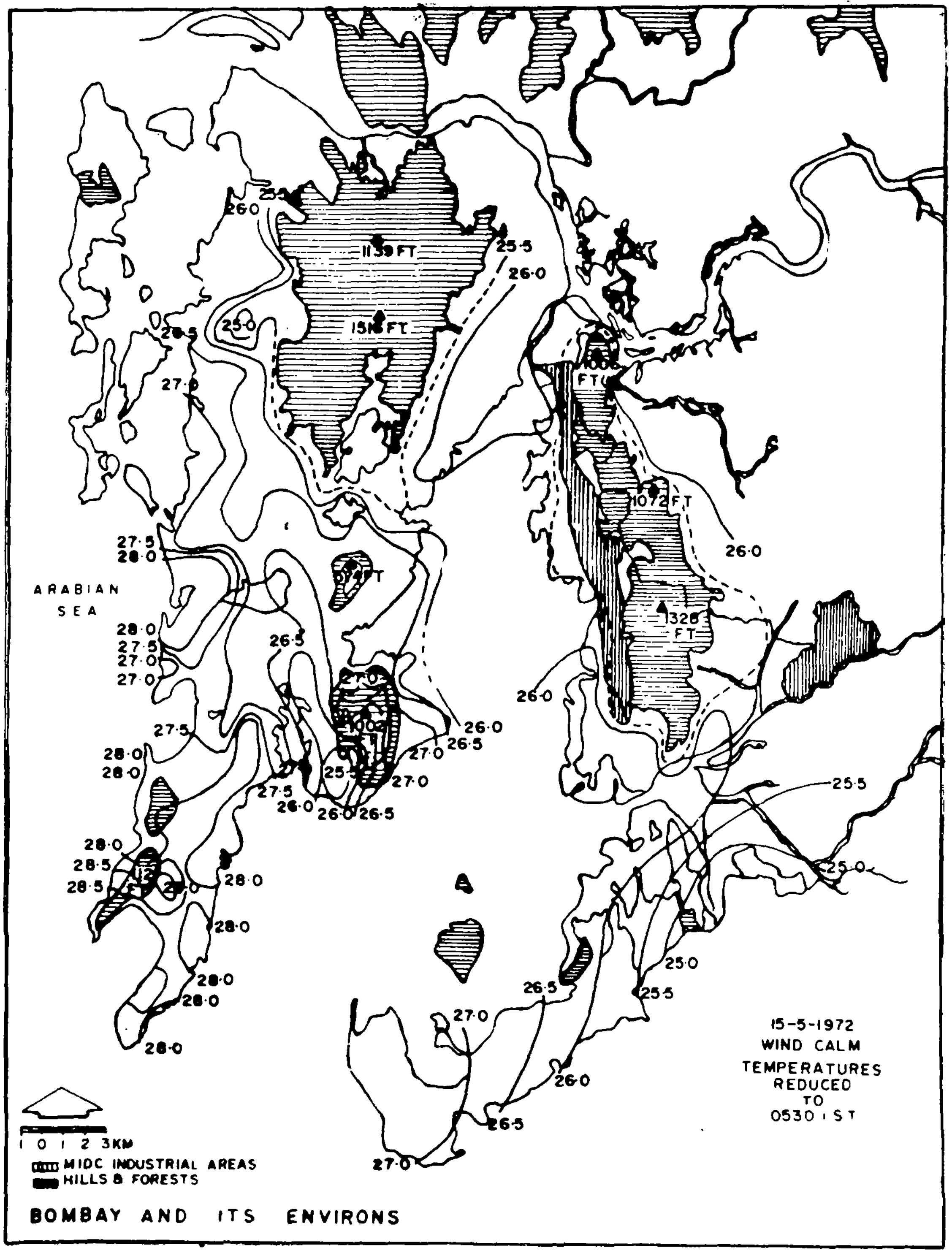

Fig. 4—Temperature Distribution (Hot Weather Period)

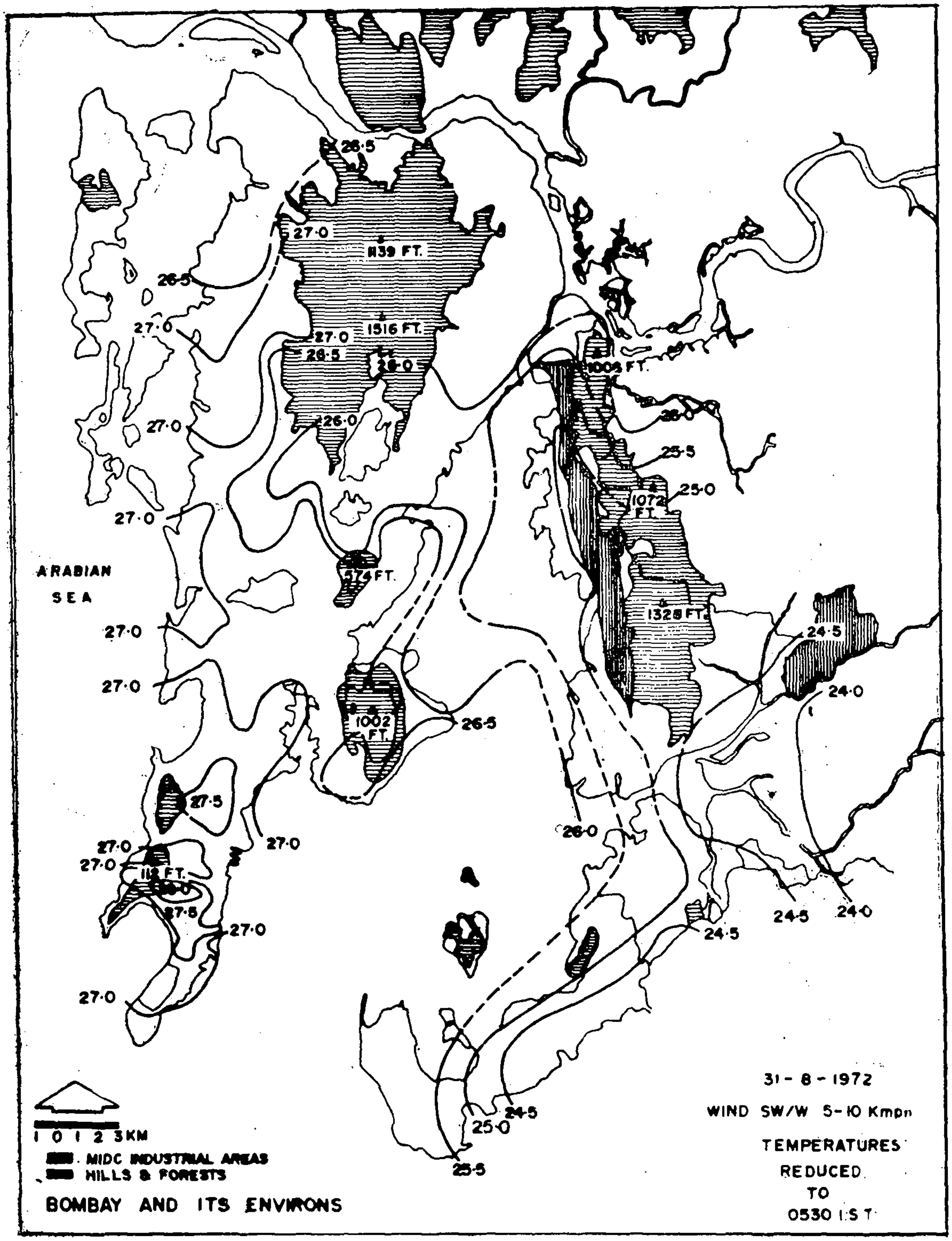

Fig. 5—Temperature Distribution
(Monsoon Period)

and the coldest area of the suburbs (18.6°C at Powai) was nearly 6°C. The 'heat island' is located over the Malabar Hill area extending into Girgaum. The gradient of temperature is very steep towards the NE from the heat island (i.e. in the upwind direction) with comparatively low temperatures over the more ventilated Reay Road—Dockyard Road area. The decrease of temperature towards the north is more gradual. The comparatively higher temperatures over Kurla in Greater Bombay can be attributed to the industrial complex and the density of factories and buildings in this region.

Fig. 2 shows almost the same pattern as Fig. 3 although the urban excess of temperature over the immediate suburbs reduces to about 4.5° to 5°C. The 'heat island' was along the Marine Lines, Girgaum area extending towards Flora Fountain. The large temperature gradient from the heat island towards the NE is also shown on this date (although to a reduced extent) when the winds were NNE 12-18 kmph. With greater mixing caused by the stronger winds, the temperature contrast is less than that on 1-3-1972 (Fig. 3).

It is remarkable that the 'heat island' area on these two dates is elongated in a direction almost perpendicular to the direction of the wind with the temperature gradient being in the direction of the wind. The effect of wind on the temperature distribution, therefore, appears to be quite significant. The 'heat island' seems to skirt the coast on these two days and seems to include the areas where high concrete structures are located in close proximity to each other. From this it would appear that the influence of the adjoining large water mass and the heat trapped between tall structures play a significant part in the formation of the heat island. There is also some evidence of the influence of Katabatic flow (lower temperatures) in the areas adjoining hills, for example, in the Chembur area. There was, unfortunately, no radiosonde ascent at Bombay either on 29-2-1972 or 1-3-1972 due to some equipment trouble. From the normal temperature profiles that one would expect over Bombay (Santa Cruz) in this season, it is obvious that the inversion would be obliterated upto a certain height over the heat island and the adjoining urban areas. With a 6°C excess of the urban temperature as on 1-3-1972 the height of this shallow mixing layer could have been of the order of 200 m over the heat island sloping downwards towards the rural surroundings in the north and north east. With a layer of temperature inversion above this shallow mixing layer, atmospheric pollutants will be 'trapped' within this 'heat dome' for several hours in the early morning during the cold weather period, until the boundary layer is broken by solar heating with the advance of day.

Hot Weather Period

The results of this survey of 15-5-1972 could be taken as representative of the hot weather period. There was no ground inversion on this day. Even over the suburban location of Santa Cruz airport there was an inversion layer only between 400 m and 1000 m as seen from the morning radiosonde ascent. There was, therefore, good mixing possible from the ground to 400 m. The temperature contrast was lower as compared to the cold weather period, the excess of urban temperature over the rural surroundings being of the order of 3-4°C only. The warmest point in the Bombay urban area was the Grant Road Junction and the coldest points were Kandivili (25.0°C), Maroli (25.3°C) and Panvel (25.2°C). There is a marked Katabatic influence as seen from the lower temperatures adjoining the hilly areas. In the absence of a strong wind field the temperature gradient noticed in the earlier surveys of February/March (Fig. 1 and 2) over the southern portions of the island is not noticed in this case. On the other hand there is a warm tongue extending through the centre of the island almost upto Mahim coinciding with the comparatively more thickly populated area of the city. Over the mainland there is a gradual decrease of temperature towards the east. Although there will be no marked 'heat dome' effect in this season, it is interesting to examine the implications of this temperature distribution as far as air pollutant concentrations are concerned. Atmospheric pollutants are expected to be well-mixed up to 400 m over the Santa Cruz region with no or very little vertical transport into the inversion layer above this height. The higher surface temperatures over the Grant Road area would indicate that the mixing layer was of greater depth over the urban complex on this day. On the other hand, for example, the lower surface temperatures at Maroli (Chembur) could indicate a smaller depth for the mixing layer over this region. Mixing layers of smaller depths could reasonably be expected to have higher pollutant concentrations as compared to larger mixing depths.

Monsoon Period

The results of this survey are more or less typical of the monsoon season. There was no inversion up to 1000 m as seen from the morning radiosonde ascent of the day. With a surface wind of 5-10 kmph from SW/W good mixing would have taken place at lower levels reducing the temperature gradient considerably. The urban excess of temperature over the rural is only 1 to 2°C. The warm area of the city is the Grant Road—Girgaum area. A *trace of the warm* tongue in the centre of the island is still seen interrupted only by a slightly colder zone extending into it from the west across the well-ventilated racecourse area. Temperatures decrease very gradually to the north and more rapidly to the east particularly over the mainland. Katabatic effects are not clearly noticeable. It is reasonable to conclude that atmospheric pollution at ground level is least during this season which is characterised by stronger winds, increased turbulence and upward motion.

Conclusions

1. The temperature excess of the urban area over the rural surroundings could be of the order of 6°C in the early mornings during the cold weather period. This excess reduces to 3-4°C in the hot weather period and further to 1-2°C in the monsoon season.

2. The 'heat island' is generally to be found over the congested, built-up area in the south of the island between Flora Fountain, Grant Road and Malabar Hill. The exact shape and the location of the 'heat island' varies with the season and the prevailing wind conditions.

3. The 'heat dome' over the city (within which atmospheric pollutants would be trapped for several hours) is to be encountered generally in the early hours of the morning during the cold weather period. In the hot weather period early morning concentration of pollutants although less compared to the cold weather period is still likely to vary with the surface temperature distribution. Pollution concentration is least in the monsoon season.

4. The temperature distribution is markedly influenced by air flow and the gradient of temperature is generally maximum along the direction of the wind.

Acknowledgements

The authors wish to express their gratitude to Shri V. Raman, Scientist-in-charge and his team of workers from the Bombay Zonal Laboratory of the Central Public Health Engineering Research Institute and the City and Industrial Development Corporation of Maharashtra Ltd. for kindly providing transport facilities and personnel support during the mobile surveys, conducted in May and August, 1972. Thanks are also due to S/shri T. V. Varadarajan, N. B. Shirali, V. A. Venkatraman and Zaheed Ali of the Bombay Regional Meteorological Centre for taking part in the surveys.

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DISCUSSION

Shri V. D. Kothiwale: (i) In the Bombay city, the population density is the maximum, leading to the pollution of air due to human habitation. Has it been possible to attribute the different diseases which have increased in recent years, to this increase in population density? (ii) Just like the temperature studies, are there any other results about the concentration of pollutants in the atmosphere?

Shri C. E. J. Daniel: (i) The authors do not have any information. It is outside the scope of the present study. (ii) Measurements of concentration of gaseous pollutants are being made by the CPHERI Zonal Laboratory at Bombay. The India Meteorological Department is planning coordinated field experiments with CPHERI for joint measurements of temperature distribution and pollutant concentrations in the near future.

Shri V. Krishnamurthy: The data on seasonal variation in temperature distribution over Bombay will serve the needs of civil engineers also. So it is requested that due information may please be supplied to concerned civil engineering departments also at Bombay. A good endeavour has been made indeed and it will be helpful for determining effects of temperature on causing cracks in reinforced concrete.

Shri C. E. J. Daniel: The studies of urban climate over Bombay will find application in many branches of engineering. The results could be interpreted to suit various needs, once we know the exact problem and requirements.

Dr. S. P. Singal (New Delhi): (i) What had been the height of measurement? (ii) Whether diurnal variation has been taken into account? (iii) Along with seasonal variation, there should be day-to-day variation also, wind being the most effective factor. Have the observations been taken over a stretch of days to come to some conclusive results? (iv) Observations should also be made with altitude. Acoustic echo sounding technique may be applied effectively to monitor thermal structure with altitude all through the day.

Shri C. E. J. Daniel: (i) The height of measurement was about four feet above ground to be in conformity with the height of the standard thermometers in the Stevenson Screens. (ii) The 'heat island' effect is observed prominently in the early hours of the morning just before sunrise. The data presented in this paper relate to this period. As the day progresses with increased convection and good mixing at lower levels, the 'heat island' gets more or less destroyed. (iii) & (iv) The future programme of work does include the study of diurnal and seasonal effects and the effect of wind and atmospheric conditions on the temperature distribution over Bombay. The study is proposed to be conducted using various techniques like mobile ground surveys, low level soundings of the atmosphere and micrometeorological measurements on towers.

Dr. K. P. R. V. Murthy: What is the effect of land and sea-breeze on the observations. One of the observations should have been in the post-monsoon period also.

Shri C. E. J. Daniel: As mentioned earlier, the study of the effects of land and sea-breeze (and similar diurnal effects) and seasonal effects will figure in our future programme.

PROC. SYMP. ON ENVIRONMENTAL POLLUTION (1973)

Preliminary Study on Diffusion of Air Pollutants in Kanpur City

B. P. SWADAS,* D. D. AGARWAL,** N. KASHIVISWANATHAN+ and G. D. AGRAWAL++

It is essential to study the dispersion pattern of air pollutants over the city complex to be able to formulate adequate control measures.

This paper presents the results of investigations on the effects of various meteorological parameters on the intensity of air pollutants in the city of Kanpur. The variation in the concentrations of sulfur dioxide and total oxidants with different heights above the ground surface, and its relation with the vertical temperature gradient have been reported. The effects of wind and relative humidity have also been studied. The pattern of variations of concentration of oxides of nitrogen from the auto-exhaust has been investigated both with time and distance from the centre of the road.

Introduction

Kanpur city is situated on the right bank of the river Ganga. Its geographical location is around the latitude of 26° 30′N, and the longitude of 80° 20′E. It is about 350 km north of tropic of cancer, and 900 km northwest of Bay of Bengal. Its 1971 population was reported as 1,275,242, which put it as eighth most populous city of the country. It has a central position in the State of Uttar Pradesh and it enjoys advantage of a river site. All these factors have promoted many industries here.

The problem of air pollution in the city of Kanpur is real (1). Though the levels of air pollutants are generally below the levels considered acceptable in the foreign cities like Los Angeles, etc., the poor standard of health in our country leads to graver effects of the pollutants. This is especially true, considering the report (2) that 76% of families in Kanpur live below destitution line, 67% had only single room tenements and some 30,000 live on streets. Studies carried out by Ghosh (3) show a pretty high correlation between the respiratory diseases like bronchitis, etc. and the levels of air pollutants in Kanpur. Low level air pollution in the city of Kanpur is shown to have a definitive reduction in height and weight of growing children, residing in higher polluted zones (4).

Thus, the dangers of air pollution to life, health and property have been well-documented. These have led to an intensive search for better planning and effective controls. It is obligatory that the future planning of the development of the city takes into consideration the likely increase in the pollution levels due to increase in industries,

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* Lecturer, Birla Vishvakarma Mahavidyalaya, Vallabh Vidyanagar.

** Research Assistant, Sanitary and Environmental Engg., Dept. of Civil Engineering, IIT, Kanpur.

\+ Lecturer, Siddaganga Institute of Technology, Tumkur-3.

\+\+ Head, Dept. of Civil Engineering, Indian Institute of Technology, Kanpur-16.

automobile transportation, etc. This should be done on the rational basis.

For the rational planning for the future development and for the economical control measures on the existing sources of air pollution, it is essential to study the dispersion pattern of air pollutants over the city. The degree of air pollution depends mainly on the amount of pollutants emitted and the diffusive capacity of the environment. The dispersion of pollutants depend, in turn, on many meteorological parameters like wind, vertical temperature gradient, etc. These meteorological parameters can not be controlled, yet it is very necessary to estimate the effects of these parameters on the dispersion of pollutants, so that the necessary planning and control in the emission rates can be rationally adopted.

The situation in an actual city is bound to be extremely complex with a large number of sources of pollutants with their emissions seldom constant with time. Additional complexities are introduced because of ever-changing meteorological characteristics. Thus, to rationally plan a scheme of controls to safeguard against air pollution hazards to health and property a simulation model, computer or otherwise, is the only recourse. Such a model will of course have to be tested on field before being accepted for use. To develop the background techniques for evolving such a model and getting a feel of the type of parameters involved and control measures emerging, preliminary studies were undertaken to study the horizontal and vertical distributions of pollutants in the city under selected simple yet practical conditions.

To study horizontal distribution, the pollutant considered was nitrogen oxides from the continuous stream of vehicles along the busiest road of the city—the Mall road. Variations in concentrations with time and distance from the centre of the road were studied.

For vertical distribution of pollutants rather calm periods during December-January were selected, since such period gives the 'critical' conditions for vertical distributions. The concentrations of SO_2 and oxidants were studied at various heights at various hours of the day near Life Insurance Corporation Building on the Mall Road.

Horizontal Distribution of Air Pollutants

The selection of sampling area required that it should have the maximum number of vehicles plying on the road with a fairly uniform distribution throughout the sampling period. For this, a traffic survey was carried out, which revealed that the Mall Road was the busiest road. Although the intensity of traffic, especially trucks, on the G.T. Road in the night was also found to be considerable it was not selected for this study as sampling would have been difficult during night time. The traffic count on the Mall road showed an average of 600-650 vehicles plying per hour. Thus the emission could be assumed to be a continuous line source at the centre of the road.

The pollutant sampling stations were located on both sides of the road, one metre apart from each other, starting from the edge of the road, as shown in Fig. 1. Thus, on one cross-section of the road, fourteen stations in all were set up. Two such cross-sections across the road were studied.

The sampling was started from 10.00 a.m. and was carried out hourly upto 4.00 p.m. The height at which sampling was carried out was kept at 1.5 m above the ground.

The oxides of nitrogen in the ambient air were determined by the phenoldisulfonic acid method (5). The sample was taken in the midget impinger (fritted glass bubbler) containing an oxidizing absorbent solution. The nitrate ions produced were determined by the colourimetric phenoldisulfonic acid method, at 400 mμ wave-length and evaluated by means of a standard curve.

Results

The variations of concentrations of oxides of nitrogen with the distance from the centre of the road at four typical timings at one location are shown in the Fig. 2. It shows that the central portion of about 14 m (inclu-

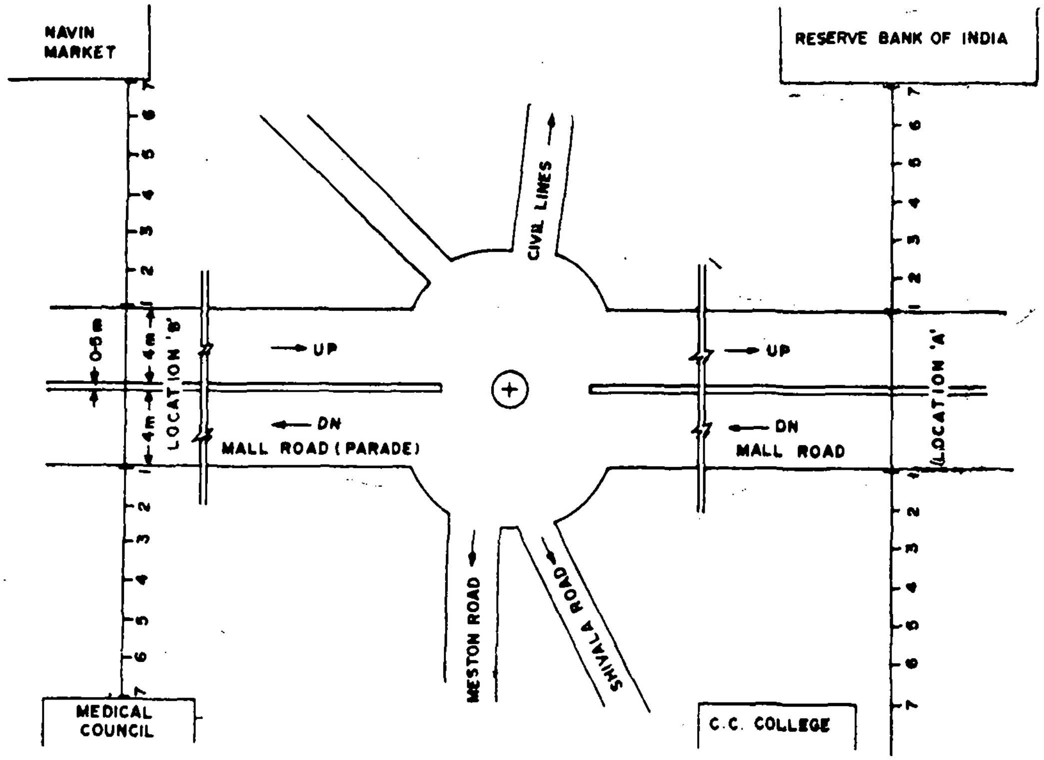

Fig. 1—Plan of Sampling Stations for Horizontal Distribution (All stations spaced 1 m apart)

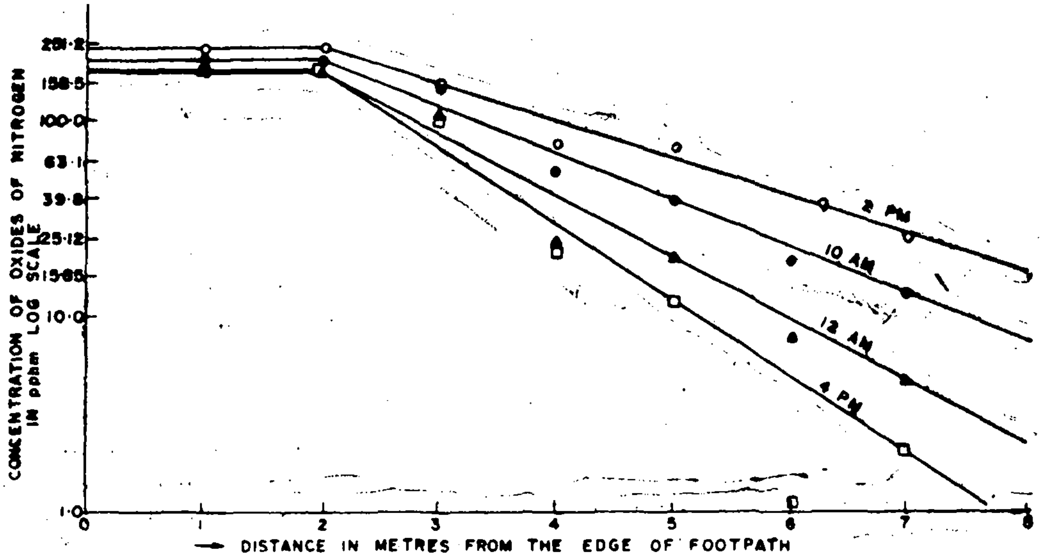

Fig. 2—Variation in Concentrations of Nitrogen Oxides with Distance

ding road width of 8 m) had uniform concentration of the pollutant. It was likely that there was a peak value at the centre of the road due to higher source strength, however, for this study the total 14 m width was considered as a line source.

The variation beyond 3 m from edge of the road (or, 7 m from the centre line of the road) on either side showed that there was an exponential drop in the concentrations. This can be depicted by a first order differential equation of the form,

$$\frac{\delta c}{\delta z} = - K.C.,$$

or

$$K = \frac{\ln c_1 - \ln c_2}{z_2 - z_1}, \text{ where}$$

c_1 and c_2 are concentrations at location 1 and 2 respectively, and z_2 and z_1 are distances across the road. K can be called a coefficient of dispersal, and will vary with meteorological parameters.

From Fig. 3, which is a plot of the dispersal coefficient K vs. time, it was found that its value steadily increased to a value of 0.5, then it fell to a value of about 0.3 at 3.00 p.m., and again rose to a still higher value of 0.7 late in the evening.

Increasing lapse rates with the approach of noon would have been responsible for the faster dispersal rates. The road temperature probably attained its maximum around noon and stayed almost constant from noon to 3.00 p.m. However, during this time, the adjoining structures also got heated up which resulted in an increase of the temperature of the layers of air even 30-40 m above road, thus creating almost isothermal conditions with very small lapse rates in the lower atmosphere. This may have been the cause of decreasing trend in dispersal rates during this period. Variation in wind might have been another important contributing factor.

The threshold value of oxides of nitrogen is considered as 5 ppm for 8 hr continuous exposure (6). It was observed that all locations upto 9 m from the edge of the road had 8-hr average concentration higher than 5 ppm. Hence, 9 m from the edge of the road on either side (or, 13 m from the centre line of the road) was the minimum safe distance for the location of residences, shops, etc. The margin of land between the road and the

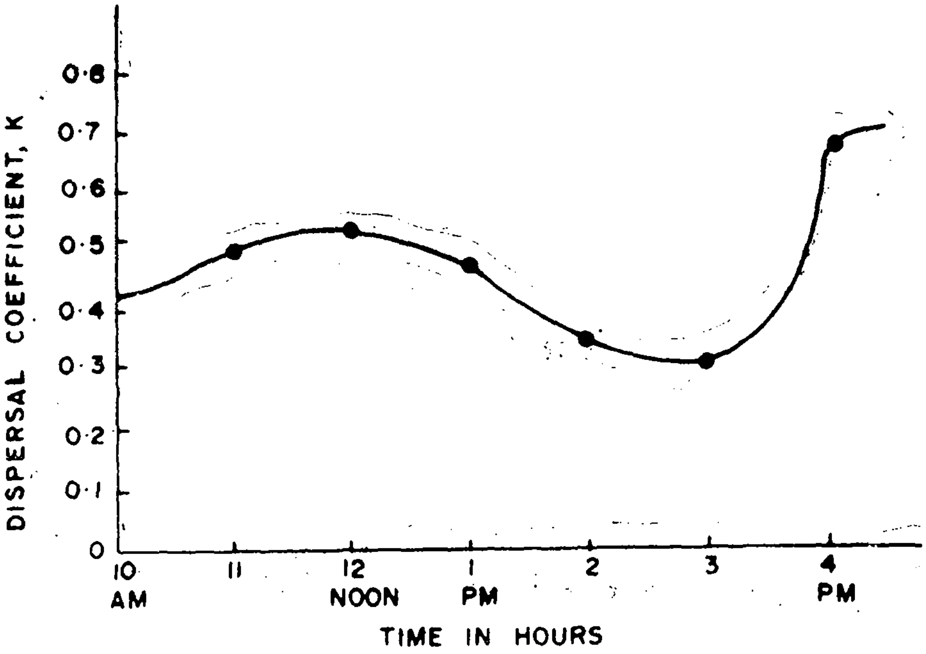

Fig. 3—Dispersal Coefficient vs. Time

structures can be beneficially utilized to provide green belt or parking space, etc.

Vertical Distribution of Air Pollutants

The temperature of the atmosphere decreases, on an average, with elevation. The rate of decrease in the temperature with elevation is known as its lapse rate. If a parcel of air is lifted adiabatically by an elevation of 100 m, its temperature falls by 1°C, which is the dry adiabatic lapse rate. The actual temperature profile of the atmosphere depends on the time of the day and the season of the year. On a typical day with light winds and clear sky, the actual lapse rate during the middle of the day is superadiabatic. With a superadiabatic lapse rate of the environment, a parcel of air, which is displaced upward from a level at which it has the same temperature and pressure as the surrounding atmosphere, will undergo a decrease of temperature corresponding to the adiabatic lapse rate and will have a higher temperature than its environment at the new level. It will be of lower density than the surrounding air, and the force of buoyancy which results will tend to cause the parcel to continue to ascend. In the like manner, if the parcel should be displaced downward, it will have a lower temperature than its surroundings and will tend to sink further. Therefore, when thé lapse rate is more than the adiabatic, all vertical movements are acclerated, and the atmosphere is said to be unstable, and good dispersion of the pollutants takes place.

When the actual lapse rate of the atmosphere is less than dry adiabatic, a parcel of air displaced upward will have a temperature lower than its surroundings or if displaced downward, a temperature higher. In this case, buoyancy forces tend to restore the parcel to its original level, and the atmosphere is said to be stable. When due to rapid cooling of the surface of the earth, e.g. in the winter evenings, the temperature of the air increases with the height; this is an extreme condition of a lapse rate less than adiabaticy and is termed an inversion. Under such conditions, the atmosphere is stable and it hinders the dispersion of the pollutants.

Thus the temperature distribution in the air and consequent stability criteria have a very important role in study of movement of air pollutants.

Test Procedures

As stated earlier, the area near Life Insurance Corporation building on the Mall Road, Kanpur was selected for the present survey. Although the concentrations of pollutants were not found to be the maximum at this place, it was selected because of the proximity of the tall L.I.C. building to facilitate the study of vertical temperature profile.

The temperature of the atmosphere was measured with a mercury-bulb thermometer reading upto 0.1°C.

The wind velocity was measured by a vane anemometer. The velocity record was cumulative for the period of measurement, and wind was classed as 'light breeze' when it was in the range of 30 to 60 metres per minute. Conditions in which the wind velocity was lower than 30 m/min., were considered as calm.

Sampling and analysis were done for SO_2 and oxidents. For the determination of SO_2 in ambient air, the West and Gaeke method (7) was used. The concentration of SO_2 was read from a standard curve prepared by using sodium metabisulphite solution. For the oxidants measurement, the alkaline potassium iodide method (5) was used.

Results

The typical graph of vertical temperature differential (t_{30} -t_1 where t_{30} and t_1 are temperatures in °C at 30 m and 1 m respectively above ground level) versus time is shown in figure 4. The variations of concentrations of SO_2 and oxidants with respect to time at the height of 1 m above ground level and at 30 m above ground level are shown in Fig. 5. The charts can be analysed taking them to comprise of four time zones.

Zone I (4.00 p.m. to 10.00 p.m.)

From Fig. 4, it is seen that around 4.00 p.m., superadiabatic conditions were prevail-

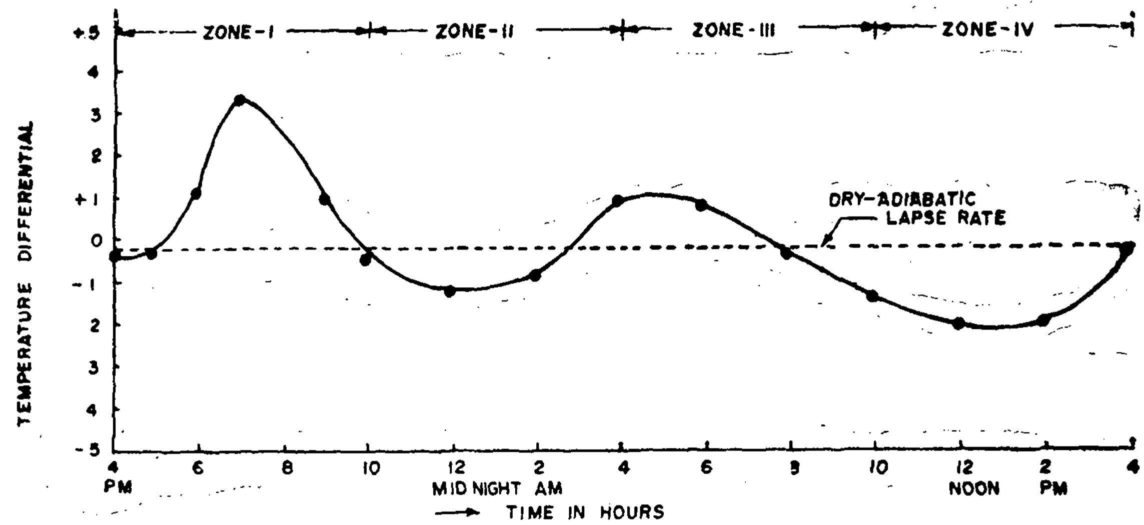

Fig. 4—Vertical Temperature Differential vs. Time

ing near the ground surface, and the atmosphere was calm. The concentration of SO_2 at the level of 1 m above ground was 0.024 ppm, whereas at the 30 m height it was 0.017 ppm, indicating an upward diffusion of SO_2 given out at road level by vehicular exhaust. As the evening wore on, the sun set, the earth started cooling rapidly and inversion conditions developed near the earth surface. The inversion conditions near the earth surface dominated till around midnight. The most severe inversion conditions occurred around 7.00 p.m. During these conditions, the concentrations, of SO_2 built up. The emission rates of SO_2 were on increase at the evening hours as the vehicular traffic increased on the closure of the offices, etc. and as the burning of coal for domestic purpose was also considerable. During this time, the atmosphere was in a very stable condition, hence the dispersion of SO_2 was prevented and its concentration built up. The maximum concentration at the road level was 0.065 ppm around 9.00 p.m., whereas at the terrace level, it was 0.085 ppm the SO_2 emitted at higher altitude from stacks was probably trapped at the higher altitude because of the steep inversion, and resulted in the $_2$OS concentration at 30 m level being more than that at ground level. Thus, during this period, horizontal as well as vertical movements of pollutants were at the minimum.

Oxidants are mainly photochemical pollutants. During the day time, the organic pollutants and nitrogen oxides absorb the energy from the sun rays, and the photochemical reactions take place, and the oxidant levels are high. During afternoon, the concentrations of oxidants were recorded as 0.123 ppm at the road level and 0.148 ppm at the terrace level. As inversion developed, it prevented the dispersion of the pollutants and build-up took place around 6.00 p.m., but, then, as the energy of the sun rays was ab-

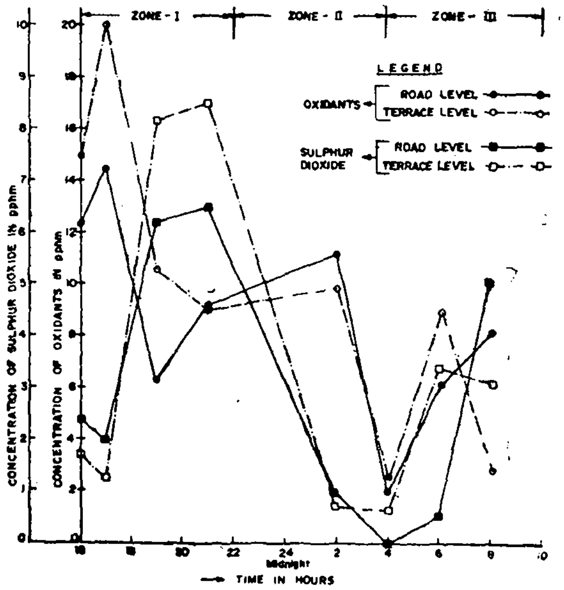

Fig. 5—Variation in Concentrations of SO_2 and Oxidants with Time

sent, further production of oxidants stopped and the concentration continued to be almost the same upto midnight.

Zone II (10.00 p.m. to 4.00 a.m.)

Around midnight, light surface breeze was recorded. This changed the condition of vertical temperature gradient, and super-adiabatic lapse rate conditions reappeared near the surface of the earth. However, it is more than likely that the inversion had only moved higher up and inversion conditions hight have been prevailing at heights more than height of 30 m at which the temperature measurement could be done. This could not be verified because of lack of instrumentation facilities at the time of these preliminary investigations.

The light surface breeze helped in good dispersion of the pollutants and the concentration of SO_2 fell down and reached to almost negligible value around 4.00 a.m. at the road level, whereas that at terrace level rached 0.007 ppm. Similar was the trend of oxidant levels, which were 0.02 ppm at the road level and 0.025 ppm at the terrace level at 4.00 a.m.

During this period, good herizontal diffusion was observed near the surface of the earth.

Zone III (4.00 a.m. to 10.00 a.m.)

In the early morning hours, from 4.00 a.m. to 8.00 a.m. inversion conditions were again observed close to the surface of the earth. meaning that the inversion had moved downwards or 'subsided'.

During this period, the concentration of SO_2 again increased. At 6.00 a.m., the concentration of SO_2 at the terrace level was about 0.034 ppm, whereas, at that time, the concentration at the road level was only 0.006 ppm. This was mainly due to the contribution from industrial sources at the higher altitude. The vehicular and domestic activities continued to be at the minimum. It was also likely that the inversion which set in close to the surface of the earth was of a subsidence type, which would have brought pollutants from the higher levels, and then trapped them inside the inversion zone.

The concentrations of oxidants also increased both at the terrace as well as the road levels, showing the similar trend, as it was for concentrations of SO_2. As during dark hours of night, no production of oxidants was taking place, the build-up of concentration of oxidants clearly indicated a subsidence type of inversion, and the pushing of the pollutants from the higher altitudes to close to the surface of the earth.

After 6.00 a.m., the concentration of SO_2 at the road level increased rapidly, as the smoke started emitting from the various hearths of the small hotels, etc. The concentration of SO_2 at terrace level slightly decreased.

Zone IV (10.00 a.m. to 4.00 p.m.)

During this period superadiabatic conditions, conducive to very good dispersal of pollutants prevailed as seen from Fig. 4. The concentrations of pollutants were hence rather low.

Conclusions

From the above preliminary study it became evident that a real attack on air pollution problem is only possible through a systems-approach taking into consideration all emissions with their exact locations and also various meteorological parameters e.g. lapse rates, wind velocities, etc. Application of idealized single emission equations such as Bosanquet — Pearson, Sutton or others can not directly predict the worst pollutional characteristics during inversion conditions in a congested city area. It is proposed to develop a digital — computer simulation model to predict such pollutional characteristics at any point given necessary input data. The applicability of such a model will depend on the feasibility of collecting meteorological data for the various layers of air in the 200 or so metres closest to earth. It should also be possible to monitor the pollutants at various levels above the earth's surface. Efforts are being made to do this by use of tethered hydrogen-filled balloons. If successful, such a monitoring technique and simulation model may mean a significant breakthrough in the field of air pollution control.

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CHAPTER-VIII

OTHER ASPECTS

PROC. SYMP. ON ENVIRONMENTAL POLLUTION (1973)

Environmental Problems in The C.M.D. - The Master Plan - & The C.M.D.A's Programme for Rescue

P. K. SAHA*

Calcutta Metropolitan District which comprises of an area of over 500 sq miles on both sides of the river Hooghly and centering around the twin cities of Calcutta and Howrah has bad reputation for environmental conditions for quite a long time.

The paper presents an account of the efforts made by various organisations from time to time to improve the environmental conditions and gives a brief resume of the various programmes undertaken by the Calcutta Metropolitan Development Authority, created in September, 1970, under the President's Act No. 17, with the goals aimed at and the progress achieved so far.

Introduction

Calcutta Metropolitan District (C.M.D.) extends over an area of over 500 sq. miles on both sides of the river Hooghly starting from Kalyani and Bansberia in the north down to Fuleswar, Budge Budge and Baruipur in the south. Bandel, Chinsurah, Hooghly, Chandernagar, Halisahar, Serampur— the settlements associated with the traders and empire builders of Europe— the Dutch, the French, the Portugese— are all here. Last to come into the list was Calcutta, the chance directed, chance erected city of Job Charnock for the British. History was in favour of the growth of these settlements but surely not the geography. "Everything was against it, Nature most of all". Nobody builds a city on reclaimed tropical swamps and saline marshes. But city building was only incidental to their commercial enterprise. The latter fluorished under the powerful protection of the Europeans and so did fluorish urbanisation. This continued through the 17th, 18th and 19th Centuries into the early part of the present century when under the strain of growing urbanisation, geography started taking its toll. The war, the famine and finally the Partition bringing 15 million refugees in its wake struck the final blow. The Calcutta region became a dark blot in the map of urbanised world—a city of 'pests and pestilentials'.

A Look into The Problem

It took the cholera epidemic of 1958 and the consequent heavy death toll to draw the Government's attention to the fact that everything was not alright in this part of the country. It decided to seek the help of W.H.O. to undertake a study on the woes of this region especially in the field of water supply and sanitation. It was evident that improvements of the city of Calcutta will not be enough to stem the rot. The scope must embrace the neighbouring areas as well. Thus came into being the Calcutta Metropolitan District (C.M.D.). After subsequent enlargements and marginal adjustments C.M.D. currently consists of 34 Municipalities and Corporations, 63 non-municipal urban areas and 544 rural Mouzas over a land area of 532 sq. miles (Fig. 1).

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* Programme Engineer (WS & EH), Calcutta Metropolitan Development Authority (CMDA), 3A, Auckland Place, Calcutta-17 (W.B.).

W.H.O. Team

The W.H.O. Consultant Team headed by Dr. Abel Wolman observed **inter alia** that:

(a) The environmental sanitary situation in the C.M.D. is considerably below the standards in respect to desirable provision of sanitary facilities to all of the population.

(b) The provision of filtered or otherwise safe drinking water is inadequate to a serious degree and has been so, for many years. Because of this inadequacy people are driven to unsafe sources of water for daily use.

(c) Sanitary removal of human waste from continuous daily contact with people is now being provided for much less than 40 per cent of the people of the area under review.

(d) Removal of storm water is not provided in a considerable part of the populated area, with the result that the people are intermittently exposed to and surrounded by pools of mixed sewage, refuse and street wash.

(e) Fly breeding is a persistent public health problem not only for the reasons above but also because of the pernicious practice of dumping refuse on public streets to await collection, poor collection facilities and bad disposal practices.

An Engineering Consortium was created in 1963 under the United Nations' Development Programme to go into a detailed engineering study of the situation to suggest possible redress. In 1966 they submitted their final recommendations in the shape of a Master Plan for water supply, sewerage and drainage for the Calcutta Metropolitan District. Together with some proposals for interim relief, the Master Plan proposed long term action programmes by dividing the time scale of action in two phases: The intermediate till year 1981 and the ultimate 1981-2001.

Water Supply Situation

During the period of study by the Engineering Consortium existing systems of water supply in the C.M.D. consisted either of the Hooghly river or of ground water exploited in the immediate vicinity of the area they served. Both these sources were also used directly by the **industrial and domestic** consumers privately. There were six municipal water works with installed capacity of 91.6 mgd in the C.M.D. of which Palta for Calcutta (84 mgd) and Howrah (4 mgd, located in Serampur) were the largest.

Substantial parts of Calcutta were served by filtered water distribution system from the Palta Water Works. There was also an unfiltered water distribution system receiving water directly from the Hooghly river through two pumping stations. Separate minor distribution grids served parts of Howrah. Baranagar-Kamarhati, Uttarpara, Serampur and Hooghly-Chinsurah from their respective water works. Parts of these municipalities received water from underground sources consisting of small, sometimes inter connected grids with one or two deep tubewells. Within these areas served by distribution grids intermittency of supply, mal-distribution, extensive leakage in the systems and high level of wastage by consumers resulted in considerable scarcity utterly disproportionate with the total quantum of supply **vis-a-vis** the population. Again leaving Calcutta and Kalyani, a population of nearly 4 million received on the average a supply just under 10 gpcd. But, even this picture was not quite representative since all were municipal areas with supply exceeding 10 gpcd deducted from the 1961 population of the C.M.D. more than 2 million people shared a municipal supply of 2.8 mgd representing a rate of supply of 1.3 gpcd. This is less than 1/3rd the minimum biological needs of human beings and no doubt majority of the population had perforce to use water from pond and shallow wells heavily polluted with pathogenic organisms.

Master Plan Recommendations

The primary objective of the proposals of the Master Plan for a safe and adequate water supply in the C.M.D. was to reduce the health hazard arising out of the inadequacy of the existing water supply facilities. The

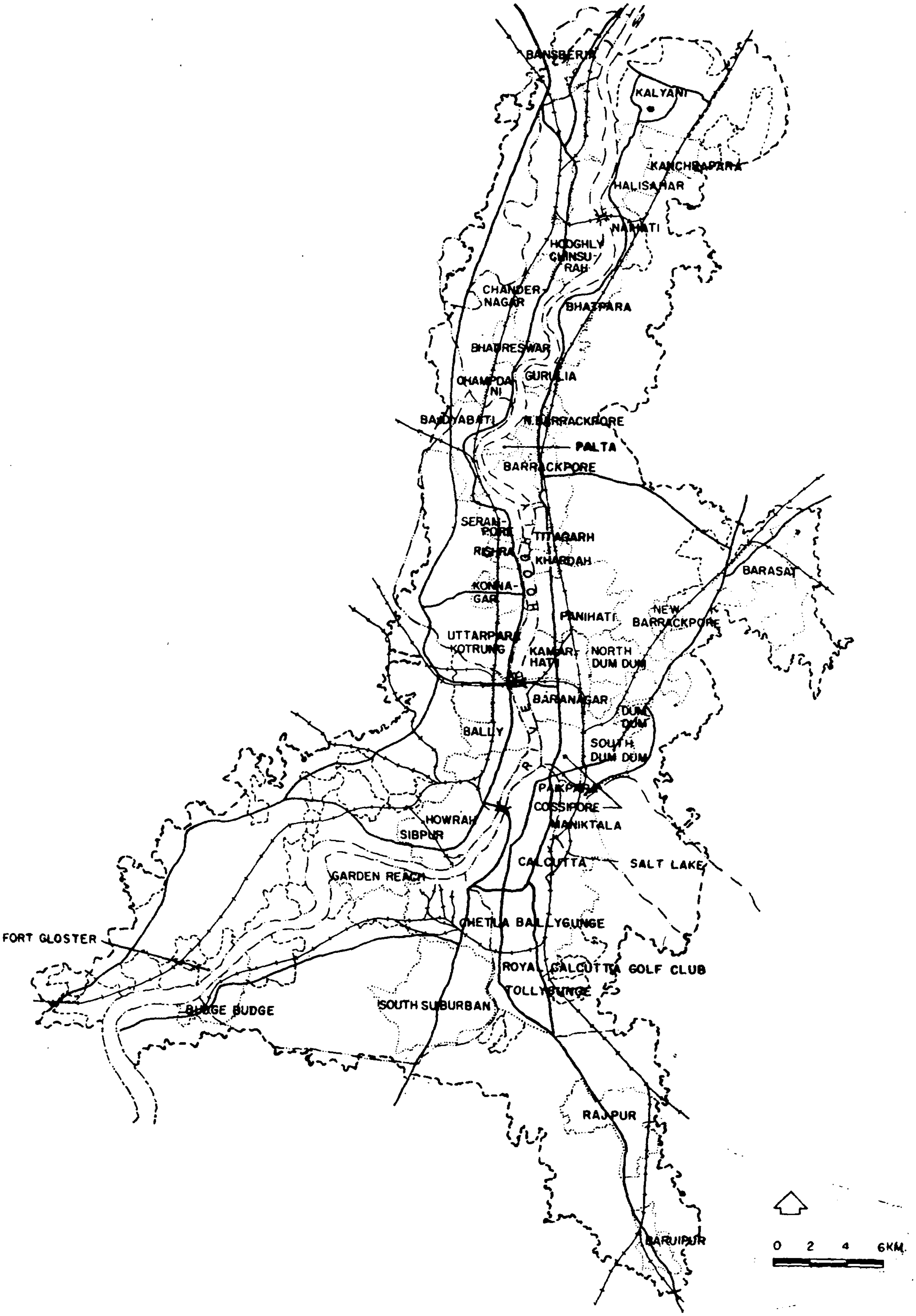

Fig. 1—Calcutta Metropolitan District

secondary objectives included provision of safe and reliable water supply to the industries especially the small ones, both as a means of increasing industrial efficiencies and as a source of revenue for running the systems; provision of water for fire protection etc. With these ends in view they recommended average supplies as:

(i) *Domestic Supply*

a) upto 1971, at 20 gpcd in all urban areas except Calcutta and Howrah where existing higher values will prevail.
b) Between 1971-81, 40 gpcd in all urban areas except Calcutta and Howrah which will have 50 gpcd.
c) 1981-2001, 50 gpcd in all urban areas and 60 gpcd in Calcutta and Howrah.

By urban areas was meant areas with overall population density of 25 persons per acre or more.

(ii) *Industrial Requirements*

The Calcutta Metropolitan Planning Organisation (C.M.P.O.) made projections for industrial employment for the C.M.D. as well as areal dispersal of industries of various types divided broadly under 4 groups: Engineering, Chemical, Jute and Textile, others. Industrial water use for these industries were predicted based upon standardised requirements. It was proposed that in areas of poor ground water quality 2/3rd of this requirement would be provided from Municipal sources and in rest of the industrial areas 1/3rd of the demand would be met from Municipal supply.

(iii) *Fire Demand*

Municipal supply for fire fighting purposes were proposed at 50% of the total (rest to be met from ponds etc.) to be available simultaneously with the maximum—day demand plus average day industrial demand at a minimum hydrant pressure of 20 psi.

Master Plan Proposals

For the attainment of the above Master Plan, the whole C.M.D. was divided into 5 service districts, namely: (i) Garden Reach, (ii) Calcutta, (iii) Palta or Baranagar-Kamarhati on the east bank of Hooghly, (iv) Howrah and (v) Serampur on the west bank. Within each service district was delineated a service area each to be supplied from surface water sources, the rest receiving water from under ground. The distribution network was to consist of primary and secondary grids. The following capacity provision for the headwork was also proposed:

Headworks	Capacity (mgd) till	
	1981	1981-2001
Palta (augmentation)	180	280
Garden Reach	60	190
Baranagar-Kamarhati	63	171
Serampur	20	78
Howrah	37	265*

(*including provision for Haldia)

It was subsequently decided to provide ground water @ 20 gpcd to the rural fringe areas of the C.M.D. with population density less than 25 ppa.

Sewerage and Drainage Situation

The Engineering Consortium also investigated into the adequacy or otherwise of the existing sewerage and drainage facilities in the C.M.D. During the study period sewerage systems were in operation in Kalyani, Serampur, Bhatpara, Titagarh and Calcutta. Kalyani, Serampur, Bhatpara and Titagarh systems were partly combined receiving limited storm run off; Calcutta had two combined grids, the Town system and the Suburban system, covering portion of the city area only, which carried both sewage and storm water draining to Palmer Bridge and Ballygaunge pumping stations where from they were pumped into open channels leading to the Kulti river. Outside these areas drainage was mainly through open channels, generally in the direction towards the Kulti river in the east bank and to the Hooghly river in the west bank; night soil was disposed of either through septic tanks or trenched after manual collection, though direct discharge into open drains was also not rare. The existing combined systems did not have sufficient hydraulic capacities to provide a reasonable degree of protection against monsoon flooding—thus overflowing frequently occured spreading diluted raw sewage over large areas and often remaining for several days. The open channels did not have hydraulic capacity for removing storm water during wet seasons. Consequently, they overflowed and spreaded sullage. Even during dry periods the open channels were often mass of putrified sewage stagnating for days together. These conditions created severe hazards to the public health.

Master Plan Recommendations

(i) *Sewerage*: The existing combined sewerage systems in Calcutta are old and have some defective design features. But the system was in good shape though in need of intensive repairs. Detailed studies revealed that the major elements of the two existing systems had adequate capacity to meet the design requirements of the sanitary flow. In addition the system had sufficient hydraulic capacity to accommodate storm water though not for the full design needs. In view of the above and also because replacement would involve huge capital expenditures and bothersome dislocations, the team proposed retention of the systems with creation of additional storm water capacity where ever needed. For the rest areas the team proposed construction of separate sewerage and drainage systems in phases.

For design purpose in sanitary sewers 80% return of domestic water consumption has been assumed alongwith an infiltration allowance of 1700 gal/acre/day. For areas with not many laterals infiltration allowance adopted was 2000 gal/inch diam of sewer/mile/day. Variable peak factors depending on the nature of the tributaries were also incorporated in the design. As a sop to industrial growth in the Metropolitan area the systems were designed to receive all industrial wastes though in certain cases pretreatments were specified. Sizable quantity of industrial wastes used for cooling purpose and steam generation were to go to the storm sewers. Specific recommendations for treatment plant set-ups were not made in the Master Plan but the team was alive to this aspect of the problem, especially of the fact that the Hooghly, the major source of water for the region was to receive a substantial part of the sewage flow. Various effluent quality criteria were accordingly specified.

(ii) *Drainage*: The Rational Method was adopted for the estimation of storm water run off in the urban areas of the C.M.D. with 2-month storm frequency. The degree of protection was based on reducing the existing frequent flooding situation nearby 15 times a year to about 1/4th as much with residual effects of briefer durations. Topographical features in the C.M.D. permitted storm drain layouts consisting of short run underground conduits discharging into the nearest open channels.

Master Plan Proposals

(i) *Sewerage*: The Master Plan identified 18 sewerage zones in the C.M.D., limited mainly to the urban and urbanising areas, based on population density, topography, location of existing facilities, location of suitable points for effluent disposal and requirement for treatment out of which details for 10 were incorporated in the Master Plan based on the urgency of need. These 10 Zones are:

Calcutta
Dum Dum
Manicktola
Howrah
Garden Reach
Konagar
Chandernagar
Tollygunge
Khardah
North Salt Lake

The proposals consisted mainly of alterations and interceptions in the existing systems, construction of new net works, trunk sewers, pumping and forced main systems. Besides, disposal points and need of treatment were indicated.

(ii) *Drainage:* The Master Plan drainage proposals for the C.M.D. were based broadly upon Greater Calcutta Master Drainage Plan 1953 for the East Bank and proposals made by the Irrigation and Waterways Department for the West Bank with necessary modifications. The C.M.D. was divided into 23 drainage basins. Detailed study for the following 10 drainage basins was undertaken :

Tollygaunge
North Salt Lake
Howrah
Konnagar
Manikhali
Manicktola
Calcutta
Bagjola
Khardah
Tolly's Nallah

Garbage Situation

The very first thing that a visitor sees and comments upon on his arrival in Calcutta is ubiquitous piles of garbage—stinking and putrifying under the tropical sun, scanned by scavenger birds and rag pickers all the year round. The collection system is slow and cumbersome, the disposal unscientific, and above all, the human elements involved are notoriously apathetic. Curiously enough, though Dr. Wolman's team commented on this aspect of the C.M.D's environment in their report, this was not covered in the report subsequently. Engineering Consortium concentrated their efforts entirely on water supply, sewerage and drainage. In fact, comprehensive study on this aspect covering the whole of C.M.D. is yet to be taken up. Mr. Jean Vincenz of the W.H.O. conducted a study of the garbage situation in the city of Calcutta in the early sixties; subsequently, C.P.H.E.R.I. undertook two elaborate studies, one for Calcutta and the other for Howrah.

Recommendations

These reports covered various aspects of the collection, carriage and disposal of garbage for the areas concerned and their recommendations included :

(a) creation of storage facilities through vats;

(b) carriage to the disposal sites through various types of motorized vehicles e.g. trucks, trippers, compactor vehicles;

(c) creation of engineering and service facilities through overhauling and expansion of workshops;

(d) disposal facilities suited to the situation covering the whole spectrum with composting, incineration and sanitary landfill with more stress on the last.

Implementation of Schemes

Because the correction of all these heritages of the past is technologically difficult, organizationally complex and financially costly, Dr. Wolman's team recognised that the situation would require complete reorganization of engineering, administrative and financial resources and accordingly proposed the creation of an Authority with Metropolitan base for the purpose. In the meantime, during the Third and Fourth Plan Periods works on the recommendations mentioned continued under the existing arrangements obtained in the State and within the ambit of the State Plan allocations. However, the results were most discouraging. It was soon clear that so massive a programme as envisaged above could not be done justice to in the normal financing and implementing pattern of the State. It was also felt that mobilisation of resources outside the meagre allocation of the State Plan would be called for to have such huge backlog in environmental improvement removed before the growth of the Metropolitan area could outstrip the planned provisions. It need be stressed here that this backlog was not only peculiar to the environmental field but extended to other sectors also. In fact a multipoint programme for Rs. 150 crores was drawn up to meet this deficit which included besides water supply, sewerage and drainage, sectors like traffic, housing etc.

Role of The Calcutta Metropolitan Development Authority (C.M.D.A.)

To meet such a need, C.M.D.A. was established in 1970 as a statutory body for financing, coordinating and, wherever necessary, executing the programmes for improvement of the C.M.D. with access to financial resources outside the plan provision. With the help of the various implementing agencies already on the job as mentioned above the C.M.D.A. immediately embarked on a programme which envisaged the following expenditure on sectorial works within the remaining parts of the 4th Five Year Plan :

Section	No. of Projects	4th Plan expenditure target
Water Supply	26	Rs. 26.92 crores
Sewerage & Drainage	56	40.78 „
Garbage disposal	4	4.83 „
Environmental Hygiene	7	7.15 „

Due to late start of the 4th Plan and further delay in establishing the necessary Metropolitan level organisation to properly handle the job the time scale for completion of the programmes had already been unsettled. However, in the meantime the growth of population and the resulting intensification of the problems continued unabated. It is the aim of the C.M.D.A. programme to restore the lost time as far as possible through telescoping the continual spectrum of the recommended time scale.

The programme started so far in the Water Supply Sector thus includes :

(i) completion of the residual works to ensure the minimum supply of 20 gpcd to all the urban areas of the C.M.D. and at the same time augmentation of the supply to 40 gpcd for such areas as have already attained the 20 gpcd supply;

(ii) ensuring of 50 gpcd supply to Howrah and Calcutta through improvement and relaying of lines and augmentation of existing head works such as at Palta; creation of additional temporary resources through sinking of deep tubewells till such time as new water works are completed;

(iii) construction of new water works of which one at Garden Reach has already been taken up. For other three, preparation of detailed plan, acquisition of land etc. have been initiated.

(iv) Construction of water supply schemes for the rural fringes of the C.M.D. to supply water at 20 gpcd.

In the fields of sewerage and drainage, works on the following Zones out of the Master Plan recommended ones have already been taken up :

Sewerage	Drainage
Calcutta	Calcutta
Maniktola	Maniktola
Tollygaunge	Tollygaunge-Panchanangram
Howrah	Howrah
Dum Dum	Konnagar
Serampur	Monikhali
Chandernagar	Khardah, Ichapur, Bagjola

Work on Sewerage Zones includes improvement of existing sewer lines, construction of new ones, provision of interceptors and trunk mains, sewering of unsewered pockets, installation of pumping and treatment facilities etc., while in the Drainage Zones works include creation of separate underground storm water drains, improvement of existing drainage channels, construction of Nikashi drains in municipal areas and improvement of outlet facilities.

For collection and disposal of garbage in Calcutta funds have been advanced to the Calcutta Corporation for implementation of the various recommendations mentioned earlier. Already land has been acquired for extending sanitary landfill facilities in the two existing dumping grounds of Dhapa and Bantala with provisions of improvement of approach roads and internal movements. Removal arrangements have been augmented with increase of the size of the fleet. Similar steps have also been taken for Howrah while for the other municipal areas tractors with trailors and night soil tankers have been provided for removal of garbage and nightsoil while more comprehensive scheme for garbage disposal is being drawn up.

In the field of environmental hygiene the major emphasis so far has been on replacement of the dry latrines with sanitary ones. It is estimated that there are about 1,50,000 such latrines in the C.M.D. A sizable number of these located in the bustee areas are being replaced under the Bustee Improvement Schemes of the C.M.D.A. while for the rest C.M.D.A. offers subsidy to the tune of 3/4th of cost with ceiling at Rs. 1200/- each for replacement either with septic tank or sewer connection as the case may be. C.M.D.A. is marketing a prefabricated variety of sanitary latrine for the purpose response to which has been encouraging.

Conclusion

Prior to the creation of the C.M.D.A., Rs. 3.14 crores was spent in 1969-70 in the whole of C.M.D. for all types of development work. Since the creation of C.M.D.A. in late 1971 the expenditure figure on environmental improvements alone came to Rs. 5.24 crores and Rs. 14.97 crores in the years 1970-71 and 1971-72 respectively and the trend is definitely upwards. While it may be infinitely argued that the expenditure figures do not reveal everything and certainly they do not represent a proportionate increase in benefit but surely a beginning has been made in Calcutta in tackling the problem of environmental improvement in a massive way. And this in itself is something unprecedented in the history of this region.

DISCUSSION

Shri A. G. Pandit: (i) What are the standards to which sewage will be treated with reference to the method of disposal of effluents from sewage treatment plants? (ii) What are the legal provisions available to take steps with a view to prevent the pollution of water?

Shri P. K. Saha: (i) A considerable portion of the sewage from the Calcutta Metropolitan District will flow into the river Hooghly after treatment. Simultaneously, a large volume of water for drinking and other purposes will be withdrawn from the same river at various points. Keeping in view the locations of the waste discharge and water withdrawal points as well as the volumes involved, studies have been made to find out the effect of waste discharge on the river water for various extents of treatment. Based on these, it has been decided that complete treatment of waste upto secondary level will be required in the ultimate phase of the programme. The C.M.D.A. has already entrusted with the CPHERI the job of carrying out a water pollution survey of the river Hooghly and to recommend if any tertiary treatment would be called for in particular cases. (ii) West Bengal do not have any Water Pollution Control Act now. But with the enactment of such a law at Centre, the State will also frame suitable legislation.

Shri J. M. Dave: Calcutta has a very comprehensive programme besides what is covered here. The programme includes air pollution, water pollution control, slum clearance, garbage disposal, etc., which are unique. When CMDA completes them, Calcutta will be a much better city.

Shri P. K. Saha: I must thank Shri Dave for his complementary remarks. CMDA's programme is a comprehensive one for development of a vast area with high urban potential as well as of infinite complexity. It is not possible even to give a very brief resume of the CMDA's activities within the few minutes given to me here. But we would be happy to provide details of any aspect of our activities on request.

Shri S. Mukherjee: CMDA has started to control environmental pollution in various ways. I would like to know whether CMDA has any programme to control air pollution in addition to the measurement of pollutants. For calcutta, it is the high time to ration the entry of automobiles especially private cars as has been adopted in other countries. These automobiles are one of the main causes of air pollution. I wish to know whether there is any direct attack on the problem.

Shri P. K. Saha: CMDA has already initiated a programme for the study of air pollution in the Calcutta Metropolitan District with the help of CPHERI. Based on the findings of this survey, suitable remedial measures are proposed to be adopted. In the meantime, some short term measures for control of air pollution are also being contemplated.

Shri J. B. Kachra (Surat): Whether industrial requirement has been considered in deciding the water supply requirement of the Calcutta city. If so, how much?

Shri P. K. Saha: Yes, in arriving at the water requirement of the Calcutta Metropolitan District the industrial water demand has been taken into consideration. Based on projections made by the Calcutta Metropolitan Planning Organisation this demand comes to 231.0 mgd in the year 1981 and 426.3 mgd in the year 2001.

Shri N. W. Mirchandani: Calcutta has a dual water supply system. Filtered water is supplied for domestic purposes while raw river water is supplied for non-domestic purposes. What is being done about this? Does the scheme cover supply of treated water only and doing away with the dual system of supply?

Shri P. K. Saha: Yes, it is proposed to phase out the unfiltered water supply system presently in use in certain parts of the city of Calcutta.

Shri S. S. Rodgi: I am happy to know about the new plans for expansion of sewer system for Calcutta. What are the plans for treatment of sewage of the city? Please inform us the details of sewage treatment methods that are going to be adopted.

Shri P. K. Saha: In the intermediate phase, i.e., till 1981, some of the plants will provide primary treatments only, whereas others will give both primary and secondary treatment depending upon the situation. But in the ultimate phase, i.e., by the year 2001, all wastes will be given treatment upto secondary level and if necessary upto tertiary level also.

Shri N. M. Basu: What is being done for drainage of those areas which are lower than the level of gauge water level during tide periods?

Shri P. K. Saha: For such areas pumping arrangements are being made for the high tide periods.

PROC. SYMP. ON ENVIRONMENTAL POLLUTION (1973)

Pollution Control with Profit

N. G. ASHAR*

The paper highlights the steps that have been taken by the chemical industry in reducing sulphur dioxide emission from conventional plants manufacturing sulphuric acid having 2,000 to 5,000 ppm SO_2 level to less than 500 ppm in the stack gases. In terms of pollutant emitted this would mean reducing from 30 kg to less than 3 kg of sulphur dioxide per tonne of acid produced. In context with the Indian conditions of sulphur and sulphuric acid prices, this paper indicates that even the present plants operating with conventional processes can be converted to the new system of Double Catalysis Double Absorption (DCDA) and thereby earn profit instead of paying for combating pollution. For new plants it is undoubtedly economical in India to put a DCDA process as against the conventional sulphuric acid plant for capacities in excess of 150 ton/day.

Introduction

With the increase in the industrialisation of India, the concern of an ecologist regarding pollution is well justified. India being in the game at a later stage when a considerable concern over the environment is expressed in all the quarters of the world, it is possible to prevent the mistakes that the developed countries made in the past. Economic and industrial growth of a country should not be retarded because of a false scare created by the environmentalists. The Chemical Industry is sometimes wrongly made the target of criticism for creating air pollution, especially by sulphur dioxide. In fact, the major contributor to sulphur dioxide pollution is not the chemical industry, but other industries that burn coal or sulphur bearing oil. And it is the chemical industry that can come to the rescue of the environmentalists and develop process technology which could form an integral part of the future plants to meet the specifications laid down by the environmental protection agencies. The paper describes development of such a process, known as Double Catalysis Double Absorption (DCDA) process for reducing SO_2 emission from 2000-5000 ppm to less than 500 ppm in the stack gases. It is also explained how the DCDA process helps to earn profit instead of paying for combating pollution.

Description of Conventional Contact Process

A flowsheet of the conventional contact process for the manufacture of sulphuric acid using sulphur as raw material and vanadium pentoxide as catalyst is given in Fig. 1. Sulphur is burnt with preheated air to produce SO_2 which after cooling is converted to SO_3 by passing over vanadium pentoxide catalyst in four stages. From equilibrium point of view the maximum conversion that can be achieved is 97 to 98% depending on the type and depth of the catalyst.

The SO_3 gases leaving the converter are then passed through a tower where 98% sulphuric acid is circulated. The SO_3 is absorb-

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* Technical Adviser (Development & Project), Dharamsi Morarji Chemical Co. Ltd., Ambernath, Dist. Thana (Maharashtra)

ed and unconverted SO_2 leaves the absorption tower. The strong acid leaving the tower is then diluted with water and cooled before transferring to the product storage. The overall conversion efficiency for various designs supplied by Process Designers of international repute, namely, Monsanto, Chemico, Lurgi, Simon-Carves etc. can be guaranteed for 95-96.5%. This would mean the raw material consumption of 0.34 ton of sulphur per ton of 100% sulphuric acid.

Description of the DCDA Process

A flow-sheet of the DCDA Process is given in Fig. 2 The sulphur is burnt with air in a horizontal spray-type combustion chamber. Before the air is admitted to the combustion chamber, it is dried by scrubbing with 98-99% sulphuric acid.

The temperature of the SO_2 gas from the sulphur burner is higher than is required for inlet to the conversion system. Therefore, the gas is cooled in a waste heat boiler, which recovers the surplus heat as by-product steam.

From the No. 1 waste heat boiler the gas flows to the first pass of the converter system where it is partially converted to sulphur trioxide gas in the presence of vanadium pentoxide catalyst. The conversion reaction produces heat. Gases leaving the first converter pass flow to the No. 2 waste heat boiler where they are cooled. Temperature of the gas stream downstream of the No. 2 waste heat boiler is controlled in the proper range by by-passing a portion of the gas flow around the No. 2 waste heat boiler. The cool gas stream flows from the No. 2 waste heat boiler to the second converter pass where additional conversion of sulphur dioxide to sulphur trioxide takes place accompanied by the generation of additional heat. Hot gases leaving the No. 2 converter pass are cooled by sending them through the tube side of the hot interpass heat exchanger. Temperature downstream of the heat exchanger is controlled in the proper range by by-passing a portion of gas around the shell side of the heat exchanger. Cooled gases leaving the heat exchanger flows to the third converter pass where additional conversion of sulphur dioxide to sulphur trioxide takes place. Hot gases leaving the third converter pass are cooled by sending them through the tube side of two gas heat exchangers, called cold interpass heat exchangers, connected in series.

Cool gas leaving the interpass absorbing tower, containing unreacted SO_2 flows to the cold interpass gas heat exchangers where it is heated by gases leaving the No. 3 converter pass.

From the cold interpass heat exchangers the gas stream flows to the hot gas heat exchanger where it is further heated by gases flowing from the second converter pass. From the hot interpass heat exchanger, the gas stream flows to the fourth converter pass where final conversion of SO_2 in the gas stream to SO_3 is accomplished.

The gas stream from the fourth converter pass flows to the super-heater economizer where it is cooled by the incoming boiler feed-water, and steam from the boiler system and then flows to the final absorbing tower. In the final absorbing tower, SO_3 in the gas stream reacts with water in the 98-99% circulating acid. The temperature of the strong acid circulated over the final absorbing tower increases due to the heat of formation and the sensible heat of the gas stream entering the tower. Acid from the bottom of the final absorbing tower is circulated through coolers and returned to the top of the tower. Sufficient water is admitted to the final absorbing tower system to control the strength of acid circulated over the final acid tower between 98-99 percent. That acid produced in the final absorbing tower underflows to the drying interpass acid pump tank.

Gas leaving the final absorbing tower flows to the atmosphere through a stack.

Estimated Cost of Sulphuric Acid Plants

The battery limit cost estimation is made for conventional as well as DCDA sulphuric acid plants for various capacities at current (1972) prices. The figures are given in Table I below :

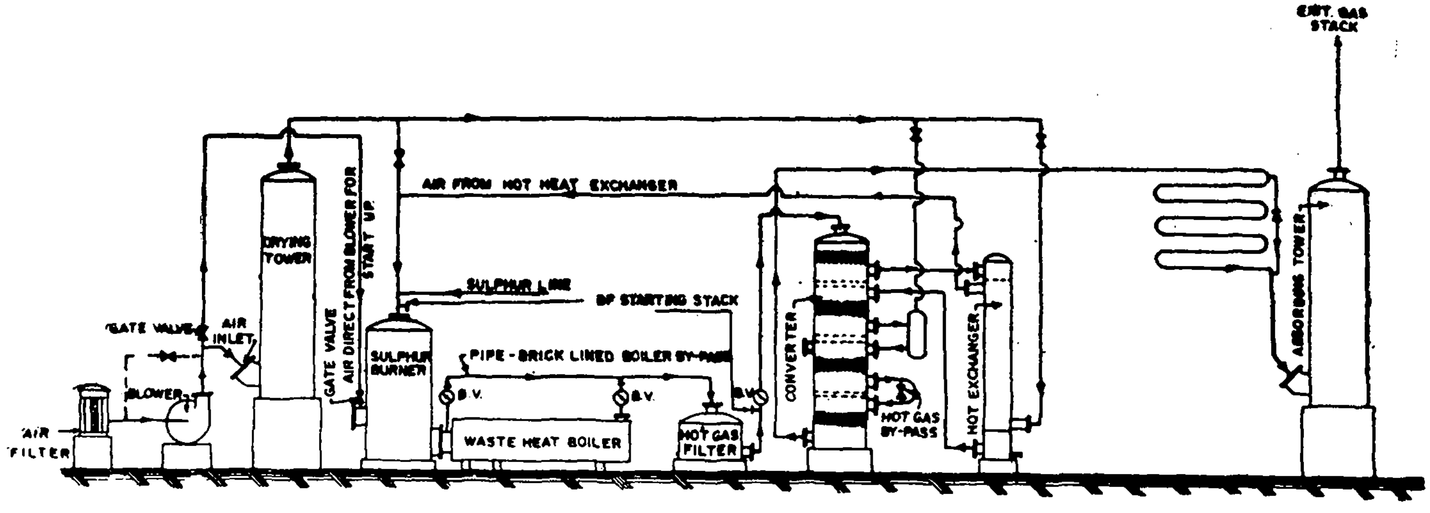

Fig. 1—Flow sheet for Conventional Sulphuric Acid Process

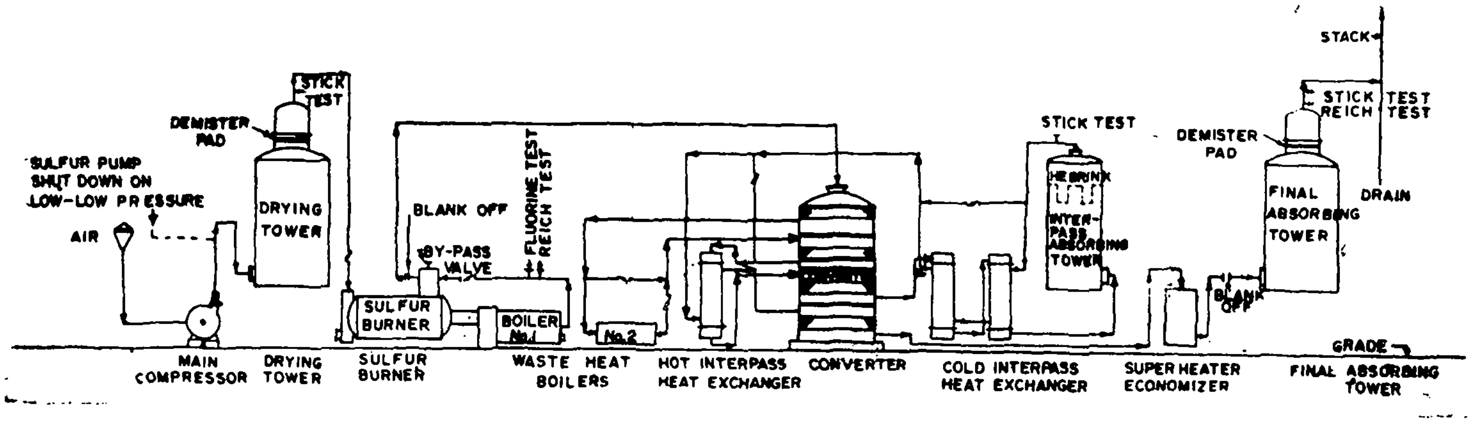

Fig. 2—Sulphuric Acid Plant—Process based on DCDA System

TABLE I—COST ESTIMATES OF SULPHURIC ACID PLANTS

(Rs. in lakhs)

Process	Capacity (ton/day)				
	25	50	100	300	1000
Conventional	35	65	100	225	315
DCDA	41.5	73	110	240	340

It will be observed that economy of scale for plants having a capacity of 1000 ton/day is quite attractive. However, a good number of plants in India are in the capacity of 50 to 200 ton/day. Very few plants are of about 300 ton/day capacity.

Cost Savings

It can be safely assumed that a conversion of 99.5% and an overall efficiency of 99% can be achieved by DCDA process. Hence the raw material consumption will be 0.33 ton of sulphur per ton of sulphuric acid or for every 96.5 tons of sulphuric acid produced as 100% about 2.5 tons of additional sulphuric acid will be generated without any additional cost of operation, except for the interest, maintenance and depreciation of the additional equipment for the DCDA process. For the basis of calculation the CIF price of Rs. 300/- per ton for sulphur and a pre-excise/pre-tax price of Rs. 250/- per ton of sulphuric acid is taken. If one takes the raw material saving, the cost saving of Rs. 3/- per ton of sulphuric acid is achieved and on the basis of finished product cost, a saving of Rs. 6.50 is achieved per ton of sulphuric acid produced. The basic additions for a sulphuric acid plant using DCDA process as against conventional process are :

(i) an intermediate absorption tower, (ii) counter-current heat exchangers to preheat the gases, (iii) additional catalyst loading, (iv) blower to take care of increased pressure drop in the system, and (v) additional acid circulation pump and drive.

For comparison the incremental cost of this for 1000 ton/day plant is approximately Rs. 25 lakhs. Based on 15% depreciation, 10% interest and 5% maintenance, this would mean an incremental cost of about Rs. 2.30 per ton of sulphuric acid produced. Hence a net saving based on raw material cost of Rs. 0.70 per ton of acid produced is achieved. Of course, saving in terms of benefits realised on additional production with no additional raw material required, is Rs. 4.20 per ton of acid produced or Rs. 13.86 lakhs per annum. It would also mean a foreign exchange saving in terms of less sulphur consumed, of Rs. 10 lakhs per year. However, as the capacity is reduced to 300 ton/day, the corresponding reduction in the additional cost of the DCDA process is only Rs. 10 lakhs. The incremental cost of the DCDA equipment per ton of acid produced is Rs. 4.50 and the corresponding gain per annum based on sales price realised is Rs. 2 lakhs and the foreign exchange saving of about Rs. 3.33 lakhs.

Table II indicates the additional return per year based on sulphuric acid price of Rs. 250/- per ton. This data is plotted in Fig. 3. The break-even capacity for a sulphuric acid plant for a DCDA process based on the Figure 3 is worked out as 160 ton/day.

Additional Capacity and Possible Cost of Conversion

An interesting feature of the DCDA process is that it can take up higher strength of SO_2 in the converter since the product of reaction will be absorbed and sent for conversion again into the catalyst bed. Also, because of the pre-heating requirement of the return gases from the intermediate absorber, it is not necessary to pre-heat the air

TABLE II—COST OF ACID PLANT PER TON PER DAY CAPACITY AND ADDITIONAL RETURN PER YEAR

(Rs. in lakhs)

Process	Capacity (ton/day)				
	25	50	100	300	1000
Cost of acid plant					
a) Conventional	1.4	1.33	1.00	0.75	0.31
b) DCDA	1.66	1.46	1.10	0.80	0.34
Additional Return by DCDA	—1.45	—1.33	—0.86	+2.00	+13.90

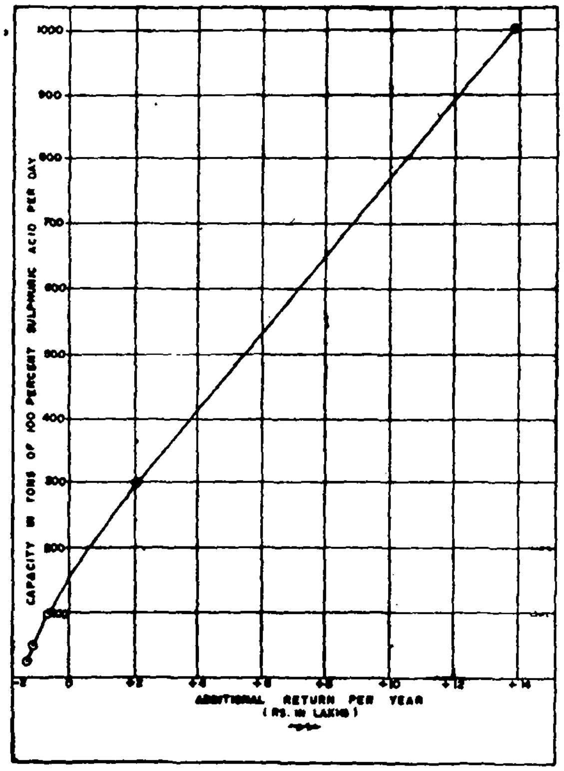

Fig. 3—Break-even Capacity for H_2SO_4 Plant based on DCDA Process.

for burning the sulphur. A conventional plant presently operated on the old process when converted to DCDA process will, therefore, have an additional capacity. It is interesting to note that an additional capacity of sulphuric acid production would cost about Rs. 1.25-1.30 lakhs per day of acid for plant having capacity near 50 ton/day, about Rs. 0.75 lakhs per ton per day for plants having capacity near 300 ton/day. The cost of such conversion for a plant of the size of 50 ton/day would come to Rs. 20 lakhs but would add to the capacity 25 ton/day bringing final capacity to 65 ton/day. Hence the net saving due to conversion would really be Rs. 2.5 lakhs. For a similar conversion for a 300 ton/day plant the cost would be Rs. 45 lakhs but would add to the capacity of about 90 ton/day thereby having a net saving due to conversion of Rs. 45 lakhs. The operational savings due to better efficiency per year for a converted plant of 50 ton/day capacity is Rs. 1.40 lakhs and for a plant of 300 ton/day capacity is Rs. 8.50 lakhs.

The above calculations indicate that it would be justified to propose converting sulphuric acid plants having capacity as low as 50 ton/day to DCDA process and gain additional return.

Conclusion

From the above analysis, it can be safely concluded that all new plants in India having a capacity in excess of 150 tons per day should be based on DCDA process with economic advantage. As regards the existing plants, if additional capacity is desired, the best course is to convert the same to DCDA process and not only obtain additional capacity but also reduce the pollution from 30 kg to about 3 kg of SO_2 per ton of acid produced. It would be profitable to do so even for the plants having capacity as low as 50 ton/day. It is urged to all environmental scientists to view the problem of combating pollution not as an enforcement measure but as a innovating effort to induce chemical industry by process changes in such a way that pollution control forms a part of the new technology.

DISCUSSION

Dr. A. K. Mozumder (Jamshedpur): In the DCDA process, there is an intermediate absorption tower between the third and fourth stage of the converter. What would happen to the catalyst mass in the fourth stage if there is an acid mist carry over from the intermediate absorptions tower due to some malfunctioning e.g., moisture ingress into the system from the drying tower?

Shri N. G. Ashar: In the DCDA process care in taken to provide a high efficiency mist eliminator between the tower and the converter so that no mist would be carried to the catalyst. Carry over of acidic mist in any form will poison the catalyst. However, the performance above mist eliminators has been satisfactory and has been proved in plants of capacities ranging around 600,000 ton/day and, therefore, there is no cause for worry.

PROC. SYMP. ON ENVIRONMENTAL POLLUTION (1973)

Environment & Economics

S. K. GAJENDRAGADKAR*

The pollution problem has been recognised by everybody. But every problem centres round socioeconomic activities—more so in developing country like ours. The economists have their own jargon & usually it is difficult to find out the cost benefit ratios and economical benefits in the long run for an Engineer. An attempt is made to formulate the externalities & internalities and a mathematical model is proposed on the basis of existing literature.

Introduction

Environmental Pollution or Ecological Slight has been an inescapable part of the industrial revolution which began with an age dependant on Coal and Iron and consequently, on pollution. Generations of economists have recognised the existence of external or 'social costs' like those resulting from pollution, associated with private production and consumption activity. Nevertheless, it was not until the last five years or so, that economists have begun to recognize explicitly that externality phenomena are a pervasive element in the exchange economies.

The economists ignored the general interdependancy of the man-environment themes due to apparent implicit belief that externalities associated with pollution were essentially two party problems: emitter vs. receptor. If the emitter and receptor are identified, if possible, then private exchange efficiency will result through equalling of marginal pollutant damage and marginal waste treatment costs. If there are any such cases of emitter and receptor identified, then they are being taken care of by legal proceedings in most of the developed countries. However, most pervasive cases, where receptors are vaguely identified, say a group of people of present and future generation, damages induced are synergistic in their effects on receptors and cannot be resolved with application of two party principles. That is why the existing economics cannot give any tangible help for the solution of this complex problem.

Wohlman (1) suggests that the low regard of the past for careful preservation of the environment stemmed from several circumstances. Those controlling the use of resources could usually avoid permanent contact with the dirt and ugliness. Moreover, environmental control required collaborative action. Furthermore, levels of income were not high enough to suggest a substitutor of beauty for physical goods and those in business of developing and disseminating good taste and sensitivity to beauty, usually had wealthy clients not the general public. The classic examples of blight polluted air, water and land were more often than not, concommitants to the process of accumulating private fortunes. To-day's interest in Western countries stems because the public is the client and secondly due to saturation of goods and services for a sector—higher middle class of society. Whether one accepts all what Wohlman and other economists have to say or not, one cannot deny the facts that

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* Asstt. Professor (PHE), Civil Engg. Dept. Victoria Jubilee Technical Institute, Bombay—4000-019.

there is a great ecological catastrophe and the global pollution has reached a dangerous limit. And that every problem has to be socio-economically understood. Hence, an attempt is made in this paper to bring out economic implications very briefly.

Economic Implications

Ecological effects of economic activities pose an increasing threat to material welfare both existing and future, production, growth and development. The vague threat of ecology has assumed the exact contour within this decade. Once the problem is defined, it is easier to find the solution. At one end, we are consuming most of the natural resources at a very high speed while at the other we are supposed to spend a great chunk of available resources in controlling the pollution. We are being cut at both the ends. This brings economics into the system.

Old Model

The model that is usually adopted by the old economists (2) is closed type (Fig. 1).

It is in this system that the policies are made on appearances and, therefore, GNP maximisation becomes the aim. The price system and its social accounting does not take into account the environmental costs and benefits. GNP concept and welfare have no direct relationship.

New Model

In view of the above, new concept needs to be introduced in the model where residuals (or wastes) do not necessarily have to be discharged to the environment. In many instances, they could be recycled back in the productive system. The model, therefore, could be changed as in Fig. 2.

Now, environmental quality comes at a cost. In some instances the cost is to be borne by us while in others, it is transferred to future. Therefore, we should agree that in a way pollution is partly the price of progress. It might be internal or external. We, therefore, start thinking of control of pollution. Pollution control can be achieved directly by banning, outlawing, regulating, requiring, imposing, insisting, and punishing, and also indirectly by putting a tag on pollution. We, therefore, need to think of cost benefit ratio.

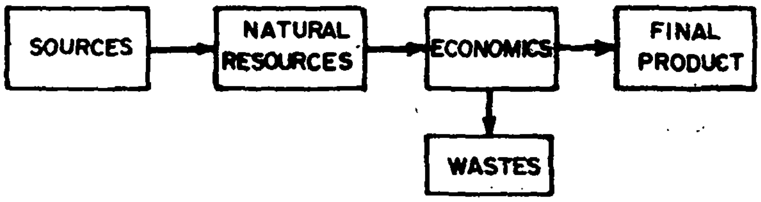

Fig. 1—Old Model

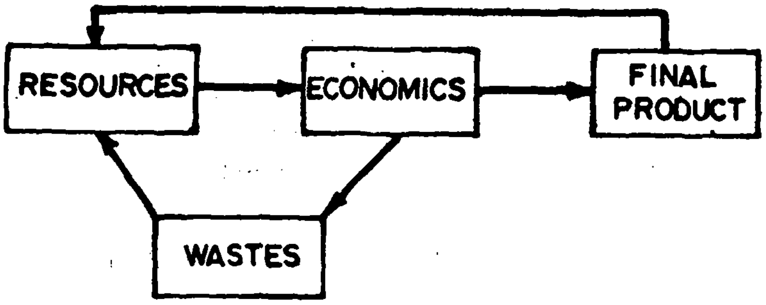

Fig. 2—New Model

Cost Benefit Analysis

Economics has two main applications to this study (3). It enables one to estimate either the extent of damage resulting from pollution, i.e., external diseconomies of production so that it can be rectified, or the market structure for the clean environment so as to determine the necessary amount of abatement. In attempting to simulate the market of pollution it is important to realise that demand and supply schedules are different for those sectors of society that produce pollution and those that are affected by it. For instance, let us consider air pollution. The sources of air pollution have a demand for "air", while receptors have a demand for "clean air". These are different commodities and as such, the demands cannot be aggregated. Therefore, the demand-supply schedules cannot be worked out in usual way. The supply schedule for clean air can be determined by estimating how much it would cost the sources to reduce air pollution. The demand for clean air can be determined by estimating the cost of the physical and psychic damage that results from different levels of air pollution, assuming that receptors would be willing to pay upto this amount so as not to incur such damage. Supposing, we have a schedule as per Table I, then we can plot the graphs showing the total costs (Fig. 3).

TABLE I—DEMAND-SUPPLY SCHEDULE FOR POLLUTION ABATEMENT

Level of Abatement (%)	Total Damage (TD) (Rs.)	Total cost of Control (TC) (Rs.)	Total cost to Society (TD+TC) (Rs.)
10	3700	150	3850
20	2700	250	2950
30	2000	350	2350
40	1400	500	1900
50	900	700	1600
60	600	1050	1650
70	450	1450	1900
80	300	2100	2400
90	200	3200	3400
100	0	4300	4300

Note—Data adapted with small changes from Reference 3.

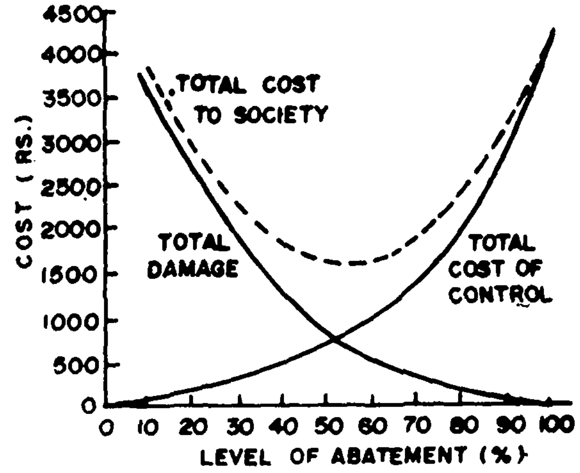

Fig. 3—Cost to Society from Air Pollution Damage and Cost of Control

One can also determine the level of abatement by charting the benefits and costs of abatement. Fig. 4 gives both the curves. The objective is to select level of abatement that maximises the value to society.

It has also been seen that the level of abatement selected, when the benefits and costs are compared, is same as the level selected, when total costs to society are minimised. Secondly, simply knowing that total benefits to society for any single level of abatement are greater than the total cost does not help society in deciding where to operate. It also does not indicate to society whether to increase abatement (as in 10-40

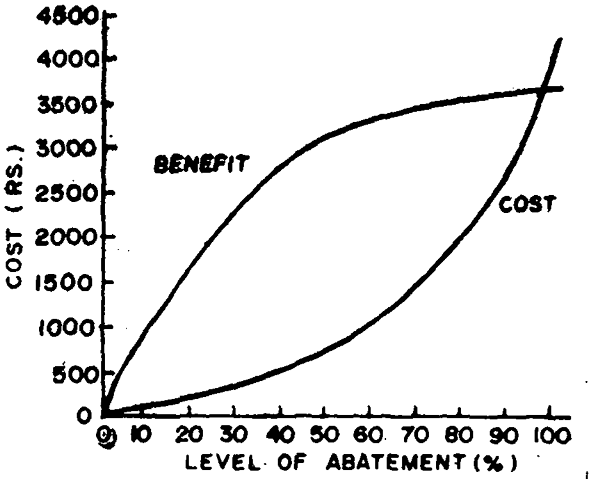

Fig. 4—Benefit and Cost of Abatement

percent region) or to decrease abatement (as in the case of 60-90% region). People often justify erroneously a level of control on the basis of the benefits of abatement being greater than the costs.

A Mathematical Model

We have already mentioned about recycling before. Here, we would like to discuss a very simple mathematical model (4).

In order to describe briefly some of the ramifications of growth and environmental quality, we shall adopt an extremely simple model of the Harrod type. Let W denote a homogeneous waste flow, F the current production of material goods, K_r a measure of the capital stock committed to augmenting the assimilative capability of the environment with $\frac{dK_r}{dt} = I_r$ and S saving. Then, in the spirit of the concept that production consumption and waste generation are joint products, the following equation is postulated :

$$W = g_c (F-S) + g_f F \qquad \dots (1)$$

where g_c and g_f are coefficients relating the amount of waste flow generated from current consumption and production respectively. Next, it is postulated that density of wastes is the proper measure of environmental quality. Let D denote average waste density, V a volume measure of the natural environment, for example the size of the global natural life zone which is assumed as fixed, and δ a decay rate in waste density which can be considered as symbolic of the natural assimilative capability of the environment. Then,

$$\frac{dD}{dt} = \frac{1}{V} W - h I_r - \delta \qquad \dots (2)$$

where h is a coefficient reflecting the rate of augmentation of the natural assimilative capability of the environment by capital investments as previously described. Now, we shall assume, K does not depreciate though the model could easily be made to accommodate instantaneous and constant decay rates in K_r From eqn. (1) and (2) we obtain simple expression relating changes in waste density to investment in assimilative capability, current saving and output.

$$\frac{dD}{dt} = \frac{1}{V} (g_c+g_f)F - \frac{1}{V} g_c S - hI_r - \delta \qquad \dots (3)$$

Note from eqn. (3) that even if current saving and investment in augmenting the environment's assimilative capacity are both zero, there is a positive rate of output which would yield no increase or decrease in waste density. In ecologist's terms, this is a natural rate of production which, at least hypothetically, balances man's proclivity to produce waste with nature's ability to absorb it—a biological equilibrium.

To complete this simple model, let us define K_f as the nondepreciating capital stock devoted to producing material output s as the marginal and average propensity to save from output, and σ as the incremental output-capital ratio. Then,

$$sF = S = I_f + I_r \qquad \dots (4)$$

$$\frac{dF}{dt} = \sigma I_f \qquad \dots (5)$$

with $dK_f/dt = I_f$ On substitution of eqn. (5) into (4), the connection between this model and the Harrod-Domar model is observed :

$$\frac{1}{F} \frac{dF}{dt} = G_f = s\sigma - \sigma (I_r/F) \qquad \dots (6)$$

Thus, if investment in non-productive waste assimilation is not undertaken, one ends up with a warranted rate of growth (G_f) equivalent to $S\sigma$. Such a rate would be warranted if the natural environment could be characterized as limitless in capacity or size and in regenerative capability. Substituting eqn. (6) and (4) into (3) and with rearrangement of terms, one obtains :

$$\left[\frac{g_c}{V} (1-s) + \frac{g_f}{V} - h_s\right] F + \frac{h}{\sigma} \frac{dF}{dt} - \delta = \frac{dD}{dt} \qquad \dots (7)$$

In order to obtain a warranted rate of growth, the constraint is postulated of *no* change in average waste density, i.e. $dD/dt=0$ Such a constraint *might not* be desirable in that variations in waste density over time may yield greater welfare and (or) less disutility associated with waste flows. However, in terms of the model proposed here it seems preferable to presume a "steady state" in terms of environmental degradation via waste flows. Such a steady state could proceed without the hindrance of a finite planning interval for man's survival or the philosophical contradiction between finite resources and an infinite planning horizon. It should be pointed out, however, that the following references to a warranted rate of growth presume not only a non-deteriorating natural environment but also one that is not allowed to improve either. With the assumption $dD/dt=0$, eqn. (7) becomes a first order non-homogeneous linear differential equation of the form:

$$\frac{dF}{dt} + \propto F - \eta = o$$

and

$$\propto = \sigma\left[\frac{g_c}{hV} (1-s) + \frac{g_f}{hV} - s \right]$$

$$\eta = \frac{\sigma\delta}{h}$$

which has a solution

$$F(t) = He^{-\propto t} + n/\propto \qquad \ldots \quad (9)$$

where H is a constant determined by initial conditions. Given the assumption that $H > 0$, *for output to increase over time*, $\propto < 0$ or $sh > gc/V\ (1\text{-}s) + g_f/V$. This simply indicates saving rates and the efficiency of investment to reduce waste density must be high enough to compensate for the wastes generated through consumption and production. As would be expected, the greater the saving rate, efficiency of investment in the natural environment's assimilative capability, size or extent of the natural environment, and the smaller the amount of waste generated per unit of output and consumption, the more likely a sustainable positive rate of growth would be which would not simultaneously involve an increasing waste density. The incremental output-capital ratio alternatively is neutral, either accelerating the rate of growth in output if the warranted rate is positive or increasing the negative change in output toward the biological equilibrium.

In order to give some empirical content to the meaning of a warranted positive or negative change in output, let us redefine the h coefficient, which connects reduction in waste density to assimilative investment, in terms of waste magnitude, i.e., $h' = h.V$ where h' denotes the reduction in waste tonnage polluting the environment per doller of assimilative investment. Next, let the savings rate equal 0.20 and the sum of g_c and g_f equal 6 pounds. The latter is consistent with the estimate for the United States. Then the criterion for a positive rate of growth in output is $h' > 30—g_c$ In other words, if pounds of waste generated per doller of consumption expenditure equal two, then an average dollar of investment in waste assimilative capacity must yield at minimum a reduction of twenty-eight pounds in terms of waste density. The efficiency of waste assimilative investments must be substantially greater for lower savings rates. Lowering the rate to 0.10 requires investments in waste assimilation via augmenting the natural environment to rise to fifty-eight pounds per dollar of investment.

Viable Economics needed

With the foregoing mathematical calculations and formulations and the discussion of the problem of the economics, ecology and environment, we very well have understood that the complexity of the problem cannot be solved by old economics. A new ecological viable economics has to be born for this purpose. The modern industrial economy based on resources need be brought in, instead of the old one where inputs are only mass and energy. Recycling of wastes, and taking into consideration these new constraints should be the basis of new economics. Both micro and macroeconomical concept should be revolutionised. The environmental quality management must involve analysis of what might be called dynamic or time related externalities—the impact of ignoring the discrepancies between private and social costs by one generation on the economic choices of subsequent generations.

Environmental Quality Requirements

Finally, let us try to answer the following questions: What do the people want? How much of other things are they willing to give up to enjoy these benefits of nature? Do we accept the idea that people's judgement truly reflect their welfare? If we could answer these questions truly and correctly the problem would become easier.

How much should be spent on environmental improvement? No transcendental guidance exists for this question. The economic guide that indicates a **minimum environmental quality control level** can be specified as those standards that yield maximum GNP net of environmental control costs. Apart from the facts that we have little information that relates environmental quality to GNP, **This guide cannot be followed** because it excludes aesthetic factor, **i.e.** consumer's preference over high quality environment at the expense of other goods and services.

Wohlman (1) has pointedly said "We should ask overselves whether we want it (quality of environment) badly enough to pay for it. The costs are not likely to be great as to affect the necessities. The debate will be over the kind of luxuries we want." Yesterday's economics was preoccupied with the need of widespread distribution of necessities.

Outlays on environmental improvement not only yield direct satisfaction but absorb resources that, if used otherwise, could contribute to environmental decay.

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Intestinal Parasitic Infections associated with Sewage Farm Workers with special reference to Helminths and Protozoa

K. P. KRISHNAMOORTHI,* M. K. ABDULAPPA* and A. K. ANWIKAR*

There are 132 sewage farms in India covering approximately 12,000 ha (30,000 acres) and utilising one mil cu m/day (223 mgd) of sewage. Normally, sewage farm workers do not use any boots, gloves and, therefore, are exposed to health hazards.

Studies have been undertaken on an all Indian basis to survey the health status of sewage farm workers and also a control population of similar economic status which does not have contact with sewage. These included the examination of stool samples from the farm workers and control population for protozoan parasites, cysts and helminthic eggs and their clinical examination. In all, 466 stool samples of sewage farm workers and 432 samples from the control population were analysed, using different methods of concentration technique.

It was observed that the incidence and multiplicity of infection clearly illustrates the health hazard involved in handling of sewage.

Introduction

Sewage farming is practised in India by using mostly raw sewage or diluted sewage and sometimes partially treated sewage. But in majority of the cities and towns mostly raw sewage is used as an irrigant for sewage farming. The municipalities and corporations get a substantial revenue by this process of land disposal of sewage. Irrigation of land with raw, diluted or treated sewage involves grave health hazards to the workers. Sewage harbours a variety of intestinal parasitic protozoans, cysts, helminthic eggs in addition to pathogenic bacteria and viruses which are known to cause a variety of intestinal diseases in man. Most of the above organisms are not completely eliminated by any of the sewage treatment methods. Therefore, the problem of using raw sewage as a source of irrigant for sewage farming is all the more hazardous for the workers in the farms.

There are 132 sewage farms in India covering approximately 12,000 ha (30,000 acres) and utilising one million cubic meters (223 mil gal) of sewage per day. Normally, sewage farm workers do not use any boots, gloves and therefore are exposed to great hazards. Unfortunately they are not given any periodical medical check up also.

It is felt in U.K. that properly managed sewage farm would not give rise to any parasitic infection amongst the workers in the farm. However, the public health authorities of California, USA prohibit the use of raw sewage for sewage farming. Attempts have been made in India by Patel (1) and Kabir (2) to evaluate the health status of the sewage farm workers of the Ahmedabad

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* Scientists, Central Public Health Engineering Research Institute, Nagpur 440020

and Madurai sewage farms respectively using raw sewage as an irrigant. These investigators have done the clinical examination of the sewage farms workers and the stool sample analysis and the results were compared with similar studies of the control groups of identical socio-economic environment. The studies showed high morbidity and high extent of helminthic infection among the sewage farm population as compared to that of control population.

With the above background in mind, studies have been undertaken on an all India basis to survey the health status of sewage farm workers and also a control population of similar economic status which does not have contact with sewage.

So far, workers at five big sewage farms in the country, **viz.** (i) North and South sewage farm at Jaipur (20 and 35 acres using 0.7 mgd and 2 mgd of raw sewage respectively), (ii) Kodungaiyur sewage farm at Madras (328 acres using 1.5 mgd of raw sewage), (iii) Amberpeth sewage at Hyderabad (1500 acres using 18 mgd of sewage available by septic tank treatment and partial dilution), (iv) Valiyathura sewage farm at Trivandrum (using partially diluted sewage) and (v) Manjari and Hadapsar sewage farms at Poona (45 and 32 acres using diluted sewage and raw sewage respectively) have been studied in detail.

These studies included the examination of stools sample from the farm workers and control population for protozoan parasites, cysts and helminthic eggs and their clinical examination.

This paper describes details of the stool examination in relation to intestinal parasitic infection.

Material and Methods

The above sewage farms were visited during 1970-72. A control population was selected having the same socio-economic condition. The workers in the sewage farm and the control population were classified in accordance with their age, sex and occupation and experience in the farm and recorded in the proforma. Differentially numbered sample tubes of 3 in. x 1 in. size corked with an aluminium scoop were supplied to the farm workers and as well as to the control population preferably in the evening. The stool sample tubes were collected in the succeeding mornings and were transported to the laboratory for analysis. Standard proforma used for the stool examination is given on next page. Physical nature of the stool like colour and consistency were recorded. The examination of the stool for protozoan cysts and helminthic eggs were done at once following the flotation technique and smear technique given in the proforma.

The technique using formal ether followed by iodine smear gave good and reproduceable results. Negative samples were examined more than once. The presence and intensity of parasites in the stool samples were recorded using +, ++ & +++ symbols indicating a rare, common and heavy infection, respectively (being used normally by all parasitologists). As far as the sewage farm was concerned, trial was made to cover the entire population of the workers as much as possible and in the control population where lots of difficulties were experienced in getting the stools sample the control population was divided in various sectors and for each sector a 10% population of the sample was examined for stool examination.

Observations

Stool samples were examined for *Ancylostoma duodenale* (hookworm), *Ascaris lubbricoides* (round worm), *Trichuris trichura* (whip worm), *Enterobius vermicularis* (pin worm), *Hymenolepis nana* (drawf tapeworm), *Entamoeba histolytica,* and *Giardia intestinalis.* The results obtained using different methods of concentration techniques regarding the incidence and multiplicity of infection of the above parasites in all the five sewage farms and the control population is given in the respective tables with all details. In all, 466 samples of stool specimen of sewage farm workers and 432 samples from the control population were analysed. *Ascaris lumbricoides* (round worm) and

PROFORMA

Record of Parasitological Findings

(Stool specimen)

1. Name of the patient :
2. Our Ref No.

Date of collection........................ Time.............. Date of examination................. Time........

3. Physical appearance of the stool

(i) Consistency: Fluid.................................Semifluid..................... Solid...........................

(i) Colour........................ Blood.......................... Mucus..........................

4. Methods used : ( ) 1. Direct Microscopic examination

( ) 2. Concentration by floatation technique

( ) a. Zinc sulphate
( ) b. Salt
( ) c. Formol ether

( ) 3. Stained smears

( ) a. Iodine
( ) b. Iron haematoxylin

5. **Parasites found:**

Protozoan cysts	( )	**Helminthis eggs/larvae**	( )
E. histolytica	( )	**Ascaris lumbricoides**	( )
Giardia intestinalis	( )	**Ancylostoma duodenale** (hook worms)	( )
E. coli	( )	**Strongyloides stercoralis**	( )
Endolimax nana	( )	**Trichuris trichura** (whip worm)	( )
Iodamoeba butschlii	( )	**Enterobius vermicularis** (pin worm)	( )
Dientamoeba fragilis	( )	**Taenia** **Hymenolepis**	( ) ( )

Parasite density : +, ++, +++
General remarks :

Signature of Investigator

Ancylostoma duodenale (hook worm) are the most dominant parasites in the sewage farm workers. *E. histolytica* dominates among the protozoan parasites. It was observed that the incidence and multiplicity of infection are far more in the sewage farm population than in the control group (very well illustrated in Trivandrum and Poona sewage farms). In the control population multiplicity of infection was confined to a combination of two parasites whereas in the sewage farm group it ranges from 2 to 5 parasites. More than the incidence, the multiplicity and intensity of infection were very predominant in the sewage farm workers than the control group (Table LIX), which clearly indicate the health hazard in handling sewage and exposure for long times.

Discussion

Mostly helminthiasis is acquired by the introduction of infective stage eggs or larvae

TABLE I—OCCURRENCE OF INTESTINAL PARASITES IN FARM WORKERS OF JAIPUR (INDIA) SEWAGE FARM AND CONTROL VILLAGE

Name of the Parasites			Sewage Farm		Control	
1	2	3	No.	%	No.	%
Ascaris	—	—	15	20.0	10	17.2
Ancylostoma	—	—	16	21.3	19	32.8
Hymenolepis	—	—			1	1.7
E. histolytica	—	—	7	9.8	8	13.7
Ancylostoma	Ascaris	—	21	28.2	9	13.8
Ascaris	E. histolytica	—	4	5.5	1	1.7
Ancylostoma	E. Histolytica	—	2	2.7	2	3.5
Ancylostoma	Giardia	—	1	1.4	—	—
E. histolytica	E. Coli	—	1	1.4		
Enterobious	Ascaris	—	—	—	1	1.7
Ancylostoma	Hymenolepis	—	—	—	2	3.5
Ascaris	Hymenolepis	—	—	—	2	3.5
Ancylostoma	E. Coli	—	—	—	1	1.7
Ancylostoma	Enterobious	—	—	—	1	1.7
E. histolytica	Giardia	—	—	—	1	1.7
Ancylostoma	Ascaris	E. Coli	1	1.4	—	—
E. Histolytica	E. Coli	Giardia	1	1.4	—	—
Ascaris	E. histolytica	E. Coli	1	1.4	—	—
Ancylostoma	Ascaris	Giardia	1	1.4	—	—
Ancylostoma	Ascaris	E. histolytica	2	2.7	1	1.7
Ancylostoma	Hymenolepis	Ascaris	1	1.4		
Positive			74	79.3	59	54.2
Total			92		107	

TABLE II—OCCURRENCE OF INTESTINAL PARASITES IN FARM WORKERS OF KODUNGAIYUR (MADRAS STATE, INDIA) SEWAGE FARM AND CONTROL VILLAGE.

Name of the Parasites				Kodyngaiyur		Control	
1	2	3	4	No.	%	No.	%
Ancylostoma	—	—	—	44	38.8	42	47.3
Ascaris	—	—	—	10	8.9	9	10.3
Trichuris	—	—	—	2	1.7	—	—
E. coli	—	—	—	2	1.7	—	—
Ancylostoma	E. histolytica	—	—	3	2.8	—	—
Ancylostoma	Ascaris	—	—	11	9.8	5	5.6
Ancylostoma	Enterobious	—	—	1	0.8	1	1.1
Ancylostoma	Trichuris	—	—	5	4.4	4	4.4
Ancylostoma	E. coli	—	—	4	3.5	—	—
E. histolytica	E. coli	—	—	1	0.8	—	—
Ascaris	E. histolytica	—	—	1	0.8	—	—
Ascaris	Trichuris	—	—	1	0.8	—	—
Ascaris	Strongyloides	—	—	—	—	1	1.1
Ancylostoma	Ascaris	Trichuris	—	9	7.9	3	3.3
Ancylostoma	Hymenolepis	Trichuris	—	1	0.8	—	—
Ancylostoma	Ascaris	E. coli	—	5	4.4	—	—
Ancylostoma	Ascaris	E. histolytica	—	2	1.7	—	—
Ancylostoma	Trichuris	E. coli	—	2	1.7	—	—
Ancylostoma	E. histolytica	E. coli	Giardia	1	0.8	—	—
Ancylostoma	Ascaris	Trichuris	E. coli	4	3.5	—	—
Ascaris	Hymenolepis	Enterobious	E. coli	1	0.8	—	—
Positive				110	96.5	65	75.2
Total				114		89	

TABLE III—OCCURRENCE OF INTESTINAL PARASITES IN FARM WORKERS OF AMBERPETH, HYDERABAD, INDIA, SEWAGE FARM AND CONTROL VILLAGE

Name of the Parasites					Amberpeth		Control (Jaipur)	
1	2	3	4	5	No.	%	No.	%
Ancylostoma	—	—	—	—	37	24.3	22	20
Ascaris	—	—	—	—	6	3.9	—	—
Hymenolepis	—	—	—	—	—	—	1	0.9
E. histolytica	—	—	—	—	6	3.9	14	12.9
E. coli	—	—	—	—	2	1.3	6	5.4
Hymenolepis	E. coli	—	—	—	1	0.6	—	—
Ancylostoma	E. histolytica	—	—	—	9	5.9	6	5.4
E. histolytica	E. coli	—	—	—	4	2.6	—	—
Ascaris	E. histolytica	—	—	—	2	1.3	—	—
Ancylostoma	Ascaris	—	—	—	19	12.4	—	—
Ancylostoma	E. coli	—	—	—	2	1.3	2	1.8
Ascaris	Trichuris	—	—	—	1	0.6	1	0.9
Ancylostoma	Hymenolepis	—	—	—	1	0.6	1	0.9
Ancylostoma	Trichuris	—	—	—	1	0.6	—	—
Ancylostoma	Trichuris	E. coli	—	—	1	0.6	—	—
Ancylostoma	Ascaris	Trichuris	—	—	1	0.6	—	—
Ancylostoma	Trichuris	E. histolytica	—	—	1	0.6	—	—
Ancylostoma	Ascaris	E. histolytica	—	—	5	3.2	—	—
Ancylostoma	E. histolytica	E. coli	—	—	10	6.6	2	1.8
Ascaris	E. histolytica	Giardia	—	—	1	0.6	—	—
Ascaris	E. histolytica	E. coli	—	—	4	2.6	—	—
Ascaris	Enterobious	E. histolytica	E. coli	—	1	0.6	—	—
Ancylostoma	Ascaris	E. histolytica	E. coli	—	3	1.9	—	—
Ancylostoma	Ascaris	Trichuris	E. histolytica	E. coli	1	0.6	—	—
Positive					119	77.2	55	50
Total					154		110	

TABLE IV—OCCURRENCE OF INTESTINAL PARASITES IN FARM WORKERS OF TRIVANDRUM (INDIA) SEWAGE FARM AND CONTROL VILLAGE

Name of the Parasites					Farm		Control	
1	2	3	4	5	No.	%	No.	%
Ascaris	—	—	—	—	—	—	6	8.8
Ancylostoma					—	—	1	1.4
Trichuris					—	—	1	1.4
Ascaris	Ancylostoma	—			2	3.3	4	5.8
Ancylostoma	Trichuris				5	7.5	—	—
Ascaris	Trichuris				—	—	2	2.8
Ascaris	E. histolytica				—	—	1	1.4
Ascaris	Ancylostoma	Trichuris			44	66	2	2.8
Ascaris	Trichuris	E. histolytica			—	—	3	4.3
Ascaris	Ancylostoma	E. histolytica			—	—	2	2.8
Ascaris	Ancylostoma	E. histolytica	E. coli		–	—	1	1.4
Ascaris	Ancylostoma	Trichuris	E. histolytica		6	9	—	—
Ascaris	Ancylostoma	Trichuris	E. coli		2	3	—	—
Ascaris	Ancylostoma	Trichuris	Enterobious		1	1.5	—	—
Ascaris	Ancylostoma	Trichuris	E. histolytica+	Strongeloides	4	6	—	—
Ascaris	Ancylostoma	Trichuris	E. histolytica	E. coli	2	3	—	—
Postive					66	100	23	32.9
Total					66		70	

TABLE V—OCCURRENCE OF INTESTINAL PARASITES IN FARM WORKERS OF POONA SEWAGE FARM AND CONTROL GROUP

Name of the parasite	Sewage Farm		Control group	
	No.	%	No.	%
Ascaris lumbricoides	—	—	3	5.3
Ancylostoma duodenale	1	2.5	8	14.3
Hymenolepis nana	1	2.5	1	1.8
Ancylostoma + Ascaris	27	67.5	1	1.8
Ascaris + E. histolytica	—	—	—	—
Ancylostoma + E. histolytica	1	2.5	—	—
Ancylostoma + trichuris	1	2.5	—	—
Ancylostoma + Ascaris + E. coli	2	5.0	—	—
Ascaris + Ancylostoma + trichuris	2	5.0	—	—
Ascaris + Ancylostoma + E. histolytica	2	5.0	—	—
Positive	37	92.5	13	23.2
Total	40		56	

TABLE VI—JAIPUR SEWAGE FARM—INTENSITY OF INFECTION

Name of the parasites	Sewage Farm Group							Control Group						
		+		++		+++			+		++		+++	
	Total	No.	%	No.	%	No.	%	Total	No.	%	No.	%	No.	%
Ancylostoma duodenale	45	22	49	16	35.5	7	15.5	34	20	58.8	6	17.6	8	23
Ascaris lumbricodes	46	8	17.5	12	26	26	56.5	23	14	60.9	3	13.1	6	26
Hymenolepis nana	1	1	100	—	—	—	—	5	3	60	—	—	2	40
Enterobious vermicularis	—	—	—	—	—	—	—	2	1	50	—	—	1	50
E. histolytica	16	11	68.7	2	12.5	3	18.8	13	9	69.2	4	30.8	—	—
E. coli	4	2	50	2	50	—	—	1	1	100	—	—	—	—
Giardia lamblia	3	3	100	—	—	—	—	1	1	100	—	—	—	—

\+ Rare ++ Common +++ Heavy

TABLE VII—KODUNGAIYUR SEWAGE FARM, MADRAS—INTENSITY OF INFECTION

Name of the organism	Sewage Farm Group						Control Group					
	+		++		+++		+		++		+++	
	No.	%	No	%	No.	%	No.	%	No.	%	No.	%
Ancylostoma	39	42.4	30	32.6	23	25	45	81.3	7	13.2	3	5.5
Ascaris	20	46.5	10	23.25	13	30.25	16	80	—	—	4	20
Trichuris	17	70.8	6	25.0	1	4.2	7	77.7	2	22.3	—	—
Enterobious	1	50	1	50	—	—	1	100	—	—	—	—
Hymenolepis	2	100	—	—	—	—	—	—	—	—	—	—
Strongyloides	—	—	—	—	—	—	1	100	—	—	—	—
E. histolytica	5	62.5	1	12.5	2	25	—	—	—	—	—	—
E. coli	17	85	2	10	1	5	—	—	—	—	—	—
Giardia	1	100	—	—	—	—	—	—	—	—	—	—

TABLE VIII—AMBERPETH SEWAGE FARM, HYDERABAD INTENSITY OF INFECTION

	Sewage Farm Group							Control Group						
		+		++		+++			+		++		+++	
Name of the parasites	Total	No.	%	No.	%	No.	%	Total	No.	%	No.	%	No.	%
Ancylostoma duodenale	91	42	46.3	26	28.5	23	25.2	33	28	84.8	5	15.2	—	—
Ascaris lumbricoides	44	6	13.6	15	34.0	23	52.4	1	—	—	—	—	1	100
Trichuris trichura	6	5	83.2	1	16.8	—		1	1		—	—	—	—
Hymenolepis nana	2	1	50	—	—	1	50	1	—	—	—	—	1	100
Enterobious vericularis	1	—	—	1	100	—	—							
E. histolytica	47	26	55.3	12	25.5	9	19.2	21	19	90.5	2	9.5	—	—
E. coli	29	21	72.5	5	17.2	3	10.3	11	9	81.9	2	18.1	—	—
Giardia	1	1	100	—	—	—	—	—	—	—	—	—	—	—

TABLE IX—INTENSITY OF INTESTINAL PARASITES IN SEWAGE FARM AND CONTROL GROUP, AT POONA

Name of the Parasites	Sewage Farm			Control Group		
	+	++	+++	+	++	+++
Ascaris	—	3	30	4	—	—
Ancylostoma	1	4	31	7	2	—
Hymenolepis	1	—	—	1	—	—
Trichuris	1	2	—	—	—	—
Entamoeba histolytica	2	—	—	—	—	—
Entamoeba Coli	1	—	1	—	—	—

into the digestive system. The incidence studies show the high prevalence of *Ascaris lumbricoides* (round worm) in the sewage farm which may be due to their resistance to unfavourable conditions like desiccation, low or high temperatures and putrification and also due to their ability to remain viable in the infective stage for a prolonged period. While Ascariasis is caused by the ingestion of ova, hook worm infection is due to the penetration of infective larvae through the skin, and the prodominance of Ancylostomiasis is due to their abundance in the sewage and the favourable conditions for development and infection. The incidence of infection in all the farms was found about 20 to 27% more than that of the control villages and can be attributed to the favourable environment provided in the farm by the application of sewage for propagation and development and also prolonged contacts of workers with sewage. The difference in incidence in Madurai is very significant as about 60% (2). It is mainly because of the omission of the most important groups of parasites namely protozoa (E.H.. etc.) and to a great extent the methodology adopted for stool examination. During the present investigations considerable infections of *E. histolytica* was seen in Jaipur, Madras and Hyderabad. Moreover the methods adopted in this survey for the enumeration of stool samples include more than one concentration method, smear and stain techniques so as to get almost all the parasites. The study also included estimation of protozoan parasites which are less pathogenic like *E. colt, Giardia, Endolimax. Iodamoeba* and *Dient* *amoeba.* The conditions in Jaipur were more or less same as those at Madurai where the workers stay inside the farms and hence have considerable exposure and infection whereas in Madras and Hyderabad, the workers stay outside the farm.

It is widely known that the environmental sanitation and personal hygiene are responsible for exposure to infection and its intensity and multiplicity. As far as sewage farm is concenred, it is apt to be a favourable environment for the development and propagation of intestinal parasites. As the environmental sanitary conditions in the control villages are not of the high order, the infections are quite prevalent in these areas also. Hence, to infer the detrimental effect of the use of sewage from the difference in incidence of infection disregarding the intensity and multiplicity will not be correct. The intensity of infection is caused by the exposure to hyperendemic conditions, repeated exposure to infective parasites or multiplication of parasites inside the system. Although the intensity of infection in Jaipur farm was not very significant, Madras, Hyderabad, Trivandrum and Poona farms showed considerable degree of infection. It is quite evident from the Tables that the control village had not even a single heavy infection, but as far as the sewage farm is concerned the constant exposure causes intense infection.

Multiplicity of infection is due to the repeated exposure to the environment with variety of parasites. As the mode of infection is different in different groups of parasites, the contact period and the opportunities available for the infection are important and the farm conditions favour all above conditions. Tables indicate that the multiplicity of infection in the sewage farms is very high to the tune of the combination of two to five parasites than the control villages where it is restricted to only two or three. It is evident that the high multiplicity of infection in the farm is result of the application of raw or partially treated sewage in the farm and constant exposure of workers. The partial treatment given to sewage in Hyderabad hardly had any effect on the removal of intestinal parasites.

Summary

1. Details of stool examination in relation to intestinal parasitic infection from workers and control population of five sewage farms in India are described in detail.

2. Stool samples were examined for ***Ancylostoma duodenale*** (hook worm), ***Ascaris lumbricoides*** (round worm), ***Trichuris trichura*** (whip worm), ***Enterobius vermicularis*** (pin worm), ***Hymenolepis nana*** (drawf tapeworm), ***E. histolytica*, and *Giardia intestinalis*.**

3. In all 466 samples of stool specimen of sewage farm workers and 432 samples from the control population were analysed, using different methods of concentration technique.

4. It was observed that the incidence and multiplicity of infection are far more in the sewage farm population than in the control group. In the control population multiplicity of infection was confined to a combination of two parasites whereas in the sewage farm group it ranges from two to five parasites. The significantly high rate of multiplicity of incidence of infection in the sewage farm group clearly illustrates the health hazard involved in handling of sewage.

Acknowledgement

Grateful thanks are due to the authorities of municipal corporations and the Department of Agriculture of Jaipur, Madras, Hyderabad, Trivandrum and Poona for providing all facilities for the work. Thanks are also due to the Superintendent of the respective sewage farms for all their help. Thanks are also due to officer-in-charge and staff of Jaipur, Madras and Hyderabad Zonal Laboratories of this Institute for all the cooperation and help extended by them from time to time. Grateful thanks are due to Shri A. Raman, Executive Engineer, Research Division, Kodungaiyur Research, Unit, Madras and his staff. The authors are also grateful to Dr. N. U. Rao, Scientist, Central

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PROC. SYMP. ON ENVIRONMENTAL POLLUTION (1973)

Sterilization of Water under Field Conditions

A. K. CHATTERJEE* and G. C. SRIVASTAVA*

The need for packed and instant water sterilization tablets was felt in field areas to cater for the needs of service personnel when they are deployed in terrain where facilities for filtered and disinfected water are lacking. Water sterilizing tablets have recently been developed at Defence Research & Development Establishment, Gwalior. Details of preparation and techniques are discussed in the paper. The observations are based on a comparative study relating to the efficacy of iodine compounds over chlorine compounds.

The disinfection property of the iodine water sterilizing tablet was studied and compared with halazone and sodium dichloroisocyanurate. Its effect on cysts; *E. histolytica, V. cholerae* **and other waterborne pathogenic organisms was studied. It was observed that the water sterilizing tablets have a high bactericidal and a slight amoebicidal activity. They, however, have no cysticidal activity.**

Introduction

The present practice of the disinfection of water supplies is to use chlorine as water sterilizing powder for bulk supplies and small containers like pakhals and chaguls and as halazone for the water bottle. Due to the instability of halazone in a hot and humid environment, the halazone tablets lose their efficiency leading to a failure of the process of chlorination. An investigation was, therefore, taken up on the preparation of a suitable substitute for the halazone tablets.

Besides chlorine, iodine is also highly germicidal in nature, being effective against bacteria, spores, viruses and fungi in water treatment. A concentration of 8 mg/l is considered sufficient to kill the vegetative forms and spores in 10 minutes. Iodine is more stable than chlorine and has been widely employed in the disinfection of skin, surgical and domestic equipment, catgut and sutures and water. The concentration of 8 mg/l for water treatment, recommended by Chang and Morris (1) appears to be high in comparison with the findings of Chambers *et al.*, (2) but it takes into account the fact that the sample of water may be of unknown and doubtful quality. The treated water will be pale down in colour and has been claimed to be acceptable without deiodination by Morris *et al.*(3) The paper describes: (i) the preparation of a stable iodine compound; and (ii) a comparative study of the biological properties of the iodine compound with those of halazone and dichloroisocyanuric acid which are recognised chlorinating agents for water. The complex polyiodides were chosen for the present investigation as they can be easily compounded into tablets with disodium dihydrogen pyrophosphate, the latter agent giving a slight acidity to the sample of water, thus ensuring the optimum condition for the germicidal activity of iodine.

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* Defence Research & Development Establishment, Gwalior-2 (M.P.)

Materials and Methods

The general method of preparation of the complex polyiodides with their properties has been described by Morris *et al.* (3) and the same method has been partly modified for potassium tetraglycine tri-iodide. This compound was selected in preference to tetraglycine hydroperiodide, aluminium hexaurea sulphate trio-iodide and aluminium hexaurea dinitrate tri-iodide on account of its ease of preparation and high solubility in water.

(i) *Preparation of Potassium Tetraglycine tri-iodide*

Iodine (25.4 g) was slowly added with shaking to a solution of potassium iodide (16.6 g) in distilled water (10 ml). Stirring was continued till the iodine dissolved. To the dark brown solution thus obtained, a solution of glycine (30 g) in distilled water (120 ml) was quickly added with continuous stirring. After the addition was complete, stirring was continued for 30 min more at 20°C when the polyiodide separated. It was filtered off and washed with chloroform to remove the adhering elemental iodine and finally dried in the desiccator. Yield—17 g; Iodine—34.0%.

(ii) *Preparation of the Tablets*

Tablets with an average weight of 100 mg were prepared from a mixture of disodium dihydrogen pyrophosphate (7.0 g) and potassium tetraglycine tri-iodide (3.0 g).

Each tablet (containing 48 mg of the active polyiodide) liberated 9 mg of iodine when dissolved in 1100 ml of water (the volume of a water bottle) under vigorous agitation.

(iii) *Halazone & Dichloroisocyanuric Acid*

Both were obtained as 50 mg tablets from commercial sources. One tablet of halazone in a quart of water gave an immediate concentration of 4 mg/l of chlorine, while one tablet of dichloroisocyanuric acid in the same quantity of water produced an immediate concentration of 8.6 mg/l of chlorine.

Properties of the Tablets

(i) *Bactericidal*

One ml of a 24 hr broth culture was added to each of two flasks containing one litre of unchlorinated water and one tablet was added to each and dissolved by shaking. The action of iodine or chlorine was allowed to continue for 10 min in one flask and for 20 min in the other. At the end of the reaction period, the content of the flask was deiodinated by sodium thio-sulphate; 1 ml of the dehalogenated specimen was withdrawn and analysed for viable count. Suitable controls were kept. The results are recorded in the Table I.

TABLE I—BACTERICIDAL ACTIVITY OF THE WATER STERILISING TABLET (1 TABLET/LITRE OF WATER)

Sr.	Tablet	Nature of organism	Initial count	Viable count after contact for	
				10 min	20 min
1	Halazone	*E. coli*	158×10^5	16096	14299
			12×10^5	13825	12047
		S. typhi	118×10^5	16827	13509
			46×10^5	6932	4443
		S. faecalis	10×10^6	13983	20079
			35×10^6	27067	24226
2	Dichloroisocyanuric acid	*E. coli*	158×10^5	189	57
			12×10^5	2	0
		S. typhi	118×10^5	302	29
			46×10^5	0	0
		S. faecalis	10×10^6	5	4
			35×10^6	2	0
3	Potassium tetraglycine tri-iodide	*E. coli*	5×10^7	0	0

(ii) *Cysticidal*

The cysticidal property was studied using cysts of *S. russelli*, keeping the iodine concentration at 0.001 percent.

The cysts were kept in content with halazone for 18 hr. At the end of the contact period, 1 ml of the suspension was centrifuged, the sediment washed twice with sterile distilled water, stained with 0.125 percent eosine and the cysts observed for viability. The results are recorded in Table II.

(iii) *Amoebicidal*

A strain of *E. hsitolytica* was used for the study. The amoebae were allowed to grow in media at different iodine and chlorine concentrations for 48 hr and the growth was observed after this period. The results are indicated in Table III.

TABLE II—CYSTICIDAL ACTIVITY OF THE WATER STERILIZING TABLETS

Organism	Nature of compound	Concentration (%)	No. of cysts per field after contact	
			Viable	Dead
S. russelli	Potassium tetraglycine tri-iodide	0.001	33 40 73	0 0 0
	Halazone	0.0004	45 52 55	0 0 0
	Dichloroisocyanuric acid	0.00086	25 20 20	0 0 0

TABLE III—AMOEBICIDAL ACTIVITY OF THE WATER STERILIZING TABLETS

Organism	Nature of compound	No. of tablets used	Growth observed after 48 hr	
			Control	Test
E. histolytica	Potassium tetraglycine tri-iodide	1 tab/1000 ml	+++	++
		1 tab/2000 ml	+++	+++
		1 tab/4000 ml	+++	++++
		1 tab/8000 ml	+++	+++
	Halazone	1 tab/1000 ml	+++	+++
		1 tab/2000 ml	+++	+++
		1 tab/4000 ml	+++	+++
		1 tab/8000 ml	+++	+++
	Dichloroisocyanuric acid	1 tab/1000 ml	+++	+++
		1 tab/2000 ml	+++	+++
		1 tab/4000 ml	+++	+++
		1 tab/8000 ml	+++	+++

TABLE IV—VIBRIOCIDAL ACTIVITY OF THE WATER STERILIZING TABLETS

Organism	Nature of the compound	Concentration (mg/l)	Viable count after contact for						
			10 min	20 min	30 min	40 min	50 min	60 min	70 min
V. cholerae	Potassium tetraglycine tri-iodide	12.5	1	0	0	0	0	0	0
		25.0	0	0	0	0	0	0	0
		50.0	0	0	0	0	0	0	0
		100.0	0	0	0	0	0	0	0
		Control	∝	∝	∝	∝	∞	∝	∝
	Halazone	12.5		28000	91000	91000	91000	91000	70000
		25.0		14000	77000	77000	77000	77000	25000
		50.0		1750	52500	52500	52500	52500	52500
		100.0		525	7000	35000	35000	35000	35000
		Control		∝	∝	∝	∝	∝	∝
	Dichloroiso-cyanuric acid	12.5	0	0	0	0	0	0	0
		25.0	4	0	0	0	0	0	0
		50.0	0	0	0	0	0	0	0
		100.0	0	0	0	0	0	0	0
		Control	∝	∝	∝	∝	∝	∝	∝

(iv) *Vibriocidal*

One ml of a culture of *V. Cholerae* was added to solutions of iodine tablets at concentrations of iodine varying from 12.5 to 100 mg/l. The viable count was determined after a contact period of 10, 20, 30, 40, 50, 60 and 70 min. Suitable controls were kept. The results are recorded in Table IV.

Observations

The data in the Tables I to IV indicate that both the potassium tetraglycine tri-iodide and dicholoroisocyanuric acid tablets have high bactericidal activity and slight amoebicidal property. They, however, have no cysticidal activity. Halazone tablets are much inferior to the other two in activity.

Acknowledgement

The authors wish to express their thanks to Dr. C. N. Haksar, Officer-in-Charge (Retired) and Prof. Bal Krishna, Director, for their interest in the investigation. Thanks are also due to the Director, C.D.R.I., Lucknow for offering the facilities for studying the cysticidal, amoebicidal and vibriocidal property of the tablets.

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PROC. SYMP. ON ENVIRONMENTAL POLLUTION (1973)

The Application of *in vivo* Radioactivity Counting in Environmental Pollution Studies

R. K. HUKKOO,* D. S. KATOCH,* (Mrs.) T. SURENDRAN* and
S. SOMASUNDARAM*

In vivo radioactivity counting offers a direct, elegant and convenient means of studying the retention and turnover of radioactive tracers in humans and other living orgaisms. The paper presents a review of the various types of whole-body radioactivity counters which have been developed and their application to studies of environmental radioactive pollution, arising from nuclear weapons testing and operation of nuclear facilities. The systems which have been designed and fabricated in Bhabha Atomic Research Centre, Bombay and the significant results obtained in their use in environmental radioactive pollution studies are highlighted. The possible applications of these systems for elucidation of the metabolic behaviour of non-radioactive pollutants in humans and large farm animals, through suitable radioactive tracers, are discussed with a few illustrative examples.

Introduction

Environmental pollution is an undesirable by-product of industrial development and urban growth. Environmentalists have voiced their concern over the unabated injection of pollutants into our ecosystems. One of the functions of an environmental protection programme is to analyse the environment, identify and determine the levels of the pollutants and to establish the metabolic pathways, assimilation rates and sites of localization of these pollutants in respect of man. This study would give a deep insight into the problem of changing environment and how to avoid or mitigate the sources of pollution. As an aid to better understanding of the metabolic behaviour of pollutants, both active and non-active, *in vivo* counting has an important role to play by permitting studies about the retention and elimination rates of radiotracers and identifying their sites of localization. The paper reviews the present status of *in vivo* counting and delineates the areas of its application in environmental pollution studies.

Radiotracer Studies

The dispersion and transport of radioactive pollutants in the atmosphere and their subsequent assimilation by vegetation, food producing animals and finally the human beings have been widely studied. Extensive data are available on radioactive pollutants **viz.** Cs, Sr, Ba-La, Zn, Mn, Ce, Ru, Zr-Nb, Cr which have their origin from nuclear weapon testing. Useful biological information on human beings have been collected from accidental cases of inhalation/ingestion of radioisotopes at different nuclear plants. Some of the pollutants studied are Cs, Co, Se, Zn, U, Th, Am, Hg, Sb, Ac, Ra and W. In case of animals, the metabolic information is generated by administering a radioisotope of the element of interest. The elements studied include Hg, Zn, Pb, Cd, Mn and Fe.

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* Health Physics Division (BBMS), Bhabha Atomic Research Centre, Bombay-400001.

The study of the metabolic behaviour of non-radioactive pollutants requires the selection of a radioisotope, preferably of the same element or otherwise having similar chemical behaviour inside the human body. This radioisotope is then administered in trace quantity to the subject (human being/animal) and measurements are carried out to estimate the amount of tracer retained over a period of time.

In vivo Counting

The *in vivo* counting technique enables the assessment of the radioactive content of a living organism (human being/animal) directly without changing its physical shape, i.e. without destroying it. For such measurements one or several detectors are disposed externally around the body to detect the radiation emerging out of it. It is also possible with some systems to delineate the regions of the body having preferential absorption of the radiotracer. The technique is, however, restricted to radionuclides emitting penetrating radiation, e.g. X- or gamma rays. β -emitters can be detected through the associated bremsstrahlung radiation but the accuracy of estimation is generally not satisfactory. α -particles having short range in tissue, are totally absorbed by the overlying skin/muscle and are not detectable.

Urine and faecal analyses may provide information about the absorbed and unabsorbed fractions of the radionuclide in the GI tract. Blood analysis may give the absorption ratio between the plasma and blood cells. Tissue analysis may provide information on the relative distribution of the radionuclide in various tissues/organs of the body. *In vivo* counting, in combination with the above techniques, may enable us to obtain a complete understanding of the metabolism of various radionuclides in the body.

The need of a system giving accurate quantitative and qualitative information about internal contamination in man due to radioactive pollutants was felt towards the end of 1920's when luminous dial painters and patients injected with radioactivity showed signs of radioactive poisoning. Subsequently, the large scale injection of radioactive pollutants in our biosphere by nuclear weapon testing and the development of the nuclear industry led to the fast pace of development of *in vivo* counting systems, culminating in the present day highly sophisticated whole-body counters.

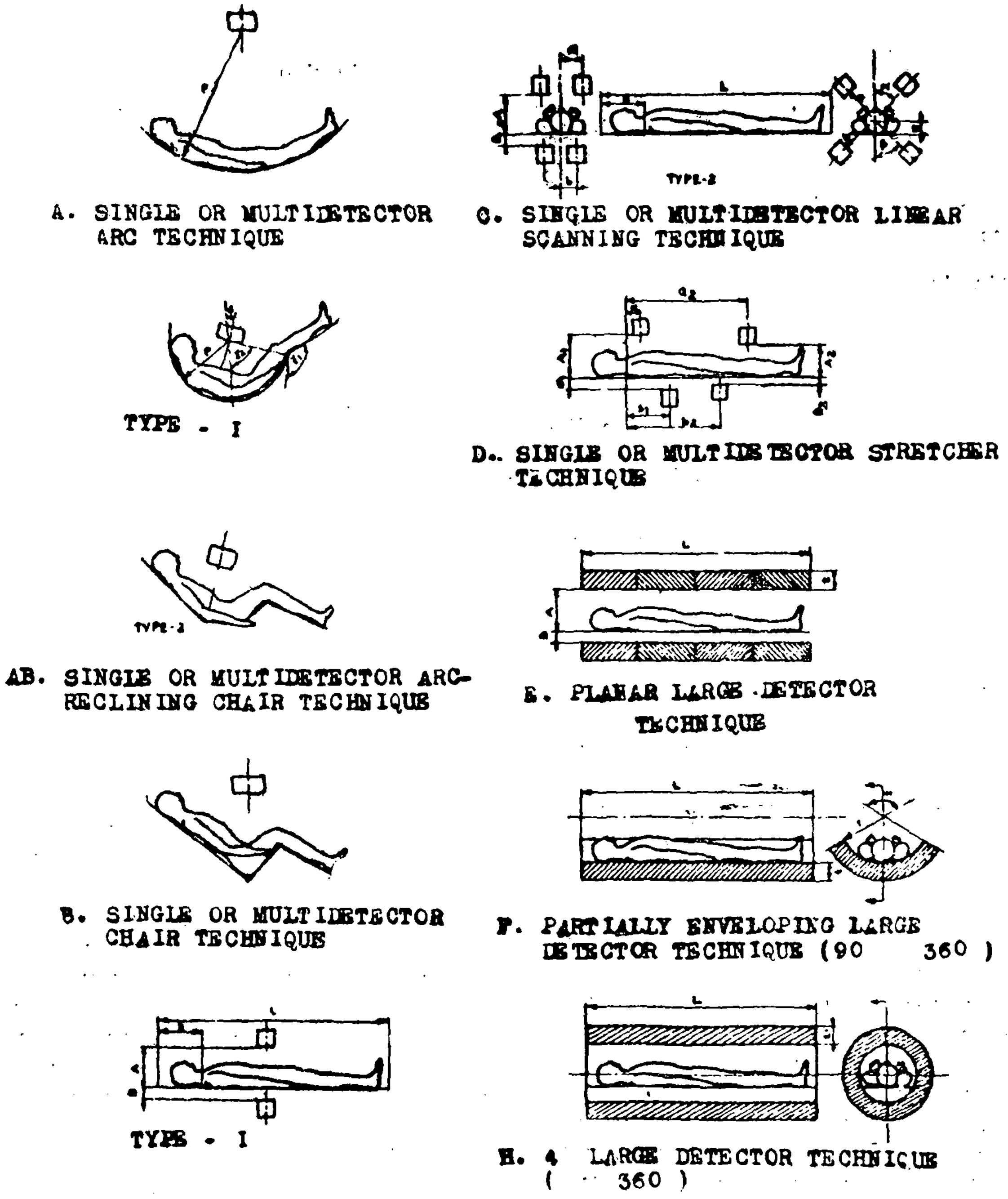
With the large scale availability of radioisotopes for clinical and metabolic investigations, a wide range of whole-body counters have been developed for both human beings and large animals. A short resume of the growth of whole body counting techniques for human beings is given below. The animal counters are not described. However, a few illustrative examples of their application in establishing the ecological pathways are given.

Requirements of Counting Geometry

It is worthwhile, at this stage, to enunciate the requirements of counting geometry for metabolic investigations. Because of the fact that in the majority of cases, the administered radioisotope may distribute inhomogeneously in the body and considerable redistribution may occur between measurements, it becomes necessary that the system yields a count rate which is independent of the location of the radionuclide in the body. The system should also have capabilities to yield radioactive profile for localization studies. The other desirable features are that the system should have high sensitivity of counting to avoid excessive radiation dose, the counting geometry should be comfortable and acceptable to the subject and it should be easy to operate. If the system is inexpensive, it would be an added advantage.

Types of whole-body counters

Fig. 1 shows the various types of whole-body counters developed so far (1). The "Arc-technique", Fig. 1—(A), with arc radius between 1-2 m has invariant response but the sensitivity is low because of the large distance between the detector and the subject. This difficulty is overcome in the "standard chair", Fig. 1—(B), where the detector face



A. SINGLE OR MULTIDETECTOR ARC TECHNIQUE

C. SINGLE OR MULTIDETECTOR LINEAR SCANNING TECHNIQUE

D. SINGLE OR MULTIDETECTOR STRETCHER TECHNIQUE

AB. SINGLE OR MULTIDETECTOR ARC-RECLINING CHAIR TECHNIQUE

E. PLANAR LARGE DETECTOR TECHNIQUE

B. SINGLE OR MULTIDETECTOR CHAIR TECHNIQUE

F. PARTIALLY ENVELOPING LARGE DETECTOR TECHNIQUE (90 360)

H. 4 LARGE DETECTOR TECHNIQUE (360)

Fig. 1—Commonly Used Geometries for Whole Body Counting

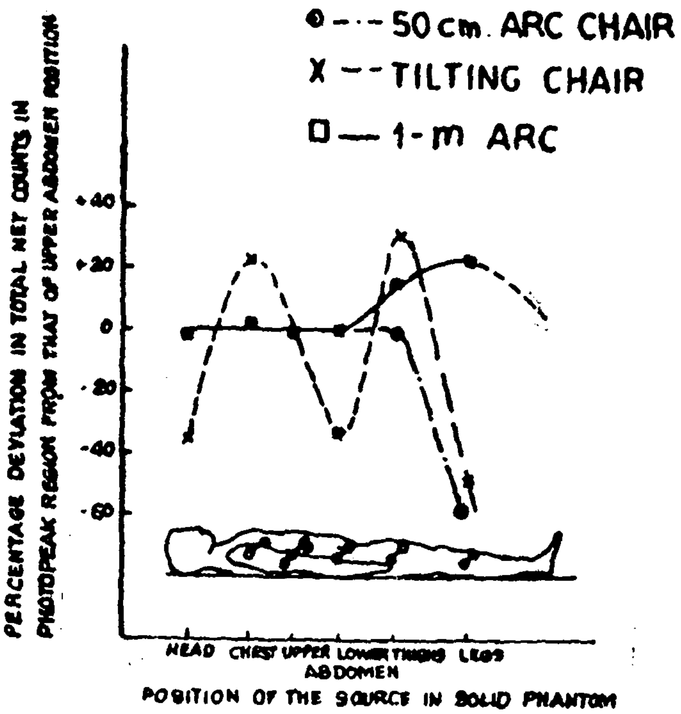
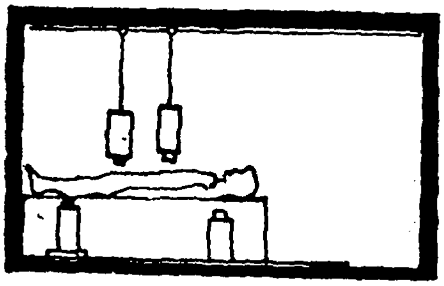


Fig. 2 (a)—Longitudinal Response of a 137 Cs Source in the three Geometries



COUNTING GEOMETRY

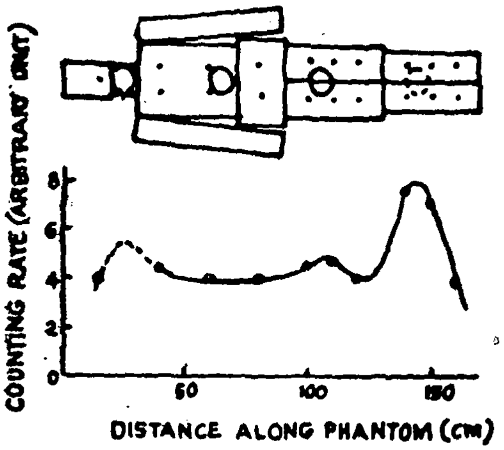


Fig. 2 (b)—Longitudinal Response of the Multi-detector Stretcher Geometry.

centre is about 42 cm from the backrest and seat of the chair, thereby increasing the sensitivity more than four times. The advantages of chair and arc techniques are brought together in arc reclining technique Fig. 1—(A B). Response variations for the movement of a point source along the longitudinal axis of the phantom for the above three techniques are shown in Fig. 2a (2).

In the stretcher system, Fig. 1—(D), one to four detectors are placed above and/or below the subject lying on the stretcher, and their position is adjusted by trial and error to achieve the desired compromise between sensitivity and response. The longitudinal response for one such system is shown in Fig. 2b. (3). In the scanning technique, Fig. 1 (C), the subject lying on a stretcher is scanned along the longitudinal axis by one or two detectors moving along this axis, thereby producing additional information about the distribution of radioactivity in the body, besides achieving good sensitivity and longitudinal response (Fig. 2—(C). (4).

Large area counters, Fig. 1—(EFH), using organic scintillators, have uniform response

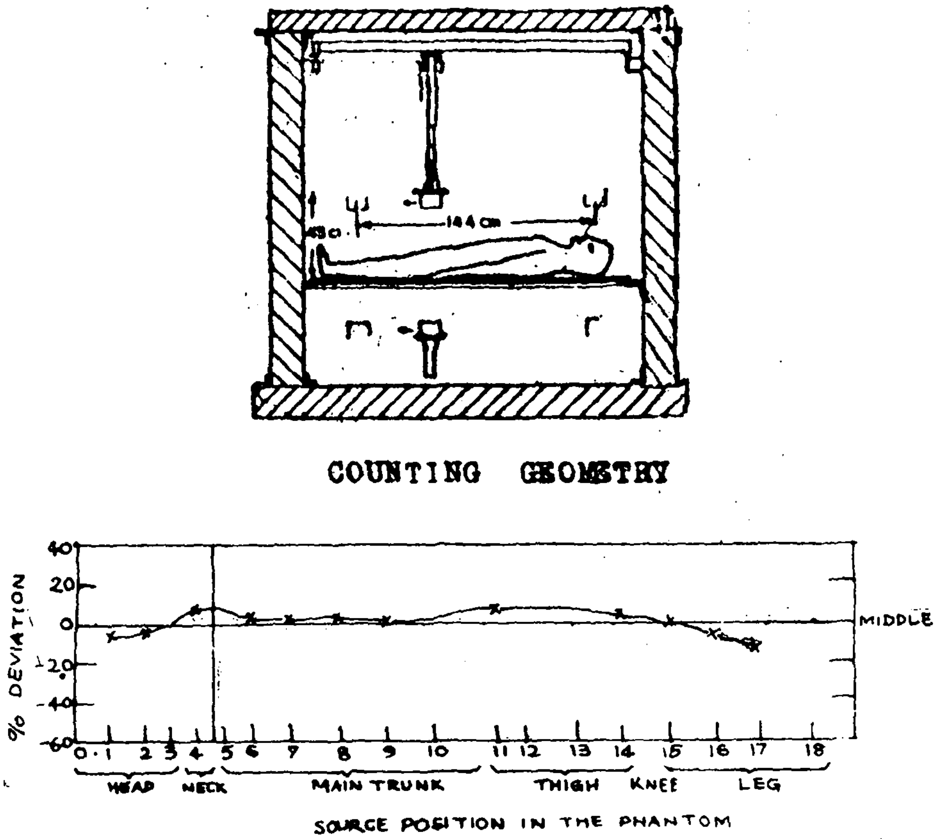


Fig. 2 (c)—Longitudinal Response for the Uncollimated Detector Scanning Geometry

and are 300 to 400 times more sensitive than the arc technique. To have the spectrometric advantage too a large area counter has been developed using 54 NaI (Tl) detectors of 15 cm diam x 15 cm thick.

Complex motion techniques, Fig. 3, commonly known as rotascan or heliscan, according to the relative motion of the subject and detector, are in principle equivalent to 4 π geometry with NaI (Tl) detectors, and provide precise information about distribution (1).

Systems Developed in Trombay

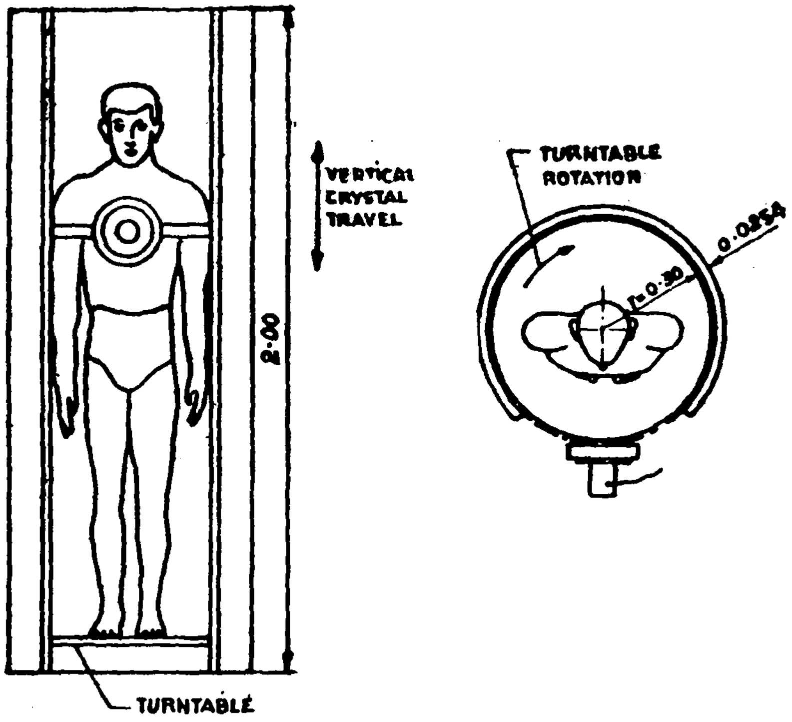
1. Total Shield System

For many geometrical and other studies requiring very low detection levels, it is necessary to minimize the external background by using a totally enclosing shield such as a steel room. The Trombay steel room (5) with inner dimensions of 8 ft x 6 ft x 6 ft has been built, using about 60 tons of mild steel in the form of ¼ in. thick plates stacked to a thickness of 8 in. The inner side is lined with 1/8 in. lead, and 1/6 in. stainless steel to reduce the lower energy component of the background.

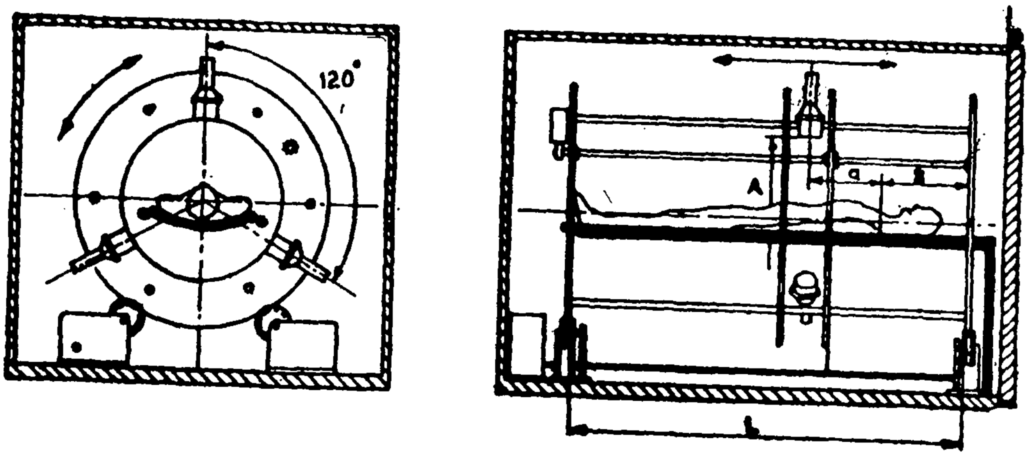
One metre arc, standard chair, 50 cm arc reclining chair and multidetector stretcher geometries have been studied and are in use at Trombay. The optimum position of the four 10.2 cm diam x 7.6 cm thick NaI (Tl) detectors used in multidetector stretcher system, for a desired value of one of the two parameters, viz. sensitivity and uniform longitudinal response over a particular length, can be calculated by a semi-empirical method using a computer (6).

2. Shielded Chair

The shielded chair counter, Fig. 4 is, in fact, a self-shielded chair geometry (7). The



ROTA-SCAN GEOMETRY



HELI-SCAN GEOMETRY

Fig. 3—Complex Motion Counting Geometries

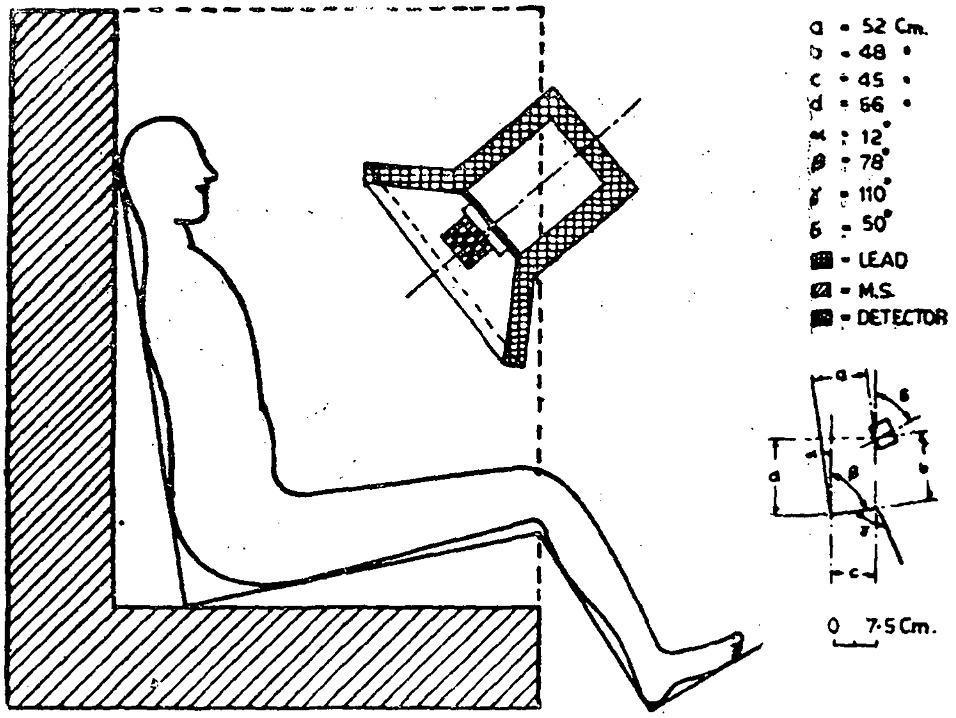


Fig. 4—Schematic Diagram of the Shielded Chair.

shield, weighing 4 tons, is arranged to a total thickness of 12.5 cm on all sides except the top and the front. The shield provides a seating place of 60 cm in width and 70 cm in depth and 100 cm in height. The detector, a 10.2 cm diam x 7.6 cm thick NaI (Tl) crystal with 3.7 cm lead shield, is mounted on a plate hinged to the side of the shielded chair frame. This system, though found useful for many investigations, does not provide any information about the distribution of the radioactive material.

3. Shadow Shield Scanner

Shadow shield is an arrangement of shield which prevents gamma photons other than from the subject, to reach the open face of the detector without passing through it (8). 12 mm (½ in.) thick mild steel plates of various sizes up to 24 in x 16 in., have been arranged in an interlocking manner and bolted together for stability, to provide a single detector scanner geometry as shown in Fig. 5. The shield tapers from 15 cm thickness at the centre to 3.6 cm at the ends. This effects a saving of nearly 1½ tons of shield material without compromising the effective shield thickness of 15 cm MS. The total weight of the shield is 4½ tons.

A 10.2 cm diam x 7.6 cm thick NaI (Tl) detector, shielded from all the sides except the face, looks at the subject lying on a motorised bed, that rolls over the top of the 12 ft long bottom shield to a maximum scanning length of 180 cm.

The static and dynamic response for a 137Cs point source moved along the longitudinal axis of the phantom is shown in Fig. 6. The range of uniform response represented by the flat portion in the dynamic response can be increased by increasing the scanning length. Table I gives the sensitivities for some of the gamma emitters along with the minimum detectable amount (MDA) and minimum measurable activity (MMA) which is the amount that can be detected with 1% statistical error in standard deviation. Background equivalent activity (BEA) is also given. These figures indicate that amounts far below the radioactive and chemical toxicity levels can be used as tracers in the metabolic studies.

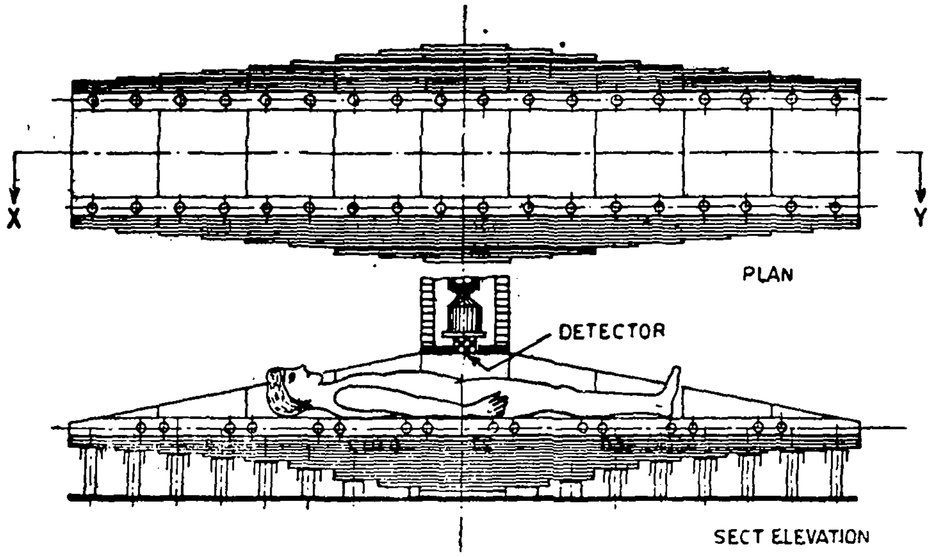


Fig. 5—Schematic Layout of Shadow Shield Whole Body Monitor.

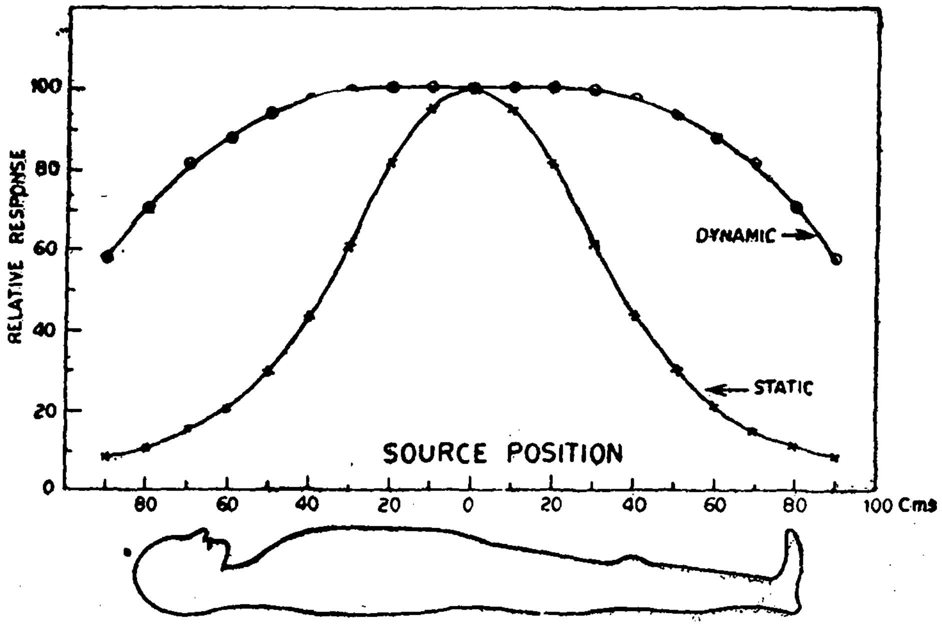


Fig. 6—Static and Dynamic Variation in Response for a 137 Cs Point Source Moved along the Longitudinal Axis of the Phantom. Response is Normalised at Mid-point of the axis.

Use of Whole Body Counter in Radioactive Pollution Studies

1. 137 Cs Content in General Public

Whole body counting of 10 normal subjects was done from 1962 to 1965 to estimate 137 Cs content and its increase in normal Indian adults (9). The average contents varied from 13.4 pCi/gmK for the year 1962 to 32.2 pCi/gmK for the year 1965. The increase by a factor of 2.5 was low compared to that of 5 to 10 obtained for man in USA with the average contents of 200 pCi/gmK in 1965. The low contents in Indian subjects are due to low fallout rate in this region and low consumption of dairy products, an important source of 137Cs.

TABLE I—COUNTING SENSITIVITIES FOR VARIOUS RADIOISOTOPES UNIFORMLY DISTRIBUTED IN PHANTOM

Radioisotope	Prominent Gamma energy (MeV)	Spectral Energy Band used (MeV)	Background count rate (cpm)	Counting sensitivity (cpm/μCi)	MMA* (μ) Ci)	MDA** (x10^{-3}μ Ci)	BEA*** μ Ci)
144Ce	0.140	0.080-0.200	445	1600	0.65	7.2	0.28
203Hg	0.280	0.190-0.350	358	1377	0.49	11.0	0.26
51Cr	0.322	0.250-0.375	199	206	4.2	52.0	0.97
131I	0.364	0.250-0.425	232	2025	0.45	5.6	0.11
103Ru	0.498	0.400-0.600	75	2675	0.18	1.8	0.028
137Cs	0.662	0.550-0.775	51	2110	0.20	1.8	0.024
58Co	0.810	0.700-0.925	26	1191	0.55	3.2	0.022
65Zn	1.120	0.980-1.210	18	815	0.45	2.8	0.022
59Fe	1.09	0.950-1.400	36	1010	0.66	4.4	0.036
60Co	1.29 1.77 1.33	1.030-1.460	27	0.012	2262	0.29	1.7

*MMA : Minimum measurable activity that can be measured with a statistical counting accuracy of 1% standard deviation (S.D.) for the counting period of 1000 seconds.

**MDA : Minimum detectable activity expressed as 3 S.D. in background counts for a counting period of 1000 seconds.

***BEA : Background equivalent activity.

TABLE II—RESULTS OF BODY BURDEN MEASUREMENTS AMONG THE COASTAL VILLAGERS(10)

Radionuclide nCi	0	1-9	10-19	20-29	30-39	40-49	50
134, 137Cs	—	87	27	10	—	—	1
60Co	22	61	20	10	6	4	2
58Co	29	89	6	—	1	—	—
131I	114	8	3	—	—	—	—

2. Radioactive Pollution in the vicinity of Nuclear Power Plants

The contents of radioactive pollutants discharged into the environment of Tarapur Atomic Power Station were estimated in 125 fishermen living close to the station (10). The results are shown in Table II. Thirty percent of those examined had total body contents more than 10 nCi and 82% had detectable radiocobalt. Sea water and sea food are the main sources of this internal contamination.

3. Profile Scanning

Fig. 7 shows the gamma-ray spectra of two individuals, (a) a radiation worker showing contamination due to 134Cs, 137Cs, 58Co, 60Co and 40K and (b) that of a non-occupational worker having 137Cs of nuclear weapon origin and 40K occuring naturally. Typical distribution profiles of two radiation workers contaminated with 60Co are shown in Fig. 8. The concentration of radionuclide

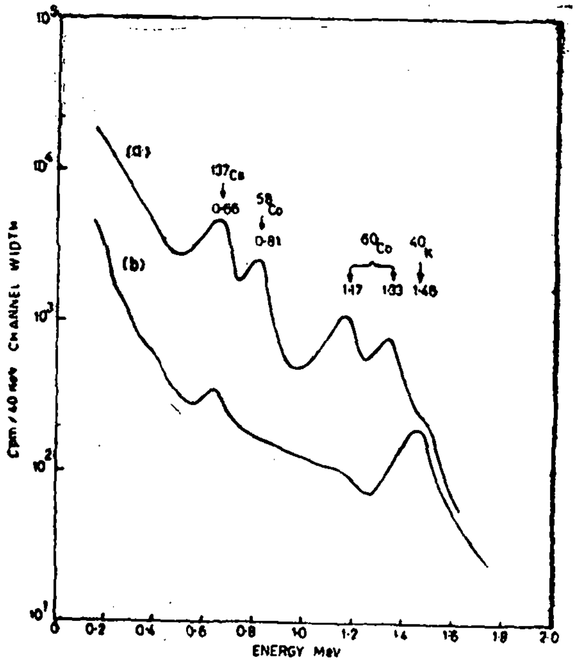


Fig. 7—Typical Gamma Spectrum of the Subjects
(a) With Internal Contamination
(b) Normal.

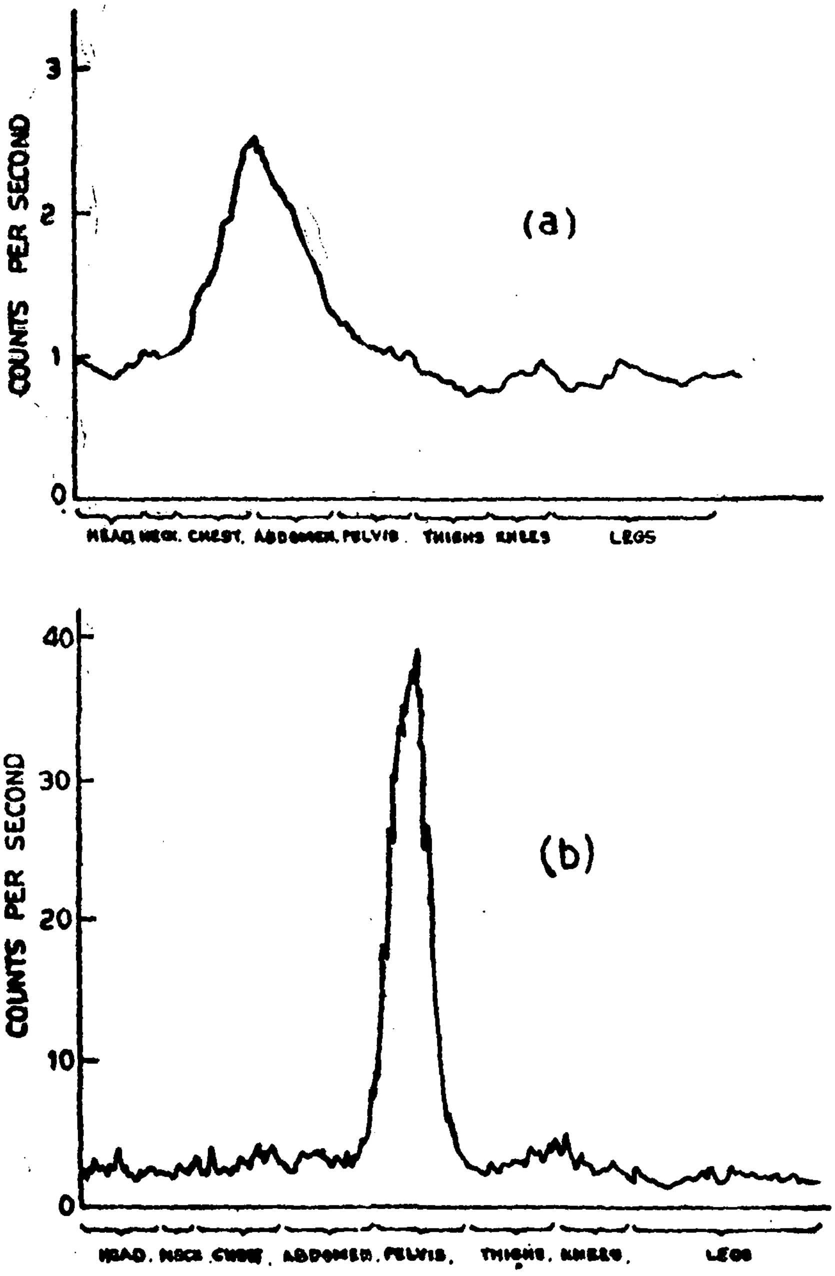


Fig. 8—Distribution Profiles of Co in Subjects of Suspected Contamination due to (a) Inhalation & (b) Ingestion.

in one case is over the chest region suggesting inhalation of pollutant being the main route of entry. In the other case the activity is lodged in lower abdomen or pelvis region, clearly a case of ingestion.

Radiotracer Techniques

Radiotracer techniques have been widely used to generate the data on biological pathways of stable elements in living organisms. Retention of heavy metals by human beings and aquatic organisms, particularly mercury, has been extensively studied because of its increasing importance as an environmental contaminant. The radiotracer technique requires labelling of animals (marine organisms) by feeding them with strongly-bound radiolabelled food. In case of human beings the tracer may be administered orally along with food. Total body or specific organ counting is carried out subsequently over a period of time to establish the sites of localization and excretion rates of label. A few of the published data are presented below:

1. Human Beings

Rahola *et al,* have studied the retention and elimination rates of mercury (elemental as well as protein-bound methyl mercury) and cadmium using the radiotracers 203 Hg and 115m Cd respectively (11). Radiotracers were administered orally (2-4 μ Ci) of Me 203Hg incorporated in fish muscle protein or 203Hg $(NO_3)_2$in water solution. In the case of Cd study, 5 μCi of protein bound 115m Cd containing 100 μ g elemental Cd was served in a calf-kidney suspension. Whole body counts were made to establish the biological half-lives of the tracers. Fig. 9a shows the retention of the labels in different subjects. The biological half-life of Me 203Hg activity was 69 days, while that of 203Hg was 41 days.

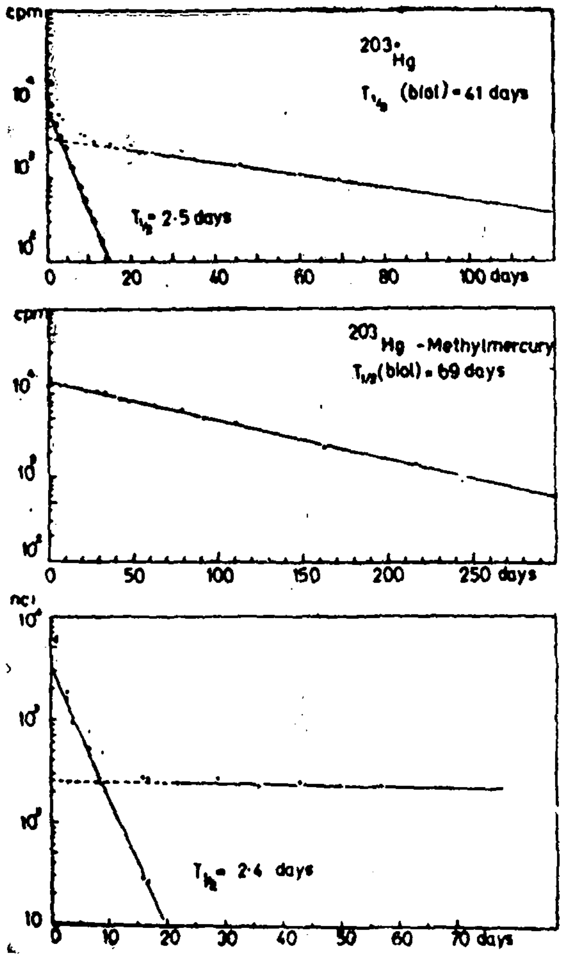


Fig. 9 (a)—Whole Body Retention after a Single Oral Dose of Radiotracer.

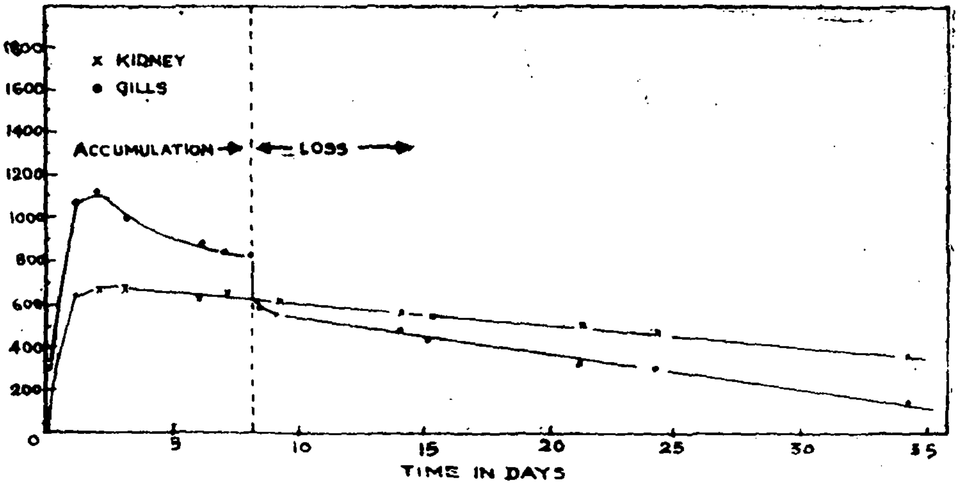
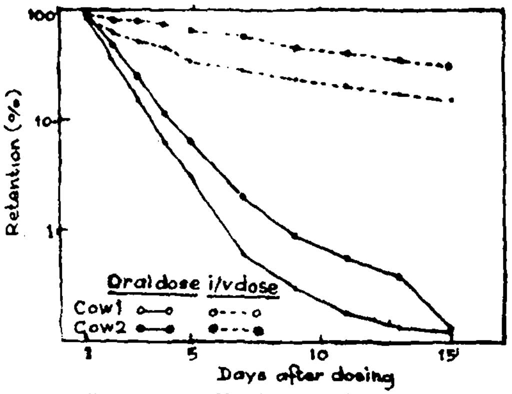


Fig. 9 (b)—Uptake and Release of 203 Hg in the Gills and Kidneys of the Goldfish *Carassius Auratus* with Time.



WHOLE BODY RETENTION IN TWO COWS OF ORALLY AND INTRAVENOUSLY ADMINISTERED ^{54}Mn.

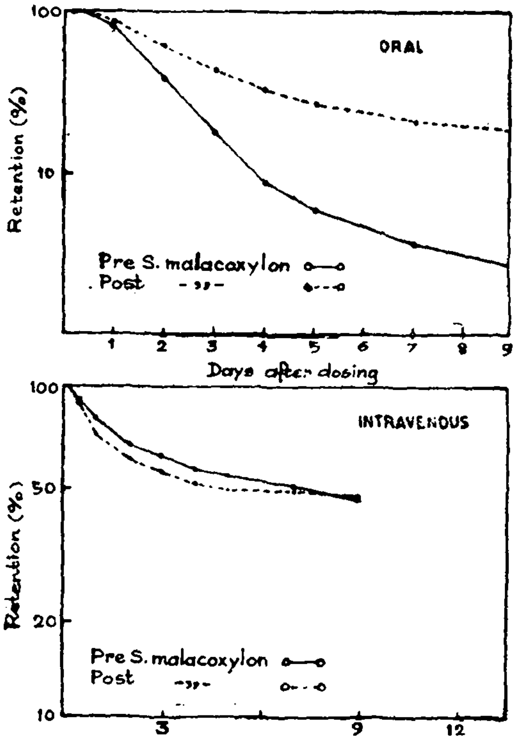


Fig. 9 (c)—Whole Body Retention of 47Ca Before and After the Oral Administration of Dried Solanum Malacoxylon at a Dose Rate of 200/mg/kg/Body Weight/Wk.

An important observation was that within the first 4-5 days about 6% of the Me 203Hg and 85% of the 203Hg were excreted, mostly in faeces. In the case of 115m Cd, it was observed that about 70% of the label is excreted via faeces within the first 3 days and that at least two components exist in the excretion function: a fast one with a half-life of about 2.5 days and a slow one having half-life of not less than few hundred days.

2. Marine Organism

Goldfish was kept in lake water containing 0.23 mg/l 203Hg in isotonic form and then put in non-radioactive water for 26 days (12). Fish kept in active water picked up the isotope through the gills which subsequently got deposited in the kidneys. Once the fish is removed to non-active water, there was an immediate and rapid loss of activity from the gills. The turnover rates established by *in vivo* counting are shown in Fig. 9b.

3. Farm Animals

In large farm animals, the conventional stable balance techniques are difficult to conduct because of the large quantities of food they consume and of excreta they produce with the resultant difficulties, first of quantifying their daily intake and second of achieving the complete collection of excreta. The use of radiotracer techniques obviate some of these difficulties and makes it possible to use a whole body counter to measure the retention of an oral dose of a radiolabel at various times after administration. Fig. 9C shows the retention of 54Mn and 47Ca in cow (13). It may be noticed that the retention of 54 Mn from an oral dose is as low as 0.4% after 13 days while for i.v. administration it is nearly 20 percent. The results with 47Ca show that during administration of *Solanium malacoxylon* the cows retained a much higher proportion of orally administered isotope.

Conclusion

The whole body counter is extremely useful in the assessment of the contents of radioactive pollutants in the population living close to a nuclear plant and, with additional information about the pathways, can lead to a better understanding of the behaviour of radioactive waste products discharged into the environment.

It may be a very sensitive and simple system to study the metabolism of various compounds in human beings by using suitable radioisotopes for labelling, thereby leading to better understanding of the uptake, distribution and elimination of chemical pollutants in the environment.

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