GHBOROUGH UNIVERSITY OF TECHNOLOGY

Department of Civil Engineering

second international conference on
environmental health engineering in
hot climates & developing countries

Water, waste and health in hot countries

21st - 24th September 1975

PROCEEDINGS edited by JOHN PICKFORD

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International Conference September 1973	ENVIRONMENTAL HEALTH ENGINEERING IN HOT CLIMATES AND DEVELOPING COUNTRIES
7th PHE Conference 1974	EDUCATION AND TRAINING FOR PUBLIC HEALTH ENGINEERING AND ENVIRONMENTAL MANAGEMENT
8th PHE Conference 1975	ASPECTS OF SEWAGE TREATMENT

W.E. WOOD

water supply as a world problem

'In engineering, as in the other arts, simplicity is the ultimate virtue'.
attributed to James Watt, 1736-1819.

'An engineer is a man who can carry out successfully, for fifty cents, something that any damfool can do for a dollar'.
attributed to Herbert Clark Hoover, 1874-1964.

INTRODUCTION

From time to time the United Nations and the Specialised Agencies (the World Health Organization in particular) make assessments of the water supply situation on a world-wide scale and put forward proposals for improving the undoubtedly serious conditions existing in many countries. The latest proposal of this nature is contained in the United Nations Second Development Decade (1971-1980) programme.

The starting point (the situation as it existed in 1970) was based on an analysis made by WHO of figures supplied by its member countries throughout the world, and targets were set for achievement by 1980. Briefly, it was proposed that a determined effort should be made to increase (during the decade) the percentage of urban dwellers supplied with piped water into their houses or courtyards from 25% to 40%, of townspeople receiving water from public standpipes from 26% to 60%, and of rural inhabitants supplied with safe water from less than 10% to at least 20%. To achieve these objectives in those countries that were members of the United Nations at that time (i.e. to cover rather more than three quarters of the world's population) would be expected to cost 9.1 thousand million U.S. dollars; one sixth of this sum would be required for rural improvements, and the remainder for urban projects.

Provided that the margins of error inherent in global estimates of this nature are recognised these figures (and their breakdown under regional headings) can give us a useful overall picture of the situation - indeed from no other source can a similar world-wide appraisal be obtained. There are dangers, however, in placing too much reliance upon their accuracy then and now, and it is even more fallacious to draw the conclusion that the water supply problems of the world are solely those of finance, capable of being neatly solved by the allocation of funds to the totals estimated.

To start with it must be obvious that although the figures, produced six or seven years ago, were obtained from the best possible sources (i.e. from the countries themselves) considerable extrapolation was involved. Assuming that such statistics as rural and urban populations, numbers of communities already adequately served with water, and so on were reliably known (and this does not necessarily apply in every country) forecasts of population growth and urban migration had to be applied to these figures to reach the estimated situation at the end of the decade in 1980. Similarly, financial estimates were based on per caput construction costs, and however accurate the figures on which these estimates were based extrapolation to cover similar projects in other countries - even within the same country - inevitably weakened their reliability. Again, such unknown factors as inflation and rising costs over a ten year period must have added, and will continue to add, substantially but unpredictably to the overall estimates.

With these reservations we have the world problem stated in a simplified form - to provide a basic piped water supply service to urban dwellers and safe water sources to serve one fifth of the rural population in the countries under consideration called for 9100 million U.S. dollars, an estimate that has almost certainly increased since it was formulated six years ago. Without denigrating the massive aid given by international and bilateral agencies or the substantial efforts made by many of the countries concerned it seems unlikely that funds on this scale will be made available for water supply within the period, however desirable we may consider this objective in comparison with the innumerable other claims that compete for whatever funds can be allocated.

In any case, under present circumstances, it is safe to say that even if money on this scale were immediately forthcoming it would not lead to the prompt and complete solution of the problem everywhere. In many developing countries lack of finance is only one of many restraints. Institutional, legislative, administrative and organizational inadequacies, lack of trained and experienced personnel, the absence of a national plan based upon basic knowledge of the situation within the country, would all have to be remedied before a constructional programme on the scale required could be embarked upon.

A further fallacy that oversimplification in the statement of present positions and future objectives may conceal lies in the confusion between the construction of facilities and the provision of water to the consumer. It is only too easy to accept the logic that because a water pumping station, treatment works and distribution system have been installed in a certain town it necessarily follows that all the inhabitants of that town will continue to receive an ample, safe and continuous supply of domestic water indefinitely. The existence of a number of expensive installations, now wholly or partly idle or operating inefficiently, in various parts of the world bears witness that water supply problems do not cease when construction is completed, and that the setting up of a management organization to finance, operate, maintain and extend as necessary is as essential as is the initial provision of pumping plant and other physical components.

In other words the objective to be aimed at is not merely the construction of facilities but the continuing and continuous supply of ample quantities of water of suitable quality in a convenient manner to every individual at a price which he can afford. (We may even extend this definition to encompass the raising of the health, social and economic standards of consumers through the provision of such a supply). Many disciplines, as well as those of the water engineer, contribute to this end, and there is a danger that in concentrating upon our own particular sector we may ignore or underestimate the viewpoint and the problems of the others concerned. The very attempt to define water supply as a world 'problem' (in the dictionary sense of 'a question propounded for solution') can blind us to the complexity of the whole subject and lead us to believe that there is such a thing as a single, simple, universal 'solution' waiting to be discovered.

The following somewhat disjointed notes, written by an engineer from an engineering viewpoint, are intended to call attention to some of the aspects of water supply generally, especially in the developing countries, that have to be recognised and reconciled if our full objective is to be approached. Some of these are our own direct concern, others may lie outside our immediate responsibility, but we cannot afford to ignore the influence that they may have on the success of our work. The comments made under each heading represent solely the opinions of the author, and are submitted as a basis for discussion rather than as incontrovertible principles.

1. a) Water Supply as a consumer problem

The most important person having anything to do with any water supply anywhere in the world is the individual consumer. He it is who suffers from the effects of deficiencies in the quality, quantity and availability of the water that he receives; he it is also who eventually has, directly or indirectly to pay the costs of providing an improved supply. The installation is intended for his benefit, and upon the care and intelligence with which he uses it will materially depend the length of life and efficient working of many of its component parts. It is surprising, therefore, that it is only rarely that he is consulted on the proposed installation, offered a choice of services to be provided, informed as to its potential benefits, or taught how to make the best use of it after completion. This is in spite of the fact that all concerned - planners, designers, health officials, engineers, politicians - are themselves, as individuals, water consumers and might be presumed to have personal first-hand knowledge of consumers' problems.

It must be remembered that everyone on earth has a water supply of some kind, otherwise life would be impossible. It may be dangerously polluted, insufficient in quantity, inconvenient in situation, seasonally unreliable, or all of these, but there is enough for his minimum needs or he would not be living where he is. Only in comparatively few instances is an installation intended to produce water where none existed before; the more normal function is to purify, store, pump and distribute water that already exists at or near to the community to be served. If the consumer takes a dislike to his new supply for any reason, for example because it is too expensive, or because the water tastes excessively of chlorine, he has the ultimate sanction available. He returns to his old, dangerous source and the new supply has failed of its purpose.

So far as is possible a new installation should always be a response to a felt, preferably an expressed, need. Consumers will be much more likely to take care of, and to pay (sometimes even cheerfully) for, something that they have themselves requested rather than something that has been provided unasked by some distant authority. To those politicians, professional men and others who are well aware of the economic, social and health implications of a good water supply it sometimes comes as a surprise to find that the criteria of potential consumers are not necessarily the same as their own. The medical officer may condemn an existing source as a bacterial or parasitic hazard; the consumer is probably unaware of the invisible dangers to his health and far more concerned about the distance he (or, rather, his wife) has to walk daily to satisfy domestic needs, or about the colour of laundry washed in iron-rich water. In such cases a preliminary campaign of education in the connection between disease and water quality may make all the difference in the attitude of the people to be benefited. If they can thus be persuaded to demand improved quality and safety the new installation is off to a good start.

A further point that should be discussed with and accepted by the consumers concerns the standard of service to be provided. Certain features of any new installation should not be negotiable - e.g. the maintenance of safe quality and of continuity of supply - and the reasons for this should be made quite clear to all concerned. With this reservation there are a number of variables that can make a great difference to the amount that the consumer will have to pay, both for capital and recurrent expenditure. It is obviously preferable, for example, that water should be piped into homes or compounds rather than delivered through communal standpipes or watering points, but equally obviously someone has to pay for the increased initial expense. The decision as to whether the additional cost is warranted ought to be made by those upon whom the burden will fall. Certain physical aspects of the delivered water, such as colour, odour, seasonal turbidity, excessive hardness or iron content, may be considered as nuisances rather than as hazards. They can be remedied - at a price. The consumers should be informed as to the options open and the comparative cost implications. Consultation on such matters can make all the difference in the acceptability of the installation by the consumers.

b) Water Supply as a community problem

Because the quality and reliability of domestic water (a very small proportion of which is actually ingested) are of such importance to health, improvements in these aspects usually constitute the principal reasons for constructing new installations. From the community point of view there are also numerous non-domestic uses to be considered, in developing countries as well as in industrialised ones, which may have a bearing on the social and economic well-being of the consumers as a group.

These uses, and the potential benefits, will largely depend upon local circumstances. In a highly developed society such tangible benefits as improved land values, reduced insurance premiums, increase in property valuation, the ability to wash cars or to water lawns may be attributable to a good municipal water supply. A tropical agricultural community are likely to be more interested in watering domestic livestock or irrigating small vegetable plots. Even in rural areas there may be a potential for industry dependent upon an ample water supply - e.g. cotton ginning, textile dyeing, pottery, fibre retting - while a variety of commercial users and tradesmen, such as bakers, blacksmiths, brick makers, slaughtermen, fish curers or tanners can benefit by a readily accessible supply. Obviously in the bigger communities such uses increase in number and diversity.

Then there are municipal and communal uses that must be taken into account. A modern city uses water for street cleansing, an agricultural village to wash down market stalls. Without a piped supply hospitals and clinics cannot operate properly, schools cannot be made hygienic, waterborne sanitation cannot be considered and adequate fire protection is impossible. Buildings, whether of modern reinforced concrete or of primitive mud bricks, require considerable quantities of water in their construction, and this use is frequently forgotten. Hotels, public bathhouses and laundries, food preparation establishments (including soft drinks manufacture) are examples of other non-domestic purposes for which water is essential.

Because the absence of water is a limiting factor for uses such as these they are likely to be absent in water-short communities. When a communal supply is to be installed or extended it is therefore a fallacy to base its design upon existing demands, even if these are extrapolated to satisfy an increasing population. Representatives of the community itself are likely to be best able to forecast the changes that the installation will produce in individual and public demand, and then only if adequate information is provided as to the potentialities that will be opened up, and of the way in which other similar communities have developed in comparable circumstances.

With this information before them the community representatives should be encouraged to share the decision as to the extent to which future needs should be catered for in the initial construction. Designers, consulting engineers and planners are often criticised for shortsightedness on the one hand (when an installation proves inadequate and has to be extended after a short time) or for extravagance on the other (when the full capacity of a new system is not immediately taken up). Weighty arguments can be produced for both pessimistic and optimistic estimating; the immediate (and almost universal) shortage of funds and high rates of interest on capital will call for initial economies and minimum designed capacities, while the high cost of enlargement or duplication later and the reducing value of money will suggest providing an ample capacity margin from the start. The skill and foresight of the designer will help him to steer a middle course between these extremes, but involvement of representatives of the community itself in the decision (after presentation of the full facts) is not only a wise precaution but is also elementary justice, since it is they that will have to live with the system (and pay for it) for many years to come.

It is also important that community representatives should know precisely what the new installation will entail, both in terms of annual costs (capital repayment and recurrent expenses) and of other non-financial obligations. In many countries it is the practice to hand over a completed installation to the local authority to manage and maintain even though construction may have been financed and carried out by the central government or other agency. This often has many advantages, including the encouragement of civic pride of ownership, but it adds to local responsibilities and there are numerous instances where the municipal (or other local) authority has been insufficiently prepared to meet these responsibilities. Operating, managerial and supervisory staff must be engaged and trained before taking up their duties; fiscal arrangements must be made if water rates are to be collected; health authorities must be prepared to exercise quality control of the water supplied; byelaws or other legal provision for the ownership, protection and proper use of the facilities should be arranged in advance; budgetary provision may be necessary for the regular purchase of fuel, chemicals and other materials as well as for the payment of operating staff; arrangements must be made for maintenance, renewals and future extensions of the system, and so on. It is also highly desirable that some form of public information service, applicable to the size and character of the community, is worked out so that the understanding and co-operation of its individual members can be assured on a continuing basis.

In short, just as individual consumers should be consulted as to their domestic requirements so the local authorities, as representatives of the consumers as a body, should be involved in the preparation and planning of the installation as a whole, so that they know exactly what will be required of them before they accept the custody and care of the works that will be of common benefit.

c) Water Supply as a national problem

The degree to which Governments are directly engaged in the planning, construction and management of water supplies varies from country to country according to the political system and other factors. Organizational patterns include autonomous water corporations; central departments within the Ministry of Health, Public Works, Municipal Affairs or other appropriate Ministry; devolution to State or Regional Governments; devolution to municipal authorities; or combinations among these. In general each system represents a compromise, best suited to national conditions, between two opposing considerations.

The arguments in favour of maximum delegation of authority include the desirability of involving the consumers to the greatest possible extent in decisions affecting their welfare; the encouragement of civic pride by local ownership and management of local installations. Those in favour of a centralised organization include the economies made possible by standardisation of designs, techniques and equipment; setting of priorities on a national scale, allocating to the best advantage scarce funds, materials and manpower; overcoming the shortage of skilled personnel that may prevent efficient supervision and operation of smaller undertakings.

In developing countries especially there are certain functions that can best (or only) be performed at national level. Some of these are the following -

Construction capital. While large cities and prosperous communities may be able to raise this from local resources, or through such means as bond issues, lotteries or bank loans, the majority of projects require assistance in the form of loans, grants or guarantees. In those countries receiving international or bilateral financial aid the donor agencies invariably require Government backing for any request. Whether national or external sources of funds are utilised the Government is inevitably involved, and this implies at least a measure of national control over the work to be carried out.

Definition of the problem. Planning and programming must start with an assessment of the problem on a national scale, an estimate of the resources required to satisfy all demands compared with the resources actually available, and a setting of priorities to make the most practicable use of the latter. This calls for action at national (possibly, in some countries, at state or regional) level.

Basic data. Among the essential tools of the planner are demographical, geological, meteorological, hydrological, topographical and other statistics, together with information on a diversity of subjects, such as anticipated future development trends, prospects of tourism, industrialisation or mineral development, planning in other sectors (e.g. air, sea or road transport proposals), all of which may affect the future of individual communities and their respective water supply needs. Usually such data can only be collected and compiled on a national basis.

Water resources exploration and development. Except possibly in the case of very large projects the cost of geological or geophysical exploration and of deep drilling for a single water supply is prohibitive, and could not be undertaken by a local authority unless there happened to be private companies operating in the area. The more usual arrangement is for a government department to undertake work of this type (either directly or by means of a multiple contract) on a countrywide basis, co-ordinating the programme of exploration and development to the priorities of water supply construction.

Standards and standardisation. A degree of standardisation (as will be discussed later) in design, in equipment, in construction techniques, in standards of service and in other factors can result in considerable economies; only a central authority, such as a government department, can provide the necessary guidance to enable local authorities to reap the benefits thereof. Further economies can result from bulk purchase and from interchangeability of spares, equipment and materials between neighbouring supplies, and a co-ordinating authority is necessary to ensure that such procedures are encouraged and facilitated wherever possible.

Recruitment and training of personnel. The attractions of water engineering as a profession are greatly enhanced when there is a unified staff structure with promotion prospects for the best men. Few local authorities will be of such a size as to warrant a professional staff large enough to offer this inducement; many will be unable to afford or obtain properly qualified officers. Similar comments apply to other senior personnel, e.g. chemists, bacteriologists, geologists, managers, and also (to a lesser extent) to sub-professionals such as draughtsmen, surveying staff, supervisors and the like. Even when there are prospects of mobility from one undertaking to another it is necessary to have nationally acceptable standards of qualification and experience, and this involves provision of training facilities that are usually only feasible on a countrywide scale.

Laboratory services. Again, few undertakings will be large enough to provide and operate laboratories solely for water quality surveillance, and although pooling of services and the use of university and hospital facilities may be the appropriate solution in many instances this usually calls for co-ordination by a central authority.

Other functions. A number of other functions, including research and development, evaluation (both engineering and health), materials testing, encouragement and standardisation of local manufacture, specialist maintenance (e.g. instrument calibration and repair), holding of emergency stocks to deal with disasters, are all more suitably undertaken centrally. In addition there are legal functions, such as water legislation, plumbing regulations and codes of practice, that must be co-ordinated throughout a country.

Irrespective of how or by what agency a national programme is implemented, the important thing is that there should be a countrywide plan, fully supported and encouraged by the central government. The problems of supplying safe water to the vast numbers of people still in need are so large, complex and diversified that only concerted effort can hope to solve them. The first step is to initiate such a programme and to identify clearly the department or person responsible for its promotion. Experience has shown, in those countries where major and widespread improvements in the situation have been accomplished, that the success has been largely due to an expressed government determination translated into action by vigorous departmental action.

Latin America provides a number of recent examples of this; under the charter of Punta del Este each signatory government set itself a target and then designated who was to be accountable for ensuring that the target would be achieved within a stated period. Momentum was maintained by the proviso that progress reports, comparing objectives with actual achievements, should be produced and made public annually. Inter-country rivalry may have played some part, but there is good evidence to show that the rate of progress achieved by this method has outstripped results recorded from other parts of the world during the same period. While it is not suggested that any one pattern of programme can be of universal application it would seem that a study of those that have been shown to be successful should provide valuable guidance in other countries where it is hoped to achieve similar (or better) results.

d) <u>Water Supply as an international problem</u>.

Assistance to developing countries for water supply construction has been forthcoming from international agencies, and from other countries through bilateral agreements, at a steadily increasing rate over the last couple of decades. The provision of good water is a particularly attractive channel into which such assistance may be directed; it is essentially peaceful in character, has beneficial effects on the health, social and economic well-being of the people, is part of the infrastructure that makes other improvements possible, and is generally and genuinely welcomed by the recipients.

It seems very probable that international and bilateral aid could and would be extended considerably if more countries had the initiative and the available technical expertise to prepare and submit soundly based and economically justifiable proposals. Money is usually available for well conceived projects, and often, when lack of external finance is quoted as a reason for non-implementation, the real cause may be a failure to present a (financially or economically) attractive proposal.

International and bilateral agencies provide assistance of several kinds, but there is one consideration that often weighs heavily with them. They prefer to deal with large projects or with programmes incorporating a number of smaller projects rather than to be concerned with numerous small and unconnected proposals.

Hence while water supplies for large cities may be acceptable (though even with these it is often found preferable to combine water supply proposals with other related improvements such as sewerage and sewage disposal, storm drainage and the like) the chance of obtaining approval for rural or small urban projects is considerably enhanced if they are combined together into a national programme. An alternative, less often adopted, is to include a community water supply project in, say, an integrated health improvement programme, and by combining the installation with other construction (e.g. hospital, clinics) to bring the total proposals to a size that would warrant consideration as a single application.

Of the international agencies the one most concerned with providing technical assistance in water supply matters is the World Health Organization (WHO). Acting on the premise that a safe and reliable water supply is a pre-requisite for a healthy existence WHO provides advice and assistance to its member countries in a number of ways, probably the most important of which is the allocation of staff members to work within the countries, training local counterparts and assisting in the initiation and implementation of national programmes. Such field staff operate from regional offices, the policy of each being directed by the countries of the region concerned. Other functions of regional offices and headquarters include the preparation of manuals, guidelines, standards and other documentation in languages appropriate to the recipient countries, the collection and dissemination of basic data to facilitate planning, and the co-ordination (through an International Reference Centre) of research and development activities in countries in many parts of the world. WHO is not a financing organization, in that it does not provide loans or grants for construction activities, but through its field and office staffs it advises and assists governments to obtain financial assistance from other international and bilateral agencies.

Of such agencies the World Bank is the most active in granting loans for water supplies. They lend to governments, at reasonable rates of interest, the cost of construction of facilities, in which they include such expenses as surveys, designs and other preparatory costs. However, any application for a loan must be supported by a considerable amount of background information relating not only to the technical aspects of the proposed project itself (including arrangements intended for its future management and operation), but also to economic and financial conditions within the country and to details as to how the investment is to be protected and loan repayments in the future are to be guaranteed.

To obtain and present this information in the required form often calls for pre-investment studies, including feasibility reports, management studies and other preparatory investigations, and these are frequently beyond the capacity of the available professional and technical staffs in developing countries. Recognising this difficulty the United Nations, through its Development Programme Special Fund, makes grants to enable governments to engage international firms of consulting engineers to carry out the required pre-investment studies. WHO assists in preparing terms of reference for such firms, in the selection procedure, and in providing guidance and co-ordination during the course of the surveys, acting (for this purpose) as representatives of the United Nations.

Other international agencies provide different types of assistance. The United Nations Children's Fund (UNICEF) have been active in supporting rural water supplies in many countries by supplying imported materials and equipment (to countries where a lack of hard currency would preclude the use of foreign exchange for the purpose) and by training of local technical personnel. The Food and Agricultural Organization (FAO) sometimes gives similar assistance to agricultural communities.

Various industrialised countries provide assistance for water supply projects under bilateral agreements. Each has its own set of conditions, and in some cases pre-investment studies are required; WHO assists (if so requested by the recipient government) in similar ways to those applicable to internationally supported projects. Bilateral assistance may take the form of loans, grants, extended credits, the provision of professional and technical staff, training of local personnel, or other arrangement. Assistance may also be forthcoming from particular institutions in donor countries, e.g. from universities, famine relief organizations, charitable and non-profit-making organizations, research institutions and the like.

In general all forms of external assistance have two conditions in common: donor countries or agencies work through recipient governments rather than deal directly with municipalities or other local authorities within countries, and they prefer to act within a co-ordinated national plan rather than to assist particular projects in isolation.

2. a) Water Supply as a health problem

Sufficient documentation already exists to make it unnecessary to describe here the connection between such 'waterborne' diseases as typhoid, cholera, dysenteries and impure domestic water supplies. Almost equally well known and accepted is the reducing effect that a pure and ample supply has upon the incidence of so-called 'diseases of dirt', including scabies, ringworm, trachoma, tropical ulcers and the like. Certain parasitic diseases (e.g. dracontiasis) and viral infections (e.g. infectious hepatitis) are known to be contracted through drinking unsafe water. Various estimates have been made of the percentage of mortality and morbidity from these various diseases in developing countries particularly, but no statistics are necessary to envisage the human misery, infantile (and adult) deaths, crippling and blindness that are transmitted in this way. Such other health improvement programmes as those for improving nutrition may be partly or wholly vitiated if the food ingested merely goes to feed water-carried intestinal parasites. Cost-benefit studies of improved water supplies may be useful in persuading economists of the advantages of this service, but we do not have to await the result of such studies to know that suffering and premature death can be prevented if waterborne and water related diseases can be eliminated or reduced.

It is often pointed out that a water supply is not the only vehicle by which such infections are carried, and that other works of environmental improvement, such as food hygiene, sanitary disposal of excreta and garbage, control of flies and rodents are also called for if health standards are to be raised. This is true, but is no argument for neglecting water supplies; indeed the presence of ample quantities of safe water may contribute to and facilitate these other sanitary measures. Ideally, raising of environmental standards in any community would call for a co-ordinated programme of improvement in all these aspects, and wherever possible this should be the approach. However, when only limited resources (of money, manpower and effort) are available there are good reasons why water supply improvement should be regarded as the first priority. Experience has, in any case, shown that other forms of sanitary improvement are more likely to follow water supply installation than vice-versa.

Another argument sometimes used when water supply expenditure is under consideration is that increasing the quantity of domestic water available may create health problems that did not exist before. A particular example is filariasis, the vector of which may breed in undrained pools of sullage water. Again there may be some validity in the argument, but it is an indictment of the designer of a system who failed to anticipate the need to dispose of waste or surplus water rather than of the principle of installing improvements. Similar reasoning applies when a muddy area around an insufficiently drained standpipe becomes the focus of a hookworm outbreak.

The need to identify and anticipate such hazards, to be able to assess health situations calling for improvement, to maintain surveillance and quality control of completed installations, to educate the public in hygienic aspects of water use, to evaluate the public health effects of proposed and completed improvements, calls for participation of the health authorities, and for a close liaison between the medical and other professions involved in planning, design, construction and subsequent management. The smaller the installation the more valuable is this co-operation likely to be, since a small community is unlikely to be able to call upon the expertise, experience and back-up services (e.g. chemical and bacteriological analysts and laboratories) that might be afforded by a large city undertaking. In the case of small scattered rural improvements the medical and sanitary staff of the health authority provide, in a number of countries, the only inspection and surveillance of village installations. Even if these latter consist solely of source improvements such as sanitary wells, hand pumps, spring catchments or rainwater collecting areas they need occasional surveillance, otherwise the very works that were installed to benefit the villagers may act as foci of disease transmission.

Apart from these considerations the health authorities can be very valuable allies to engineers and others engaged upon water supply improvement. By stimulating demand, initiating planning, justifying expenditure with supporting health statistics, pressing for quality standards, guiding public opinion, identifying health hazards of an endemic or local nature, and in many other ways they can complement the efforts of other professions. Health problems usually constitute the principal motivation for water supply improvement (and for the allocation of funds for this purpose); it is only logical that health authorities should be closely associated with every stage leading to solutions of these problems.

b) Water Supply as a finance problem.

There is a great deal of truth in the generalisation that large urban water supplies can be made self-supporting financially by wise management, but that rural and small urban undertakings can never be viable without subsidies or other assistance from a central authority.

There comes a point, however, when a country's water supply coverage has extended to include the majority of the population, and when this point is reached all consumers will be paying their own subsidies directly or indirectly. Although this fortunate position has, as yet, been reached by few developing countries any national programmes that lead to complete coverage must take the eventual possibility into account.

There is an almost universal (and somewhat natural) reluctance to paying for water as such; the argument that it is a 'free gift of God' can only be countered by an explanation that what is charged for is not the water itself but its extraction, treatment and conveyance to the point of consumption. This is part of the public relations message and is best delivered before the installation of a new supply and the arrival of the first bills. At that time consumers should be made aware of what their liabilities will be in the future; where water rates are to be collected separately the wording of the demand can continue the message. Properly presented the cost of a supply can be shown to be a bargain, and can be favourably compared with the charges for electricity (which are usually accepted without undue question) or with the cost of private water carriers.

Even when community supplies are subsidised from central sources there is a great deal to be said for the consumers bearing at least a portion of the cost, either individually or through community taxes. It is also highly desirable for separate accounting to be done for each supply, showing clearly the proportion attributable to capital repayments, operating and other recurrent costs, and the degree to which the total is subsidised. A simple accounting system, incorporating easily understood forms for annual returns, applicable throughout the country, is well worth inauguration; it permits easy comparison between similar undertakings, is helpful to local authorities, and is informative to consumers themselves who should be encouraged to take an interest in the efficiency of their own systems.

Almost certainly some assistance in the form of loans, revolving funds or other devices will be necessary for most supplies requiring capital expenditure on a scale beyond the community's capacity to finance from its own reserves. Repayments will be needed over a period of some years (with or without interest according to government's financial policy). It is often useful to continue collection at a similar rate after loan repayment is completed in order to build up a reserve fund for replacements and extensions, thus avoiding having to take out another loan when such expenditure later becomes necessary.

Methods of collecting the cost of delivered water vary widely according to policy and custom, and broadly fall into three categories - payment for the amount of water received, payment of an individual rate, or inclusion of water charges in other communal taxes. Each has its advantages and drawbacks, so that none can be said to be universally applicable, even within a single country. Payment by quantity received penalises the poorer consumers and those with large families; it also has the additional disadvantage that when other, unsafe sources become available during the rainy season consumers may make use of these to save money and thus throw away the health benefits that the supply was designed to provide. On the other hand it is often felt that this is the fairest way of distributing the cost - each paying in proportion to what he uses. From a practical point of view it is usually the most expensive method, calling for metering of individual connections or for attendance and collection of cash at public watering points.

Individual rates, whether levied on a per caput basis or graded according to the value of a dwelling, may be less fair to the careful consumer but are more practical and easier to collect, especially if this is done by an existing rate-collection organization within the community. Disadvantages are that waste is less easy to control, and that it is difficult to charge for casual use by non-ratepayers.

Incorporation of water charges into community taxation is probably the simplest method, but it may help to conceal inefficiency and does not conduce toward a viable self-financing undertaking. Personal involvement of the consumers and their sense of joint ownership is reduced, and there is less inducement to reduce waste and use the installation carefully.

Whatever system is adopted there must be adequate budgetary provision for the forward purchasing of fuel, treatment chemicals and other recurrent expenditure, including wages. It is dangerous to separate income from expenditure in such a way that necessary purchases are delayed until funds are made available from other communal sources, or until rates have been collected.

c) Water Supply as a maintenance problem

It may appear illogical to consider the subject of maintenance before those of design and construction, but the maintenance facilities should have an important bearing on the type of equipment installed. It should be an absolute rule that nothing should be included in any system that is beyond the capacity of the local people to operate, and for which there are no facilities for service and repair easily accessible.

If a designer wishes to include, for example, submersible electric pumps, electrode controls or individual house metering for the first time in a country he must ensure that there are personnel trained to service these items properly and also workshop facilities to enable them to do this. There must also be advance arrangements to permit them to undertake work of this nature for others. If, for instance, there is an adequate water meter calibration department in a large city undertaking this may have the capacity to serve the needs of smaller neighbouring supplies that do not have such facilities, but prior agreement of both authorities is necessary before it can be said that adequate servicing arrangements have been made.

In the absence of adequate servicing facilities the planner has two options open - to have the design changed so that simpler equipment is called for (even though this may involve a nominal reduction in efficiency) or to include within his project the provision of the appropriate maintenance facilities.

Another subject worthy of special mention under this heading is that of mechanical well drilling equipment. A common fallacy that has proved extremely expensive to many governments is that the provision of drilling rigs automatically ensures unlimited water everywhere. Apart from the questions of personnel and of hydrogeological investigation (referred to later) it is no exaggeration to say that a drilling programme depends upon, and is as good as, its maintenance and servicing facilities. Even when rigs have been furnished free from external sources they can prove a liability rather than an asset if there is no mechanical and skilled staff to keep them operating efficiently. Furthermore, the service requirements of different types of rig (percussion, rotary, hammer-down-the-hole) are so different that the addition of another type should always be preceded by special training and the acquisition of appropriate spares, repair tools and workshop facilities.

Construction equipment (e.g. concrete mixers, portable shuttering - even hand tools) and transport require regular inspection and maintenance. Their use also calls for careful planning if the best advantage is to be made of them; faulty logistics is one of the easiest ways to boost construction costs even on labour intensive projects.

On piped water supplies one of the most neglected items of maintenance is the distribution itself; actual studies of existing systems that have been in operation for some years have revealed losses, in some cases exceeding 30% of the distributed water. Mains leakage constitutes not only a major operational expense but also a considerable health hazard when negative pressures draw polluted surface water into the system through breakages and faulty joints. Proper design with this in mind, adequate training and equipping of waste control teams, and a carefully worked out programme of inspection and regular checking can do much to minimise these losses. On large distribution systems the initial outlay can almost always be justified.

d) Water Supply as a source problem

It is obvious that a primary requirement for any water supply is an ample source of raw water suitable for processing and delivery to consumers. It has been the experience of the author that in the majority of cases this condition presents fewer technical problems than at first appears. Difficulties, when they arise, are more often those of economics; the most suitable sources (from the point of view of quality and quantity) being sometimes at a distance, or capable of development only at a relatively high cost.

One reason for this is that existing communities have usually been founded and have grown up near to a water source. Many major cities are sited on river banks, smaller settlements make use of streams, springs or wells, but all have some form of supply or they would not be where they are. (There are exceptions, of course, such as communities serving oil refineries, mineral development or military posts, but these are special cases outside the scope of these general notes). The usual problem of the planner is therefore to increase the quantity or improve the quality of an already available source. Only when this is impracticable does the question of finding and developing completely new sources arise.

A perennial subject of discussion is whether quality or quantity of the raw water should be the more important criterion. Treatment to improve the former is usually more easily and cheaply installed than additional works to augment the latter, but the greater the reliance on treatment to make unsafe water potable the greater the danger of human error putting the entire body of consumers at risk. It is suggested that the prime consideration should be reliability and potential for expansion.

In a number of documented accounts of waterborne epidemics it has been shown that the public water supply, built many years previously, was not the vehicle of infection, but that inadequate and intermittent service drove many to drink water from other, unsafe, sources. This is most evident in cities around which large overcrowded slums or 'squatter towns' have established themselves - a development not anticipated by the original designers of the municipal water supply, but one that must today be regarded as an ever-present possibility, given a continuance of the present trend of urban migration in developing countries.

Much has been written about the competition among different types of usage for scarce water resources, e.g. the conflicting claims of hydro-power, agricultural, industrial and other agencies for sources that may be required for community supplies, but such conflict is not very common in practice. Except for the largest cities the quantities extracted are comparatively small, and where there is an adequate system of sewerage and sewage disposal treatment a substantial proportion is returned to the watercourses, even though this may be degraded in quality.

A common difficulty experienced by designers of water supplies is the lack of basic data on the resources available - hydrogeological and hydro-logical information concerning ground and surface waters respectively. Collection of this data cannot be done quickly - vital information such as stream gauging and groundwater table fluctuations have to be continued for at least a year to have any significance, preferably they should cover several years. In most cases the water supply project is urgent and the engineer is under pressure to go ahead with design based upon inadequate data. Occasionally this results in failure (e.g. a dam that does not fill, a stream intake that dries up in a period of drought, an overdrawn aquifer that ceases to produce because of insufficient recharge), but more commonly the designer 'plays safe', thus producing a project that does not take full advantage of the resource potentialities and hence is more expensive than necessary.

The additional costs so incurred are not obvious (except to the designer himself) and so cannot be compared with the cost of undertaking investigations in advance, but there seems little doubt that when a country has a programme of water supply development extending over a period of years it is worth while initiating a systematic hydrological survey well in advance of design and construction. It will usually be too much to expect that all potential sites can be covered in this manner, but basic investigations in sample areas representative of typical conditions can be most valuable. Such investigations might include stream gaugings related to catchment areas, meteorological records, rates of evaporation and run-off; draw down and recovery rates of typical aquifers during test pumping; seasonal fluctuation of spring discharges and of the chemical composition of ground waters; dates and levels of river flooding.

Ground water exploration is a subject upon which there is much misconception in many countries. The myth persists that geophysical equipment is the answer to all problems, there being a choice of mysterious 'black boxes' that enable an unskilled operator in unknown country to locate water, oil, coal and mineral resources, and to obtain accurate information on their depth, abundance and chemical composition. There is, unfortunately, no such substitute for the skill and experience of the geologist, though suitable geophysical equipment may be most useful in extending the range and accuracy of his investigations. A long term programme of geological surveys, backed by samples and records from well sinking and drilling operations, is the most (probably the only) effective method of predicting ground water occurrence. The earlier such a programme is set up the more accurate the picture that emerges; this is especially true when a widespread rural water development programme is under contemplation.

With regard to ground water extraction another common fallacy is that mechanically drilled boreholes are necessarily better than hand dug wells under all circumstances. This is by no means always the case, and hand digging should not be despised as outdated, particularly for supplies to smaller rural communities. There are, of course, a number of geological formations that cannot be effectively penetrated by hand methods, but in general there are probably more people in the world being supplied from hand dug wells today than from any other form of ground water extraction. A hand dug well programme is cheaper than mechanical drilling, requires simpler equipment and less imported materials, makes use of relatively unskilled operatives, calls for less supervision and back-up services. In favourable conditions it may actually produce more water. On the other hand individual wells take longer to construct, and the method is more suited to sinking in sedimentary formations and weathered strata than in hard granites or similar bedrocks.

Drilling can rarely be carried out efficiently on a single rig basis, and is best organized as a programme operating with grouped rigs in one or more areas. Maintenance facilities are vitally important (as has been mentioned earlier) and transport must be continually available to service the drilling teams with fuel,water, fishing tools, casing, and to move rigs from one drilling site to another. Ancillary craftsmen (e.g. blacksmiths for tool dressing) must be at hand. When a single project (e.g. a city supply) calls for exploration and construction holes it is usually worth considering bringing in experienced drilling contractors unless there is already a strong drilling department with proved expertise in the type of borehole required.

e) Water Supply as a rural problem

There are almost as many definitions of 'rural' (as distinct from 'urban') water supplies as there are countries; for the purpose of these notes 'rural' installations will be taken to mean supplies for those villages and other communities that are not large enough to have a local organization capable of constructing and managing works on their own. Hence planning, design, construction, operation and management are the responsibility of a regional or other 'group' authority, and the supply itself is one item within such a group.

From the engineer's point of view the difference in approach between urban and rural projects is greater than would at first appear. The multiple nature of rural projects calls for special techniques, and it is a misconception to think that these small supplies are merely 'scaled-down' versions of urban installations, calling for less engineering skill and ingenuity. The exact opposite may often be the case.

In those countries that have made good progress in their water supply programmes, particularly in the countries of Latin America, it is noticeable that priority has almost invariably been given to urban projects, with the result that such communities are now much better served than are the rural ones, even though the latter may represent the major proportion of the country's population. There are a number of reasons for this, including the greater political pressure that can be brought by larger communities, the increased hazards of epidemics when large numbers of people depend on a single water source, the fact that townspeople are usually more able (and more prepared) to pay for an improved supply. Perhaps equally significant is the fact that comparable effort on the part of the design and construction staff can produce greater and more immediate results in terms of the number of people served when dealing with compact communities; also that those same staffs are often reluctant to travel into remote 'bush', with the attendant problems of transport and accommodation. The natural tendency is to concentrate, where possible, on the jobs nearest at hand. In addition there is usually more professional satisfaction in successfully completing a few 'tailor-made' 'showpiece' projects than a large number of less interesting repetitive schemes.

Yet it is in such repetitive work that considerable ingenuity is required if maximum results are to be obtainable with inadequate funds, a shortage of skilled and supervisory staff, and with special difficulties of communications and logistics. Of these restraints staff shortage is often the most serious, and it is not too much to say that this factor alone would be enough to make the provision of rural supplies on the scale required impossible in many countries if reliance were placed solely upon conventional procedures.

The first bottleneck is at the investigation stage, where ideally a topographic survey with levels should be carried out as a preliminary to producing a design, estimate, list of materials, specification of pumps and similar preparatory details for each project. For large schemes, and for certain of the more difficult small ones, these preliminaries are essential, but there are very many cases where the requirements can be relaxed if adequate precautions are taken. Given specific training an assistant can produce, during one visit to a village, a sketch based on pacing and a hand-held level sufficiently accurate to enable an experienced engineer at headquarters to judge whether a detailed survey may be dispensed with. If his decision is that there are no complications calling for a further visit the sketch is passed to a designer and estimator to select standard items of equipment and standard design details suitable for the project.

To do this involves some loss of efficiency - for instance a limited number of pump types and sizes must be available, each having broad characteristics that will permit their use over a wide range of heads; a few sizes of mains piping must be decided upon and selected from even if some oversizing is inevitable; type plans of a few stock sizes of reservoirs, tanks, watering points should be available, of which the quantities and costs are known from experience. A simple multipage form can be worked out, of which the surveying assistant (or sanitarian) completes part in the field. This would consist of basic demographic figures, notes of special demands such as schools, clinics or commercial premises, together with his sketch and proposed siting for intake, storage tank, pumphouse, standpipes. Upon receipt in headquarters the design engineer decides whether the project is sufficiently straightforward, or whether he himself should visit. If the former, he selects his standardised equipment and type designs and passes the form to the estimator, who prices the construction work, estimates running and other costs (for the information, inter alia, of the local authority) and the document in due course goes (when permission to proceed with the job is obtained) to the storekeeper to issue the necessary materials and equipment from his central store. Thus a single form constitutes the record and history of the project from initial inspection to completion.

Construction procedures can also be simplified by standardisation and the use of type designs, but special preparation and training may be necessary. It is possible to make use of semi-skilled, often illiterate, men to carry out repetitive work of some complexity; a trained team of local masons, for instance, may be able to construct a particular size and type of storage tank without even being able to read a measuring tape, let alone a plan.

Nowhere is this more evident than in the task of well sinking. Once the techniques have been worked out and the teams have completed a few wells under close instruction and supervision they can often be entrusted to repeat the same techniques, unsupervised, in remote locations. Experience has shown the precise quantities of materials required for a specific task, and also the length of time it will take. Adopting these techniques a single foreman can supervise work on a number of sites where traditionally a skilled man should be in charge of each.

The above methods presuppose a prior knowledge of local conditions, and also of the intended water sources. There are bound to be areas where this knowledge is lacking and investigations (with consequent delays) are inevitable, but in tropical countries especially there are usually large areas over which similar conditions pertain, and engineering judgement is needed to identify where this can be relied upon.

f) Water Supply as a design problem

Owing to the nature and number of the variables encountered in water supply design there can never by a 'cook-book' giving instant solutions to all problems.

Large projects particularly repay careful and accurate design. In a city supply a small percentage variation in the efficiency of a pump or in the rate of flow through a filter may represent an appreciable increase or decrease in construction or in operating costs; sound engineering practice demands that each stage be examined for alternative possibilities, and that, after comparison, the most economic (not necessarily the cheapest) of those found feasible should be incorporated into the final design. Such supplies are considered in isolation as 'one-off' projects, and each must have its own provision for stand-by plant, emergency breakdown and regular maintenance spares.

Obviously one of the variables to be considered is the speed with which replacement equipment can be obtained and installed, and the inland city in a developing country remote from the place of manufacture will have to carry a much higher proportion of unused capacity (in the shape of spares and stand-by equipment) than those that can get replacements within days or hours after a telephone call to the suppliers.

In the case of smaller urban supplies this 'factor of safety' provision becomes more onerous. When a number of projects are planned they tend to fall into groups of similar (though not identical) design - e.g. those utilizing river intakes, boreholes, or impounding reservoirs as sources. Savings in capital outlay can be made by standardising equipment and holding replacement stocks within the country so that they are more readily available when required. This leads to simpler and more repetitive design, with less burden on design staffs, though some loss in efficiency may result. A careful appraisal of these opposing factors will be necessary. However, the advantages of standardising on a limited number of equipment items are not limited to the original design and construction stages.

Slow running reciprocating pumps (for use both above and below ground), belt driven by one of a small range of engines or motors, may not be as efficient as high speed turbine or electrosubmersible pumps. For larger schemes one of the latter will probably be specified; for numerous smaller supplies the former, with their flexible performance and adaptable characteristics, may be much more suited to a country's requirements. Maintenance is greatly simplified, reconditioned pumps and engines can be held and quickly substituted in the event of a breakdown, thus reducing the need for standby boreholes, intakes, pipework as well as the plant itself. Mechanics and fitters can become thoroughly conversant with a few types of equipment, pipework and bases can be of a pattern to permit interchange, and so on.

By adhering to a particular material and standard for the more usual sizes of distribution mains, a common pattern of joint, and as few different specials as possible throughout the country, training of mainlayers will be greatly simplified, stocks of spares may be reduced, neighbouring undertakings can help each other in an emergency, and the prospects of human error are reduced.

One external difficulty that may have to be overcome if the full benefits of plant standardisation are to be fully realised is the budgetary policy in many countries, whereby the requirements for each project have to be the subject of separate competitive tender. The advantages of large bulk orders covering a number of years should be stressed. Apart from obtaining better prices for such large orders manufacturers can often offer better service, such as holding quantities of spares at their own expense within the country, and will usually help in training maintenance staff by receiving them into their own factories for a period.

Apart from mechanical equipment and imported materials there are a number of in situ construction details that can with advantage be standardised throughout a country. There is little merit in the individual design of pump bases, filter shells, storage tanks, even valve and hydrant boxes, when similar items have been already constructed elsewhere in the country. A series of designs of such details in a range of sizes, with accompanying quantities, lists of materials, and estimates, available centrally and used wherever applicable, can be a very valuable investment in time and effort. It is also sometimes possible to use these as a basis for prefabrication of such components as reservoir roof slabs, caisson rings, meter boxes and covers, and other items that ingenuity may suggest.

Design must always take into consideration the limitations of available materials, expertise and constructional equipment, Since in most developing countries unemployment is an ever-present problem, the more labour intensive construction methods will be welcomed, and design should make provision for these. At the same time foreign exchange is usually scarce and the maximum use of locally produced materials is to be encouraged. Thus when designing, say, a reservoir dividing wall the use of reinforced concrete poured into steel shuttering, mechanically vibrated and incorporating a concrete waterproofing agent may be the correct and obvious choice in a country where reinforcing steel, mechanical plant and skilled operatives for reinforcement setting are available. In a developing country there may be advantages in hand placing and ramming of mass concrete between two skins of masonry or brickwork to serve the same purpose. At first sight this may seem retrograde and old fashioned; young local engineers anxious to gain a reputation for modern thinking will certainly condemn such a suggestion. Yet if the simpler (cruder, if you like) method is what the economy of the country demands it is the better design.

Similar considerations will determine the choice of treatment and other stages to be incorporated by the designer. It could be that local conditions make it essential to instal rapid gravity rather than slow sand filters - the inexcusable design fault is not to have considered all aspects of the two alternatives before deciding upon one or the other. To specify boreholes (mechanical plant; imported fuel and casing) where hand dug wells (labour intensive; some reinforcement the only imported item) would produce the same or better results could only be justified if the pros and cons of each had been carefully weighed.

g) Water Supply as a legal problem

In a number of countries experience has shown that the construction and management of water supplies have been hampered by the lack of, or the out of date nature of, appropriate legislation, including byelaws, codes of practice, plumbing regulations and the like. Although this subject may seem out of place in notes written by an engineer, it is worth placing on record a few instances where legal questions may hinder the engineer's functions.

Ownership of water sources. In many countries the ownership of natural waters (ground and surface) is vested in government and presents no problem. There are other places in which a complicated system of traditional water rights persist, adding greatly to costs and to delays in getting work started.

Ownership of land. Suitable sites for intakes, pumping and treatment works or reservoirs may be privately owned, and again involve time and expense in their acquisition. Difficulties may also arise in obtaining wayleaves for transmission mains and the like.

Ownership of completed installations. When a new water supply is to be handed over to a local authority or other body on completion, the procedure and the responsibilities accompanying the new ownership should be clearly defined in advance.

Right of entry. Cases are not uncommon where staff (e.g. geologists, surveyors) have been prevented from entering upon private land to make preliminary investigations.

Supply of information. Much valuable information regarding aquifers and other sub-surface conditions may be in private hands e.g. mineral or oil exploration companies. To prevent duplication of effort it is often useful to have legislation insisting that records of all deep excavations (including well sinking and drilling) be deposited with the government geologists.

Quality surveillance of water. The respective duties and functions of health and of water agencies in testing and maintaining the quality of raw and delivered waters should be defined. It may be considered that nationally accepted quality standards may also be of assistance in carrying out surveillance.

Prevention of pollution. Powers are needed to prevent private (or departmental) actions that might prejudice the safety of a water supply. It should be remembered that the river intake of one local authority may be put at risk by the actions or negligence of an upstream body over which the affected authority has no control.

Plumbing regulations. Once water leaves the supply mains it usually passes into private property, connections being made within the consumer's premises by privately engaged plumbers. Without powers to regulate and inspect their work the main supply may be put at risk by cross connection or other fault, and in any case shoddy plumbing can cause considerable waste.

Protection of installations. Powers are necessary to prevent damage through vandalism, carelessness or misuse; trespass and casual defecation in a protected area (e.g. around an impounding reservoir) may have to be controlled. Where access and recreational use is permitted a standard of hygienic behaviour should be laid down. Even in the simplest of improvements (a village well or protected spring) uncontrolled use may cause hazard or damage - a hand pump is especially vulnerable. As with most of these comments the best protection is an educated and co-operative public, but sanctions may be necessary if persuasion fails.

Code of practice for waterworks employees. Just as the waterworks staff may be hindered by private interference or non-co-operation, so the public may have to be protected from over-zealous officialdom. Rights and duties should be clearly defined on both sides.

If the planners of a water supply programme consider that these and other points might have a bearing on the success of the completed installation they should bring them to the attention of the appropriate government department. While the drawing up or revising of water legislation requires the advice of a legal specialist the engineer can be of considerable assistance in identifying loopholes in existing laws and in foreseeing the consequences of new legislation.

h) Water Supply as a planning problem

Reference has been made in a number of places in the foregoing notes to the necessity of having a national plan for water supply improvement if the problem is to be tackled efficiently and comprehensively. Such a plan will normally comprise both long-term and immediate measures, the former outlining strategy leading to a complete coverage of the country, urban and rural, and the latter will show the tactics suitable to the country's current economic overall proposals during a definite period (often five or seven years).

Apart from the specific objectives already mentioned, such as the introduction of standardised designs and techniques, recruitment and training programmes, forward investigations, setting of priorities and the like, a national plan can take into account the acceleration in construction that may be expected to result from increasing experience of all grades of staff, from the planners themselves down to the mainlayers and well-sinkers. A temptation in, say, a five-year programme is to budget for one fifth of the available construction capital each year and assume that output will similarly remain constant annually. This can lead to disappointment with progress initially, and sometimes to unjustified attacks from outside on the credibility of the programme as a whole. Over-optimism in estimating early short-term progress can be damaging to the chances of acceptance of long-term proposals.

Another factor to be taken into account is the necessity of purchasing, early in the programme, tools, construction equipment, transport and of setting up drawing offices, investigation units, accounts systems, stores and other administrative mechanisms. The full benefit from such activities may not be felt until later stages, but expenditure will be needed in the first few years.

Thus two factors - staff inexperience and the call for expenditure that is not capable of producing an immediate return - combine to force up unit costs in the early years and equally to slow down the rate of progress during the same period. For these reasons it is highly desirable to relate short-term activities to a long-term programme so that future potential benefits can be added to immediate progress when justifying early expenditure.

Countrywide planning has so many aspects that there is space here only to list a few considerations, some of which are occasionally overlooked though experience has nevertheless shown them to have an important bearing on success.

i) Initiation. Some agency (or, more probably, some person) must be sufficiently convinced of the need for planning, and possess the necessary drive and persistence, to stimulate the appropriate authorities into taking the action required to set up a national plan.

ii) Assessment of national need, immediately and in the future, so that the true extent of the problem can be presented. Included with this must be an estimate of the cost of filling that need in terms of money, manpower and materials.

iii) Estimates of resources available (and expected to become available) for carrying out the work involved, separated under such headings as foreign expenditure, government (or state) commitments, locally available resources. At this stage financial arrangements must be decided upon in principle, so that an idea may be gained as to the proportion of costs that will be borne by consumers, grants, loans, subsidies or other devices.

iv) A matching of ii) and iii) to enable long and short-term programmes to be drafted within the limits of practicality.

v) Deciding upon the criteria that will determine relative priorities when formulating the early stages of the programme.

vi) A clear and unequivocable identification of who is to be responsible for the various stages of planning, programming, implementation and subsequent management of the various elements of the national plan. The setting up of a mechanism for regular reporting to ensure that each agency is accountable for its particular responsibilities, that targets and progress can be periodically compared, and that shortfalls can be seen and studied with a view to rectification.

The foregoing comments apply to the planning of water supply improvements as such. There is another consideration that must not be disregarded - the water supply element within other forms of planning. Only too often developments, such as schools, hospitals, housing, industry, transport and the like, are planned and approved without due regard having been given to their immediate and future water needs. Where there is a national water plan such an omission can be obviated by close integration of the various programmes, but in all cases it is essential that water supply interests should be represented in the planning of every type of development that could be jeopardised by lack of adequate water, or that could adversely affect other existing or potential users through excessive demands upon restricted resources.

i) <u>Water Supply as a manpower problem</u>

In many countries the greatest single obstacle to successful construction and subsequent management of water supplies is the shortage of skilled and experienced staff. If a countrywide programme is to be prepared it is as essential to forecast the requirements of manpower as it is of funds. Finance may be forthcoming from external sources, but for personnel reliance must be placed on local recruitment (with the possible exception of the temporary employment of a few foreign specialists) and, while funds can be used immediately they are received and allocated, staff have to be trained in advance.

In this context the word 'staff' is loosely used to cover all types of personnel from engineers and managers down to village operatives - anyone, in effect, that can only carry out his job properly after receiving a period of instruction. Such periods may range from a few weeks to as many years, but unless the training is given the health of the consumers and the value of the capital investment of the installations concerned may both be put at risk.

The cost of training is itself an investment, recoverable (with interest, it is hoped) when the trainee becomes an asset rather than a liability to the programme as a whole. There are several ways in which this investment may be wasted, e.g.

: by selecting the wrong type of candidate, or one without the necessary background knowledge to benefit from training.

: by failing to have a sufficiently attractive staff structure, with salary and promotion prospects, to retain the skilled men after training.

: by an unbalanced training programme, leading to the misuse of trained men in carrying out subordinate work (e.g. qualified engineers having to perform draughtsman's, surveyor's or clerk's duties owing to the lack of supporting staff).

: by failing to anticipate training needs, so that staff are not ready to take over their duties when required.

It is therefore important to plan recruitment, training and staff requirements together and in advance, and also to ensure that the needs of government, local authority and private employees are all taken into account, otherwise there may come a time when all three sectors are competing for an insufficient number of qualified men.

The private sector is the one most frequently forgotten. National firms of consulting engineers should be strongly encouraged as they may make a most valuable contribution to a national programme, but much of this value is lost if they are only able to recruit staff from among existing government employees. In the same way local contractors and private plumbers, to play their proper part in the national plan, must have facilities to engage trained men, or to train their existing personnel, without prejudicing the ability of government departments or local authorities to carry out their respective functions.

Qualified men (in various grades) are required at three stages - planning, construction and subsequent management. With forethought the earlier stages will provide experience for the needs of the later ones, e.g. junior planning assistants will go on to senior posts in construction projects; artizans engaged on construction may become operators of the supplies they have helped to build. When installations are to be handed over to municipalities or other local authorities upon completion it should be a condition that the managerial and operating staffs (or, at least, the key members of these) should be nominated and recruited well in advance - preferably before construction starts - so that they may obtain experience by being engaged at this earlier stage.

Training should be considered as a continuing rather than as a once-for-all-time activity. The best men in any grade should be encouraged and given the opportunity of qualifying for duties with a higher responsibility, their subordinates should be preparing to step into their positions when this happens. In-service training may be effected by a number of methods; e.g. fellowships and short university courses for professional staff; seminars and travelling lecturers for professionals and sub-professionals; summer schools, travelling instructors and demonstrations for craftsmen and artizans. Arrangements whereby operators from small installations work for a time in larger plants, and similar devices suitable to the conditions within a country, are inexpensive but effective ways of raising the standards of the water supply services.

When external firms of consulting engineers are engaged within a country, training of counterpart and other staff (not necessarily restricted to professional grades) may be built into their agreements. They may also be asked to plan and recommend the selection of suitable candidates for external fellowships, such as those granted by various international agencies. When contracts for the supply of equipment and plant are awarded to foreign firms it is often possible to include a provision for training of fitters and maintenance staff, either within the country itself or in the place of manufacture, as part of the conditions of acceptance.

To sum up: the planners of any project or programme should not restrict themselves to the construction of physical facilities, but should advise upon and do their best to ensure that arrangements are made to enable those facilities to be efficiently managed and operated after completion.

CONCLUSION

Water Supply as an engineering problem

A successful water supply consists of four parts:

1. An ample and continuous supply of source water.
2. Physical installations to extract, process and deliver this water to consumers.
3. An organization capable of managing, financing and operating the supply under all circumstances.
4. A satisfied body of consumers.

To ensure the last condition the first three are essential. No.1 is obvious, and must be the primary consideration of the planner. No.2 is the result of the combined efforts of a number of disciplines. No.3 is the one most frequently neglected, but its breakdown can be as disastrous as a failure in either of the first two.

No one man can hope to be an expert in all the aspects of water supply. As has been shown (it is hoped) a single installation may call for such varied preparatory work as -

: An economic appraisal and justification.

: Meteorological, geological, hydrological, epidemiological, demographical and topographical investigations.

: Chemical and bacteriological analyses.

: A study of social and religious traditions of the community.

: Physical planning

: Financial planning and the setting up of an accounting system.

: Legal considerations.

: Staff planning and training requirements.

To bring together all the disciplines involved there must be a single focal point at all stages, and if this point is to be the engineer (as the author firmly believes it should) it is most necessary that he should understand, and be concerned with, the problems of the other specialists involved.

Whether this engineer is described as a 'water' engineer, a 'sanitary' engineer, a 'public health' engineer, an 'environmental' engineer or other title (according to his country of training and qualification) is of less consequence than his attitude of mind towards his task. The important thing is not so much that he knows everything about his profession as that he realises that his knowledge has limitations. The ability to listen to others, both within and outside his profession, is one of the signs of experience; a degree of humility is another.

In countries such as our own our experience is enlarged by professional contacts with our colleagues, especially at conferences like the present one. Sometimes we fail to realise how much we owe to such interchange of ideas, and how much our counterparts elsewhere may lose through lack of opportunities for mutual discussion. It may be that one of the ways in which we could assist them is by fostering and supporting engineering institutions overseas. It might even be that we ourselves could learn something in the process.

discussion

CHAIRMAN: Professor Sir Norman ROWNTREE, BSc, FICE
President, Institution of Civil Engineers

The CHAIRMAN offered his personal welcome to everyone and introduced Mr Wood. He looked on Mr Wood as one whose life had been devoted to doing good work for people all over the world. He worked as a municipal engineer before going to Nigeria. He then worked for consulting engineers after which he went to New York with the United Nations Water Resources Centre and from there to the World Health Organization. As a result he had made friends all over the world.

2. Mr W.E. WOOD said water engineering was one of the oldest and most honourable professions in the world. Its basic principles had remained virtually unchanged from the times of the earliest civilisations; only in the technical aspects of how these principles could best be applied did our outlook today materially differ from those of our predecessors.

3. Even our technology changed relatively slowly. During the lifetime of those present there had been few really radical improvements which would justify the modern term 'breakthrough', nor did there appear much likelihood that in the near future any startling or revolutionary solutions to our practical problems would emerge. Our task was likely to remain the selection and application of existing knowledge to devise the most appropriate solution in each case. No panacea could be counted upon to obviate the continuing need for professional judgement based upon experience, investigation and painstakingly-acquired background knowledge.

4. Because of the unchanging nature of the basic principles of the profession it was virtually impossible to present a general paper without repeating what had been frequently said before, and for such repetition and for the absence of new ideas Mr WOOD apologised in advance. What he had attempted to do was to note a number of 'fringe' or associated problems with which the engineer working in developing countries was likely to come into contact, in the hope that the ensuing discussion may shed new light on some of these.

5. As his introduction he quoted from a paper he prepared nearly ten years ago; subsequent experience had not made him want to alter it in any fundamental way. After discussing some of the potential sources of international and bilateral finance for water works construction he expressed the opinion that in many cases lack of funds, difficult as this may be to overcome, was by no means the only or the most serious deterrent to progress in many parts of the world, and he listed the following as factors that held back water supply provision in a number of countries:-

> "The first is the lack of an active driving force within a country that recognises the problem and is determined to do something about it. It is noticeable that the most spectacular results are obtained wherever there is a powerful department or individual to press for water supply improvements, and where such efforts are reinforced by a well-informed and articulate public opinion.
>
> The second is the want of a national plan for undertaking water supply improvements on a comprehensive and systematic basis rather than tackling the problem in individual towns piecemeal. The setting of national targets,

integrated into economic development plans, and the annual comparison of progress planned with progress achieved, have proved to be stimulating factors of considerable potency.

Third, a multiplicity of agencies concerned with water supplies within a country, often unco-ordinated, sometimes mutually distrustful, can prevent an integrated approach to the problem as a whole.

Fourth is the lack of trained staff for planning, as well as for design, construction, management and operation. On a professional level particularly this problem is compounded by the difficulty of recruiting and training suitable candidates.

Finally there is the inability, usually due to one or more of the preceeding factors, to represent the claims of water supply development in national economic planning, especially when in competition with more spectacular projects, and those which at first appear to be of more immediate economic benefit to the country."

6. In connection with this last point Mr WOOD suggested that the engineering profession could and should play a much bigger part in presenting the arguments on which economic policy decisions were based, and added

"Within a particular country the problem is essentially the concern of the profession within that country but, unfortunately, in too many instances our colleagues are few in numbers, overworked, insufficiently articulate as a body, and (for these and other reasons) at a disadvantage when trying to make their voice heard in the company of economists and other policy makers. It is felt that they could be helped and strengthened by support from the profession as a whole, and that such support would be of benefit to the people everywhere as well as to the engineers themselves."

7. Mr P.A. OLUWANDE commented on two aspects of the paper. The first was about feasibility reports for works for developing countries. World Bank financed projects normally had experts of receiving countries as counterparts, but for locally financed projects many consultants did not use local experts and often disregarded their views. They tended to base reports on experience acquired in other developing countries and felt that this experience was suitable for all developing countries. Mr OLUWANDE had read a report written by a consulting firm which had only spent two weeks in the particular country to produce a very detailed report. He felt it was important for firms to use local experts as much as possible and also perhaps to form a consortia with local firms and so avoid many of the problems raised in Mr Wood's paper.

8. The second point was the standardized design which Mr Wood recommended. It was a good idea but could only be used in small countries with a military form of government where a single government was in charge of all the city construction works and water supply. In big countries with separate state governments which tended to seek the expertise of consultants from different parts of the world it would be difficult to have standardized design.

9. Mr WOOD gave an account of experience he had with two firms of consulting engineers from different countries, both firms of good international reputation, who were working in two different developing countries on the same sort of job. He went to the first firm and found they had the usual troubles with currency and customs and insufficient information. At the end they made a big point of the fact that the government were quite unlawfully insisting that their engineers should all become members of the local institution of civil engineers. This they said was an insult to the qualifications of their staff and was not in the terms of their contract and they wished Mr WOOD to get this sorted out. The second firm in a different country had the same troubles of currency, customs etc. Mr WOOD asked if they had any trouble with the local institution of civil engineers. They replied they had not had any trouble although they had been invited to become members for the time they would be working there and of course they had accepted. From what he had heard, the relations between consulting engineers and the staff of the country were very good and many of the national engineers had cause to thank the incoming engineers for their guidance.

10. Dr S.M. ROMAYA wished to highlight some of the problems between water engineers and planners. It was difficult for planners to dictate where the money should go and the general priorities to be pursued. Investment had to be directed to creating more employment. Even with the distribution of water, priority was generally given to

industrial estates. Mr WOOD felt it was impossible to have industry without the infra-structure that included water supply, but industry could bring in the economic wealth which would finance water supplies. There was no general rule and there should be engineers on the water side as strong, enthusiastic and articulate as economists on the other side.

11. Mr B.M.U. BENNELL said he was an inarticulate engineer surrounded by hordes of economists. Although he was enthusiastic for water supplies, especially in countries which they tried to help, he was faced at every turn with the difficulty of finding factors, figures or even case histories showing that the provision of water supplies for small communities had produced quantifiable benefits. With the limited capital development aid available, greater attention should be given to writing case histories of successful schemes in the developing world to enable engineers to stand up in their battles with the economists who wished to put the money into what seemed to be more worthwhile projects merely because the benefits could be easily justified.

12. Mr WOOD said that water supply rarely occurred on its own. The very act of putting in a water supply often produced subsidiary benefits and a general lifting of the social condition of the people in the small developments. It was impossible to take any particular item out and say it was due to water supply only, although water supplies could be related to statistics for cholera and other diseases. For ten years the World Bank had been trying to get out some plausible cost analysis figures but had never managed it. One or two minor jobs had been written up: the Zaina project in Kenya was one of them, but was not really big enough to be statistically significant. There should be more "before and after" studies, but usually the engineer constructed a scheme and was onto the next job without having the time, facility or mandate to return to see what the effect had been.

13. Dr I.C. AGARWAL said that consumer participation was a complicated problem; who should represent the consumer? In developing countries, especially India, because of widely varying educational, economic and social ways of life, conflicting interests had to be satisfied. What type of consumer participation did Mr Wood recommend? Mr WOOD said there should be consumer participation to the extent that the local political system and the local administrative system allowed. He did not think it was an engineer's job to try and alter the existing system; he should work with it. Professor S.V. PATWARDHAN said that the efficiency of water systems was important. If the government gave loans there were always political aspects.

14. Mr WOOD said subsidies did not invariably mean government subsidies. A good example was in the Sudan, where the cotton industry subsidised water supplies for people working on the Gezira cotton area. Very few villages could produce the necessary capital to put in a piped water supply. There was no way of recovering the cost of a water supply from a villager on subsistence wages. If it was decided for health, economic or any other reason that water supply would reduce disease or improve efficiency, then arrangements (either subsidy or otherwise) should be made to enable them to get the facility.

15. Professor N. MAJUMDER had noted that in the paper Mr Wood had mentioned that to provide a basic piped water supply service to urban dwellers and safe water sources to serve one-fifth of the rural population called for 9.1 thousand million U.S. dollars. If this money was not readily available, how should priorities be decided? Mr WOOD said he had quoted from a U.N. report.

16. The CHAIRMAN said on the question of the settling of priorities, he felt as he got older he became more cynical, and wondered whether perhaps the one who shouted loudest had the priority.

17. Mr D.M. TURNBULL referred to studies in the Orkneys and Mexico. A problem that always arose with town versus rural supplies was whether there would always be rural life on the scale of the past. In agricultural communities there was higher production with less people. There was also an increase in birthrate and the general tendency was for people to leave the villages. If resources for water were limited it was always more efficient in economic terms to put them into a larger urban community than into a rural area. Mr TURNBULL felt therefore that while in emotive terms lack of water supply to a rural area was more distressing than in towns, in efficiency terms it was necessary to have a thorough look at the future of a rural community. In Europe, except the UK, all the villages were slowly disappearing. Mr WOOD said there was a great danger of using this argument the wrong way as an excuse for postponing action in the country.

18. Professor MAJUMDER felt the disappearance of villages was not to be encouraged.

He was not convinced by the argument that since villages were disappearing water supply should only be provided to urban communities. He suggested that if the water supply and other amenities were improved in rural areas, people would be tempted back and create less problems in urban areas.

19. Dr ROMAYA suggested that villages should be maintained if only to produce more food. Many developing countries were turning from food-exporting to food-importing. It was necessary to establish a balance between the rural and urban communities. The effect of migration was caused by the pull of the city and the push from the villages, and more investment in urban areas would assist the push factor from the villages. Ultimately there might be smaller villages and they might be mechanised and more sophisticated, but it was necessary for them to exist to provide food. The ideal size, distribution and location had to be decided. Mr TURNBULL was not suggesting depopulating the countryside by not putting any water supply into villages. The CHAIRMAN suggested what was being said was that the water planning had to adapt itself to the requirements of the country and not to dictate them.

20. Mr W.C. CARNEY said that the cost per person of rural area water supply was always more than urban supply. If economic planning favoured developing a rural area for a particular purpose then there was a yardstick against which it was possible to gauge the value of a water supply. In developing countries, setting emotive circumstances such as health to one side, it was essential to have an economic plan and know what achievements were hoped for.

21. Professor D.J. BRADLEY felt the last few speakers had tended to over-simplify the position, and particularly in respect of priorities. It was easy to say that it was much more expensive to improve a water supply for a rural area than for an urban one, but this begged the question of the degree of improvement. It might well be more expensive to provide the same sort of water supply in the country as in the town, but a simpler rural supply at the same cost per person as the town supply might be more relevant. Water policy should not dictate the overall development priorities. During the 1960s technological development produced national priorities and led to urban investment. Economists in developing countries were becoming increasingly concerned about redistribution of wealth. In most parts of East Africa 95% of people lived in rural areas; if policy aimed at wealth redistribution it would involve water supplies, and it would be necessary to think about the sort of water supplies to be provided.

22. Professor MAJUMDER said the cost of water supply to rural areas depended on the quality and quantity of water to be provided. In many rural areas in India a limited quantity per person was acceptable and the cost per person was fairly low with a decentralized type of source. However, if water had to be piped the distribution network added to the cost. It all depended on the local situation; the social pattern and type of living did not always demand that water be piped to each individual home. The capital cost of rural supply was sometimes cheaper than urban water supply.

23. Professor PATWARDHAN said the cost of satisfying the basic needs of man in a city area for water supply and other services was three and a half times that in villages. Migration of rural people into urban areas created tremendous social problems and the cost of providing services for them had to come from the entire urban community. The CHAIRMAN said it was necessary to have a much more sophisticated water supply for large communities for reasons of public health. Dr ROMAYA remarked that in urban areas a higher standard of infra-structure was provided, so the comparison was not valid.

24. Mr OLUWANDE said that in some parts of Nigeria people worked in villages for perhaps six months of the year, and also had houses in the town. This pattern of living caused problems: it was difficult to focus the attention of policy makers on helping people while they were living in the villages.

25. The CHAIRMAN said the discussion had mainly been about community problems and consumer problems and perhaps it would be appropriate to pass on to water as a national problem. Movement of people presented a health problem as well as an economic one. If a country had rapid town development then it needed a rapid sophisticated water supply development with all that that implied in terms of education and other requirements for high technology. It seemed to him that more was involved than just the cost.

26. Mr W.C. HALL said the Institution of Civil Engineers had recently introduced "the engineer in a community" into their examination syllabus. He thought that social aspects were as important as technical

aspects. Dr ROMAYA pointed out that most politicians relied on the advice of professional people and each professional needed to convince the politician of the validity of what he was arguing for. Certainly it was accepted that the final decision came from politicians but professional people had to put their case as best they could and leave the final judgement to the politician. Professor BRADLEY added that the professional who thought he was not taking a stance, but was merely following what the politicians did, in fact influenced the sort of policies that were introduced, whether he liked it or not. Mr WOOD said it was right that the water engineer should get his instructions from the policy makers. But it was the engineer's responsibility to advise before that decision was made and give some idea of the consequences of that action, which often economists did not appreciate. He believed if engineers restricted themselves to the technical side then it was not really water engineering - just a technologist's job.

27. Mr F.W. CROWLEY felt much more emphasis needed to be placed on the health aspects of water supply. In a community where there was an outbreak of cholera or some other water-borne disease attention was focused on water supply very quickly and within a very short time that community would be served with a new piped water supply. He thought that improvement in health could be quantified in real terms. Mr WOOD said it was very difficult to put a value on the death of one child whether it was half-way round the world or in one's own family. Mr CROWLEY remarked that surely statistics would show instances of particular water-borne diseases occurring in areas not served by a piped water supply and Mr WOOD felt it was up to the economists rather than the engineer to give the value in dollars.

28. Professor MAJUMDER said statistics had definitely proved that water had saved lives and the first demand on water was health, but he agreed there were other factors contributing to the uses of water. Naturally the water demand in certain communities was much larger and different qualities of water were required. The CHAIRMAN said the number of deaths was interesting, but was not used as a real priority. For example in Britain far more people were killed on the roads in a day than had died on oil rigs ever since oil rigs had been in the North Sea, but a lot more fuss was made of the oil rig casualties. He felt it was fear of particular forms of accidents and in the case of water-borne illness it was something that came unbeknown and put great fear into communities. Mr WOOD added that it was not only the deaths, but also the crippling load of illness on a community - the number of blind people from filariasis; children at village schools dragging themselves about because they all had intestinal worms, or at home because their parents were ill. These were things which could not be quantified.

29. Mr R.A.J. SIMKINS said that a properly carried out cost benefit analysis could at least attempt to take these things into account. Illness and death could be valued. The CHAIRMAN said the trouble was that there were usually too many intangibles. As had already been said, few people carried out cost benefit analyses after the job was done. Dr ROMAYA remarked that more often than not the cost benefit analyses were geared towards direct capital returns and how long it would take to recover invested capital rather than taking an overall assessment of lives, livelihood and working days, which were indirectly saved through direct investment in water supply.

30. The CHAIRMAN then drew attention to a matter he felt was under-rated, not only in hot countries, but in all countries - water supply as a maintenance problem. Some things concerning maintenance were not properly dealt with at the time of design: amongst them were the training of operatives for the future and ensuring there were resources available for repairs (for material as well as manpower).

31. Mr WOOD instanced a small well-designed water works in a South American country. It had rapid gravity filters with automatic backwash, a modern console round the switchgear, and was now completely derelict. The consoles had been stripped down and none of the filters were working. At the back was an old man with a drum of chloride of lime which he dribbled from a cigarette tin into the water as it went past, and that was the only treatment left. Evidently no-one had budgeted for materials or staff. The old man was probably appointed because he had driven the chairman's car on one occasion and therefore knew all about mechanics! There was a tremendous waste of money for various reasons and Mr WOOD believed the question of maintenance needed to be solved before construction. It was no good putting instruments in if there was no instrument repairer to keep them adjusted and calibrated; it was no good putting meters into a city supply unless there was a meter repair shop and people trained to carry out

the repairs; it was certainly no good handing over a completed water works as a going concern to a local municipality if there was no organization for collecting the revenue to purchase supplies and no mechanism for training the staff that would be required.

32. Mr R.P. WHITING thought that even though consultants did their work well, once a scheme was set in working order, often they left it and never returned. It would be good if authorities appointing consulting engineers required them to return at say 3-yearly intervals and produce reports on how things were going. During that visit the consultant should see all the works that had been installed and give advice and help to operators. The report would make known what was happening and would also serve as a feedback to the consultants and to the sponsoring bodies where they were not responsible for maintenance. It might make sponsoring bodies wary of providing further help to authorities who did not maintain works properly.

33. Dr ROMAYA had found the main difficulty in running equipment was at the technician level. There was a great shortage of technicians. One or two institutions had been started for training technicians to maintain machinery and equipment. However, after four or five years these institutes struggled towards progress, and before long had turned into another establishment for training engineers rather than technicians.

34. Mr P.S. DURRANT agreed that the funding body should keep a continuing interest in works which had been constructed, and require designers to report back on the running of the works.

35. Mr WOOD felt there was some confusion. The aim was to supply water. Too often engineers thought they were providing a water works, and the two were not necessarily the same. A water works was an instrument towards getting the water, but the only thing that really counted was the water that came out of the tap, pure and wholesome 24 hours per day. It was no good providing one stage unless the remaining stages were provided. These were the organization, personnel and the public spirit necessary to keep the works operating indefinitely. No water works was ever finished: from the day it was opened there was a demand for an extension or improvement. There were certainly training and manpower implications: the committee and even the storekeeper needed training.
Mr WOOD thought the man who designed and built that water works must take an interest in how it was going to operate afterwards.

36. Mr CARNEY said that in the past management skills had been developed through years of experience. He wondered how much emphasis was now given to management training in universities, particularly in the developing world. Professor PATWARDHAN felt there was total neglect by institutes of management of works. Roorkee had started a course some years ago and those who came from the department had to take a management course.

37. The CHAIRMAN said that the Institution of Civil Engineers rarely published papers on the subject of operation and maintenance of works: they were nearly all about the glamour of building new ones.

38. Mr E.J. FELTS was actively engaged on the rehabilitating of water supply schemes. Problems of maintenance revealed that simplicity of the scheme was most important. There was a shortage of training for skilled personnel (plumbers, fitters etc) and emphasis should be put in any water undertaking on this. On the distribution side, mains and services were laid without considering the question of road improvements or possible increase in traffic. Due often to salary structure, there was a tendency for skilled water personnel to go to contractors. After the construction of a scheme, there was a grand opening and then financial difficulties arose with failure in collection of rates etc. Skilled personnel left the industry, leaving unskilled people to deal with things and creating serious problems for the years ahead.

39. Mr H.J. GILES described the situation he found during a visit overseas to a large rapidly expanding town which was acutely short of water. Notwithstanding the shortage a fractured main within the main treatment works had been allowed to flow at an estimated 10 000 gallons per hour for three weeks whilst the Municipal Water Engineer sought authority to spend money on the necessary repairs. The municipality had no stores of any kind, and all pipes and valves had to be purchased from the local bazaars where even the purchase of a three inch sluice valve could involve a morning's bargaining. In this situation the overstretched work force could not cope nor would training provide a panacea. Training in isolation without a change in the work situation will only lead to increased frustration and bitterness. Facilities to train managers already existed in the U.K. under the auspices of the Training Division of the National Water

Council, who had assumed the responsibilities for the activities of the Water Supply Industry Training Board. Additionally they provided training in the wide range of activities associated with water supply, river control and sewage disposal, and could provide training for overseas students.

40. Mr TURNBULL referred to bulk-buying of equipment. Each country ought to adopt its own patterns for pipe sizes and fitments. Some years ago he was required to put in a mains to an I.C.I. works in a hurry; there was a shortage of pipes and fittings and on one 1½-mile length of pipline there were thirteen different types of joints. A lot of the trouble with maintenance and skilled people could be reduced if thought was given to how few different standards of pipes and fittings it was possible to manage with and accepting some of the shortcomings that arose from this.

41. Mr WOOD believed standardization was very important for several reasons. It was possible to interchange from one place to another, and thus to reduce the amount of capital tied up in spares. It was also a question of the skill of the jointer: often a man who had been used to asbestos pipes could not manage polythene. With very little effort it was possible to build a distribution system with built-in provision for waste detection by putting by-passes in areas specifically for this purpose, providing the men were trained and apparatus provided. A large number of long mains were laid in tropical countries without beacons and then a lot of time was spent looking for a main due to the thick growth of bush, or a long time could be spent looking for 'Old Joe' - the only person who knew where the valves were. These were things taken for granted in Britain and sometimes appeared to be too small for consideration when working on the other side of the world.

42. Dr AGARWAL considered that most of the maintenance problems were due to the adoption of sophisticated designs. Simple designs were neglected as they appeared to lack technological sophistication. Water engineers in developing nations fearing to be thought out-of-date tended to neglect simple designs, but more emphasis given to the development of designs suitable for local conditions would go a long way towards good maintenance.

43. Mr OLUWANDE said another aspect of maintenance in developing countries was lack of spares for moving parts of equipment. This problem would be minimised if the designers only specified equipment which they knew to be easily available in developing countries.

44. Professor MAJUMDER agreed that design had to be very simple so that maintenance was easier. However, in developing countries like India there were areas where it was possible to find sophisticated technology and efficiency should not be sacrificed for simplicity of design. Maintenance was primarily an administrative problem. Very often the administration did not have adequate foresight in terms of maintenance. He had seen very good water supplies go to pieces because the administration had not thought of having suitable services to keep them going. With the limited financial resources available, politicians or administrators wished to put in more and more installations to gain popularity, forgetting that one put in years before had not been kept going. Thus the importance of reserving finance for maintenance instead of releasing money for other installations was often lost sight of.

45. The CHAIRMAN said the maintenance problem was not found only in developing countries. An executive of the new Welsh National Water Authority told him that he did not need to build any new sewage works to solve the pollution problem in Wales; he merely had to make the existing ones work. The new water organization in Britain seemed confident they would be able to train themselves, but the CHAIRMAN hoped it would not be the same people training each other to do all the wrong things. There were experts in training outside the industry itself who ought to be brought in.

46. Were the administrative systems of various countries suitable for development of water systems or did they hold them back? It had been discovered in the U.K. in the last five years that there was plenty of technological ability which was not fulfilled because the administrative system did not allow it to be. Did this apply elsewhere? Were administrative systems able to take full advantage of technological advances?

47. Mr OLUWANDE said in Nigeria the set-up was very suitable. Every state had formed a water corporation to manage the provision of water for the people and the Federal Department of the Environment encouraged provision of environmental services to the country. There was now no administrative constraint on developing water supplies.

48. Mr WOOD said there were a lot of cases where the mechanism was there if only the people would get together and make use of it. He had in mind one country with a magnificent water works to the capital city with laboratories of their own which were better than anything the Ministry of Health had, and yet they would not accept people for training from other cities in the country. It was a municipal undertaking and they were not concerned with the towns a few miles away.

49. Professor PATWARDHAN said there were separate problems in different countries. There were some cases in India where a scheme was prepared by government and put to local bodies for their approval. However, approval was unimportant because even if they did not approve of the design, the scheme was put up. Political pressures were so great that the local government could not do anything about it. The CHAIRMAN said that not enough attention had been given to the interests of the consumer. Mr WOOD added that in many cases the government did not give the local people a choice. Experts might say it was necessary to have water piped into the house: this was a good thing but it would need paying for, and the man who had to pay should have a say in what he was going to have. The basic necessities were purity and a 24-hour supply, but when it came to convenience and something like iron removal (i.e. the frills) then every community and every consumer in that community should know the capital and recurrent costs.

50. Mr E.L.P. HESSING commented on the responsibility of the engineer working in the water supply field. He did not like an engineer who could say "That's not my job" when talking about something that was not technical. Water engineering in hot climates was part of the development work in general. The aim was the social-economical well-being of the people and that meant engineers were working in the field of social engineering. Mr HESSING disagreed with anyone who said that social engineering was out of scope. The impact of what was being done to the community in general did affect what engineers should aim at. The only question was how far an engineer's responsibility went beyond the technical aspects. Dr ROMAYA suggested that the report of the water engineer would go as far as saying he could provide this at this cost or that at that cost and give the choice to either the people in the community or the politicians.

51. Professor MAJUMDER felt it was a good point that the consumer's opinion should be considered but he wondered whether the consumer was in the best position to decide whether a water supply was necessary when he was already getting water from another unprotected source. He felt the decision should be made from a health point of view because it was difficult for the consumer to decide. Mr WOOD thought it was important that people were given the background information. It was easier to operate a water supply if the people were for it right from the start. That might involve education on the health implications of water. Mr CARNEY said that in Britain the consumer had a right to object to a scheme, but had no real right to advise on what the scheme should be.

52. Professor MAJUMDER said involvement by the local people was definitely required. In India no rural water supply project was undertaken without the whole community being involved. Could the consumer be relied upon to make a decision in respect of spending their money on this particular project or that particular project? The decision of providing a water supply in the form of decentralized hand pumps located at different points or a piped water supply to the community was made by the water engineer and administrators, not by the villagers. Once the decision was made the population was involved as much as possible not only from the monetary point of view, but by giving their labour and any other way possible. Should the villager decide whether safe water was a necessity? If there were two alternatives could the choice be given to the local community? Would it not be outside their scope to make the decision?

53. Mr HESSING agreed it may be beyond their scope to make the decision, but he felt the reason for this was lack of information. Who was able to give the necessary information? Professor MAJUMDER replied that water engineers and administrators had to give the necessary information and give the alternatives. Mr HESSING said that giving information meant transferring knowledge, but were engineers prepared to do that and were they trained to do it? Professor MAJUMDER said that however well engineers and administrators were equipped to transfer the knowledge, an attempt should be made to pass it on.

54. Professor PATWARDHAN said that when schemes had been constructed a meeting was called of all the councillors and chairman

of different local municipalities. When they realized it would cost everyone ten rupees a month they said "you have done a nice job, but take it away; we don't want it".

55. Mr P.W. ROYDHOUSE was rather baffled as to how to put the choice to the consumer. If it was motor cars or motor bikes, they would know the answer straight away, but the difference between a piped water supply into the house and a standpipe outside may be beyond their realms of knowledge in most cases. Mr WOOD said it was true that the villager was much more concerned with the colour of his washing or the distance that water must be carried and they were certainly not all going to be convinced, but there were ways to persuade them to want water supply on health grounds. As a generalisation most water supplies were put in for health purposes and most water supplies were wanted by consumers for completely different reasons. It was sometimes the case that in marshalling the arguments to persuade others the engineer might be persuading himself.

56. The CHAIRMAN suggested that much as one would like to give choices to people who were not experts, it was probably inviting trouble to do so. The community needed to be involved in order to understand what was going on as far as possible, but really it was the engineer who had to make the decision, but the consumer must appreciate why a certain decision had been taken.

57. Mr HESSING asked whether motivation of the community was part of the engineer's task. Was the engineer himself really motivated enough? The CHAIRMAN said it did not mean that every engineer had to be motivated. There were some brilliant engineers who would never inspire others, but who would ensure that works were carried out satisfactorily. There were others who talked about the job but could not do it. Professor MAJUMDER felt that while motivation was lacking, the programme would suffer.

58. Mr HESSING said that from another point of view it could be said that motivating people was in effect nothing more than creating demand for water supply and if work was wanted overseas then maybe it was possible to motivate people into asking for a water supply!

59. Mr J.J. FAIRCLOUGH said that the basic assumption had been made that when thinking of the options available, the consumer had to pay for the supply. Did this mean that those unable to pay would not get a treated supply? Mr WOOD replied that someone had to pay.

60. Mr BENNELL said that through the activities of ODM the British Government took an interest in rural water supply because of the health benefits. They also wished to maintain the population in rural areas and one of the means of so doing was to provide a reasonable health service. Health led straight to the question of water supply. However, problems arose when it came to a question of payment. These people had probably struggled to some degree for their water supplies in the past which were probably inadequate, and they would suddenly be presented with a brand new source of treated water and told to pay up. It was very hard to convince them that in paying up they were achieving some benefit which was tangible.

61. Mr WOOD said very few people objected to paying for electric light because it was something they could see and it was also something of social consequence: it was a great shame to be the only man in the village not connected up to the current. There were social aspects involved: if one village could be persuaded to have a water supply, it was not necessary to persuade a nearby one - they would ask for one. Surprisingly enough, people would often want to pay if they could be persuaded that it was a good thing.

62. Mr N. ARIF said no mention had been made of another type of developing country - namely desert countries, where water sources were very scarce and the problems were different from those already discussed. In these countries if there were natural sources of water available, they were always in limited quantities. What happened when demand exceeded capacity of this source? The only answer they had was desalination and there was no way of keeping this simple for maintenance etc. Water charges to the consumer were for two purposes:

a) Providing funds for extension of the works

b) Setting up control of the water used by the people - if a man knew he was paying more for the amount he used, he would economise. This was quite important in places where water was scarce, and only available in limited quantities.

The CHAIRMAN said this was part of the finance question: was water supply at any cost to be provided or was it to be limited by the price the consumer could afford to pay?

63. Mr TURNBULL said as far as the U.K. was concerned water had always been a free raw material. In the past it had been available in reasonably good quantity because the number of people had not been so great. Surely the stage had now been reached where water should be considered as a manufactured article. It was now a question of supply and demand; without water there was no economy and possibly no life.

64. Mr W.P. SCOTT said in a country he had visited recently, each consumer was metered, and the consumer paid an ever-increasing amount per thousand gallons. This was opposite to the method of charging for electricity and gas.

65. Mr WHITING said that in most developed countries it was regarded as essential that there should be continuity of supply, and it was almost a matter of honour amongst engineers that their supplies should not break down. Often it was possible to get a certain supply with a certain degree of assurance at a certain price, but to get a greater supply or a greater degree of assurance, the price might go up very considerably. This would happen particularly in arid countries where perhaps so much could be obtained locally and relatively cheaply from boreholes, and beyond that it was necessary to turn to more remote sources or desalination.

66. He had come across an example in Africa where according to limited data available the local river could be relied upon to supply a certain amount. Perhaps once in ten or twenty years there would be insufficient. The engineer had to decide whether to recommend the provision of a supply of water which might be inadequate occasionally and so keep the price down. This could be the best course even though on occasions there might have to be rationing. After a few years the community might decide to bring in a further supply of water at a greatly increased cost.

67. Mr WOOD felt that this went back to the argument about where that decision should be made. Should it be made at the capital city or should it be made at the level of the community? Those most concerned were the community and Mr WOOD thought they should at least have a say in making that decision. Mr WHITING suggested that a local decision might not be realistically based in the first instance. After some years of operation the local people would be better able to judge what was involved in having the additional supply.

68. Mr HESSING suggested that perhaps it could be done even earlier. If people could be convinced that the water treatment plant would pay for itself by way of the improvement of social economical development of the village, then perhaps it would be possible for them to give their impressions at an earlier stage. A good approach would be to show the impact of bringing water into a community by doing it together with other projects such as building houses or introducing small industries.

69. The CHAIRMAN did not think this was really feasible. There was great jealousy between disciplines. If an engineer started to talk in the company of economists on economic matters he would, as a matter of policy, be held down and vice-versa. There was not enough tolerance of other peoples' views. He said it was noticeable over a few years when he was involved in the semi-political side how quite good ideas came from people outside the professionn but there was a big difference between ideas and being able to do it. People from outside could often provide ideas but could not do them and it was the expert who had to choose which ideas were practicable. However, engineers had a responsibility to know something about the scene around them and have ideas about that.

70. The CHAIRMAN thanked everyone taking part in the discussion over a wide range of topics. He especially thanked Mr Wood for the enormous amount of effort he had put into writing the paper and for introducing it.

WRITTEN CONTRIBUTION BY Mr K.G. STRATFORD

Due to the limitations of time the Chairman closed the discussion on the maintenance problem at a point where training had been raised. The suggestion that the firm of design engineers should return after a period of time to evaluate plant behaviour is not always applicable.

I have in mind a case where the water supply installation of an equatorial town of some 175 000 consumers had been well designed and operated decades ago but today the metered consumers only get about one third of the quantity they require and are prepared to pay for. The quantity they do get is about half of that put into the system at the source treatment works. The source of the supply is virtually unlimited but due to disrepair, leakage and a large number of useless meters together with a steady deterioration in the physical state of the works and its management, the undertaking cannot be a self-supporting and reliable enterprise without a drastic re-organization of its management systems.

The deficiencies in waste detection, meter repairs, budgeting for maintenance and renewals, control of operational efficiency and so on are evident, but so is the absence of provision for training and retaining the right staff to operate the system as an ongoing process - training especially for those who have the responsibility for recruiting and managing the maintenance staff.

Perhaps donor organizations could do more in this field to encourage off-the-job training so that the leaders in such undertakings may see the benefits of operational techniques as applied in developed nations. Such techniques may never fit the local situation but the leaders would be motivated to return to their own situations with a greater enthusiasm for initiating improvement and change.

S.V. PATWARDHAN

low cost water treatment for developing countries

INTRODUCTION

Developing countries in hot climatic regions have some major problems in common. India is the largest country by size and by population in this group. Problems of India are, therefore, likely to be representative of the problems of the countries in this group. Some of the major problems faced by India are:

1. Limited capital resources with nearly unlimited demand for capital investment in diversified fields making it difficult to fix priorities.
2. Lack of appropriate technology (in different fields including water treatment) to suit the prevailing conditions(1).
3. Large variations in temperature (season and location wise).
4. Cost and availability of power, materials and labour is in reverse order to that of industrialized nations.
5. Shortage of skilled and trained personnel.
6. Inadequate facilities for repairs, maintenance and communications.
7. Large scale unemployment or under employment of unskilled labour.
8. Large number of small isolated rural sectors (Table 1) (out of 550 000 villages 380 000 have populations of less than 500)(2). The majority of people of the rural sectors are illiterate, tradition bound, and poorly informed about advancements in science and technology.

Table 1 Population Percentage in Rural Sectors.

Industrialized Regions				Developing Regions				
N.Am.	U.S.S.R.	Europe	Average	INDIA	S.ASIA	E.ASIA	Lat.Am	Average
26.6	43.7	36.5	34.4	80	76	74.5	31.2	73.8

9. A large back-log in the provision of basic amenities in the rural sector resulting in a higher rate of migration to the urban sector.

10. Larger rate of population growth as compared to the industrialized nations(3) (Table 2).

Table 2 Population Growth Rate 1960 - 1970

Industrialized Regions				Developing Regions				
N.Am.	U.S.S.R.	Europe	Average	INDIA	S.ASIA	E.ASIA	Lat.Am	Average
17	18	8	13	22	27	19	34	25

These problems have considerable impact on the status of water supply and sanitation facilities in a country. The gravity of the impact will vary from country to country depending upon the availability of resources, population densities, education level and relationship with industrialized countries. The impact on the Indian scene, especially in the field of water treatment, can be summarized as follows:

1. Due to inadequate capital resources and pressing demands from agriculture, industry, education, family planning etc, in the first five 5-year plans, water supply and sanitation has received lesser priority (Table 3). The rural sector, though four times larger in population than the urban sector, has received very small allocations in the first four plans. The fifth plan, however, shows a slight reversal. The majority of the rural sector is still not covered with protected water supply. Out of 567 163 villages 28 830 were proposed to be covered till the end of the sixth plan.

Table 3 Capital Investment Allocations for Water Supply and Sanitation (In 100 000 Rs.)

Plan	I	II	III	IV	V
Urban sector	12.72	57	80.84	285	439.35
Rural sector	6.0	28	16.63	131	564.23
Total plan outlay	2356	4500	10 400	*15 904	37 250
Percent of total	0.8	1.9	0.9	2.6	2.7

(*Provisions for agriculture and transport were 2728 and 3287 respectively)

2. Due to lack of appropriate intermediate technology the bias is towards adopting the more sophisticated 'Western' solutions. In the last few decades conventional rapid sand filtration plants have become more common. A survey of ten representative water treatment plants carried out by NEERI nagpur(4) revealed the following:

   a) More than fifty percent of plants had rapid sand filters and others had a combination of slow sand and rapid sand filters.

   b) In eighty percent of the plants alum dosing equipment was out of order and very unscientific methods were adopted for dosing alum.

   c) Sedimentation and pretreatment practices greatly varied. At some places sedimentation tanks were breeding grounds for molluces and sponges.

   d) In fifty percent of plants chlorine dosing equipment was out of order. In most of the plants capacities were inadequate for adhering to break-point chlorination or prechlorination.

e) Counts of coliform and fecal streptococci were often recorded in finished waters.

f) Filtrate turbidity ranged between 1.3 to 7.2 mg/l.

3. Due to paucity of funds sizes of treatment plants and water supply schemes are kept to the minimum (130 to 220 l/p d for towns and 50 to 75 l/p d for rural areas). The majority of the plants for towns have capacities between 8 to 30 Ml/d while those for rural areas have capacities between 0.5 to 5 Ml/d. For conventional rapid sand filter plants, cost per Ml/d varies inversely with plant capacity. A plant with higher than 50 Ml/d capacity is likely to cost £5000 per Ml/d while that with 10 to 25 Ml/d capacity may cost £6000 to £7500 per Ml/d. The cost of plants smaller than 1 Ml/d may be as high as £10 000 per Ml/d.

4. The migration from rural sector to urban sector has adversely affected the agriculture oriented economy. The slums in urban areas are growing. The conditions in the rural sector become unstable and unpredictable, and in certain cases population is decreasing. Due to unprotected water, water-borne diseases still take a major toll. The only remedy is to provide the basic amenities including safe water supply and sanitation facilities to the rural areas without any further loss of time.

5. In nearly all the cities water is supplied only for a few hours a day. This has not only adversely affected the rate of development but has made it difficult even to sustain the present growth. Ever-growing population and growing slums in cities are rapidly worsening the situation. The problem has to be faced and effectively solved.

6. Due to hot climatic conditions, exposed large areas of water (such as in large settling units and slow sand filter units) give rise to problems of algal growths and to breeding of insects and micro-organisms. The temperature of a large water mass usually differs from the temperature of influent water which causes short circuiting and allied problems. Dust storms and cyclones cause wave action and dust pollution problems. Due to rise in temperature during the day time, floc and sludge particles get entrained with air bubbles and are difficult to retain in settling units. Solubility and reaction rates of chemicals are affected. Considerable water losses are also likely from large exposed water surfaces.

7. Rainfall is quite heavy and occurs within a short specific period of the year. This causes large fluctuations in the quality and quantity of surface sources. The large amount of suspended load causes silting of water channels in the treatment plants and blocking of valves, sludge pipes and other equipment. Turbidity load is also very high during these periods.

The above discussion leads to the following conclusions:

1. The rate of providing water supply and sanitation facilities in developing countries needs to be increased manifold.

2. The conventional water treatment plant commonly used in industrialized countries is quite costly and has not proved suitable to the conditions prevailing in these developing countries. An effective alternative has to be found.

3. To meet the challenge effectively, it is necessary to develop an appropriate intermediate technology.

This paper is a humble effort to suggest some approaches for developing such an appropriate intermediate technology in the field of water treatment for the developing countries with hot climatic conditions.

REQUIREMENTS TO BE SATISFIED

1. Reduction in Cost. In the words of Lord Rutherford 'Americans (industrialized nations) have money, we have none hence we have to think'. The cost of water treatment plants, especially for small capacity plants, will have to be brought down to one third or one fourth (£2500 to £3000 per Ml/d) so that three to four times more population can be covered in the same allocations. However, low cost treatment does not mean low quality treatment. It means that ways and means have to be found to reduce cost without sacrificing quality.
2. Use of local material (such as construction material, filter media etc.) should be made possible.
3. Power requirements and requirements of chemicals should be kept to the minimum.
4. Finished water quality should not deteriorate with time.
5. To reduce undesirable effect of hot climate, large exposed water surfaces should be avoided.
6. The plant must be simple to operate and mechanical equipment should be kept to the minimum (nearly nil).
7. Costly and complicated controls should be eliminated.
8. Plants should be more sturdy and reliable. As chlorination cannot be fully relied upon, higher bacterial removal efficiencies should be aimed at in pretreatment and in filters.
9. To reduce cost and time in erection and installation a single unit treatment plant which could be prefabricated should be aimed at.
10. To avoid double pumping it should be possible to install the entire plant into a pressure system.
11. Chemical dosing equipment should have a wide range for dose adjustment. Dosing should automatically stop (during power failures) when the flow to the plant stops. The effect of temperature on the solubility of chemicals should not cause inaccuracies in dosing. The effect of chemicals on equipment parts (corrosion, deposition etc.) should not affect the accuracy of the dosing equipment. Unskilled or semi-skilled labour should be able to rectify it whenever necessary.
12. The plant should have adequate arrangements to deal with heavy silt and suspended load wherever it is expected.
13. Depth and other dimensions should be flexible to achieve economy under local conditions.

PROPOSED APPROACHES

Economical and adequate ground-water is not available at many places and so tapping of surface sources becomes necessary. Depending upon the major conditions affecting the treatment required, the sources should be grouped and an economical treatment process should be evolved to suit the particular group. The surface water sources available in India could be grouped in the following categories:

GROUP A Sources where turbidity is below 20 mg/l for nine to ten months of the year and seldom crosses the limit of 100 mg/l. Chemical impurities are within tolerable limits. No serious algal colour or odour problems exist.

Springs and Khadas (small streams through rocky areas) in hilly areas of Punjab, U.P., Himachal Pradesh and other states, comparatively clear tail waters of power houses (like that of Koyana, Bhira etc.), waters of shallow wells and high level storage reservoirs and lakes fall in this group.

GROUP B Turbidity is below 50 mg/l for about eight to ten months but for the remaining months it rises very high even beyond 3000 mg/l. Suspend load and silt load is also heavy. Chemically the quality conforms with permissible standards. Pollution is moderate because high dilution is possible.

Ganga canal and other similar canals, rivers receiving melted snow, reservoirs in catchments receiving heavy rains (like that of Vaitarna) fall into this category.

GROUP C Turbidity is usually higher than 100 mg/l and varies considerably during the year. Pollution is of higher degree, but problems of odour and colour are not serious.

Rivers taking sewage of cities and towns or where rains are well distributed over the year fall into this category.

GROUP D Sources where serious algal problems exist or where certain chemical contaminants or toxic materials need to be dealt with.

Certain pockets of Rajasthan, Gujarath, Orrisa, Assam, Tamilnadu, Maharashtra, have such situations. In some places salanity is of the order of 1500 to 3000 mg/l, fluorides are beyond 4 mg/l, iron and manganese beyond 5 mg/l.

In India the majority of the sources fall into the first two groups.

APPROACH SUGGESTED FOR SOURCES IN GROUP A

For sources in this group a single unit treatment using a suitable filter should be possible. To develop a filter unit to suit all the sources in this category may not be possible and economical, and therefore, a flexible design approach has to be developed. For a small village the unit has to be very simple, which can give longer length of runs and which can be locally fabricated using local materials. If it is not attended the quality should not deteriorate, though the quantity may get reduced. For higher altitudes a prefabricated compact unit which can be easily transported has to be developed. The quality of the sources may considerably vary from place to place and economy could be achieved if the design is flexible enough to take advantage of favourable situations. The presently used conventional rapid sand filters or even slow sand filters have nearly a standard design and need a particular quality of influent for succesful operation. However, to achieve economy a flexible design to suit the conditions of the source will be required. To develop a filter unit that will be most economical and suitable under specific conditions, proper understanding of filtration mechanism and parameters and relationships to measure and predict the filter performance have to be developed. A comparatively easy design procedure can then be evolved. Presently available information could be made use of for this purpose and if necessary research work has to be undertaken to evolve a sound and simple design procedure. The author had an opportunity to devote some years to this purpose and design approach evolved is presented in brief:

To measure filter performance a filter coefficient

$$\lambda_o = \frac{\log_e c_o/c}{L} \qquad \ldots(1)$$

has been commonly used(5,6). It has dimensions of L^{-1} and it is dependent on media grain size 'dm'. The author has suggested a new filter coefficient called the 'filter coefficient of contact', denoted by 'E'(7). It is defined by the relationship

$$(1 - E)^n = \frac{c}{c_o} \qquad \ldots(2)$$

c_o - initial concentration

c - concentration after 'n' contacts

n - number of contacts or media grains along the flow line given by L/dm where dm is the media grain size.

L - length of filter media along the flow

The filter coefficient E is dimensionless and is nearly independent of media grain size and hence is more suitable where local sands with varying grain size will have to be used (Table 4).

Table 4 E_o and λ_o for different filter columns (for nearly the same value of n)

Grain size, mm	2	1.41	1	1.41+0.6	2+0.6	1.2+0.6
Length, mm	500	350	250	350+150=500	300+200=500	400+100=500
n	250	250	250	500	484	500
c_o	46	46	46	41	41	41
c	13	13	11	0.15	0.21	0.15
Rate - v *m/h	5.4	5.4	5.4	5.4	5.4	5.4
E_o	0.00506	0.00502	0.00506	0.00118	0.0117	0.0118
λ_o	0.02	0.0316	0.049	0.112	0.106	0.112
Alum mg/l	nil	nil	nil	20	20	20

*m/h = cubic metres/square meter per hour 1 m/h = 1.67 cc/sq cm per minute

(Only coagulated water was used as filter influent. E_o and λ_o are values of respective filter coefficients for clean beds.)

The most significant removal mechanisms in filtration of water through sand are:

1. Mechanical straining
2. Sedimentation
3. Coogulation and electrokinetic phenomenon.

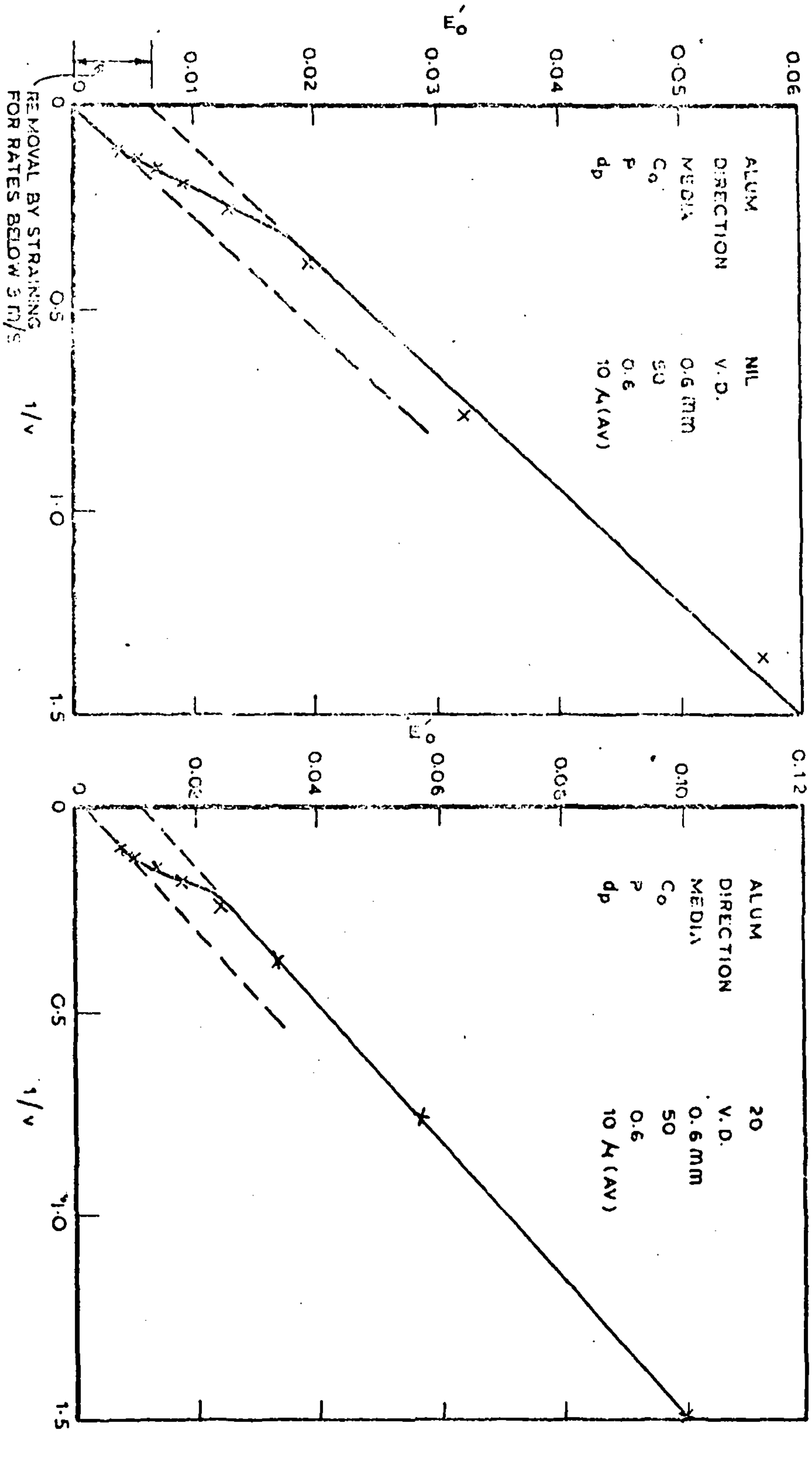
The contribution to removal by mechanical straining could be obtained by using the relationship

$$(E_o) Str = 3.5 \left(\frac{dp}{dm} \right)^{\frac{3}{2}} \qquad \ldots (3)$$

dp - size of particles in suspensions.

To avoid deterioration of quality with the length of run, and to achieve higher bacterial removal by the formation of a mat similar to that in slow sand filters 'dm' has to be properly chosen. The value of E_o is nearly inversely proportional to the rate of flow v. So an appropriate rate of flow can be chosen to suit the sand that is available in the local area. Figure 1 gives the variation of E_o' (value of E_o corrected for the effect of 'n', depth and rate of flow (v)). From Table 4 and figure 1 it can also be seen that by using a suitable dose of coagulant, a higher value of E_o could be obtained. Alum dose increases head loss and forty percent of the optimum alum dose found by jar test gives the optimum filter performance(9).

Figure 1 VARIATION OF E_o' WITH 1/v (FINE SAND)



The head loss at any time during the filter run could be estimated by the relationship

$$H - H_o = K\sigma \qquad \ldots (4)$$

H - final head loss

H_o - initial head loss

σ - specific deposit (by volume)

K - a constant

Removal by mechanical straining is not very much affected up to the rate of flow of 3 m/h (7) (figure 1). The following design procedure is suggested:

1. Some trial runs should be carried out with the water to be treated using a standard filter column. A filter column with 1 mm sand 100 mm deep can serve the purpose. The rate of flow on this filter could be maintained at 6 m/h. Raw water coagulated with 40 percent of optimum dose (as given by the jar test) should be used.
2. From the data collected the value of E_o (filter coefficient of contact for standard filter column) and the value of K should be estimated.
3. By using the following relationship(7) a suitable filter design to give the desired value of filtrate quality could be arrived at.

$$E_o = E_o \left(\frac{N_1}{N_s}\right)^P \cdot \frac{v}{v_s} \qquad \ldots (5)$$

N_s - operational number of standard filter $\left(= \frac{L}{dm_s v_s} = \frac{10}{0.1x10} = 10\right)$

N_1 - operational number of proposed filter $\left(= \frac{L}{dm \cdot v}\right)$

E_o - filter coefficient of contact for proposed filter

v - rate of flow in the proposed filter

P - a constant (average value 0.55)

L - length of media in the proposed filter

If the value of K is obtained for the sand to be used, and for the rate of flow adopted, the head loss at any time during the run could be estimated.

Thus it will be seen that by using local sand and local material it should be possible to design a filter that can suit the local conditions. If the sand size is kept about 0.5 mm and rate of flow is kept between 1.2 to 3 m/h it should be possible to obtain the desired filtrate quality throughout the entire length of filter run. Table 5 gives the performance obtained with fine media low rate filter columns.

Different types of filters that have been tried either with a laboratory scale model or with a pilot plant are shown in figure 2 to figure 5.

<u>Fine Sand Low Rate Filter</u> (Figure 2)

In this filter the sand size could be from 0.3 mm to 0.55 mm. The depth of sand bed will be between 150 and 300 mm depending on the sand size. The rate of flow could be between 1.2 and 3 m/h depending upon the influent quality, sand size and final head loss desired. The depth of filter tank could be kept between one to two metres depending upon the local conditions. The rate of flow does not vary appreciably and so an automatic rate controller is not required. Initially the water level in the filter could

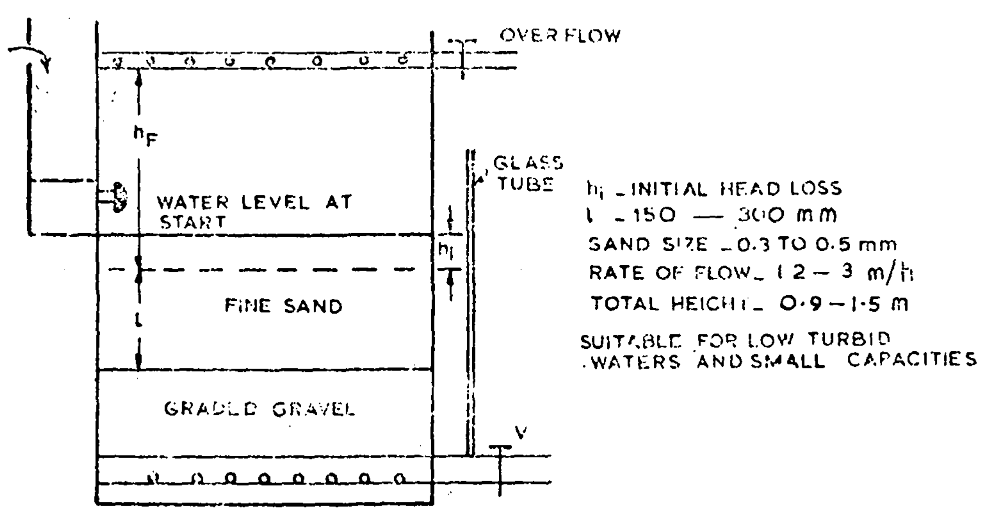
Table 5 Performance Data for Fine Sand Low Rate Filters (Laboratory Studies)

C_o 40 to 50 mg/l Alum 20 mg/l Temperature 15^{o} - 19^{o}C.

Time after start in min	A. Sand - 0.55 mm uniform Rate - 3 m/h Depth - 300 mm		B. Sand - 0.4 mm Rate - 1.8 m/h Depth - 150 mm	
	C	Head loss mm	C	Head loss mm
0	1.5	100	1	60
120	0.5	110	0.3	70
240	0.2	120	0.1	78
420	0.15	150	nil	170
720	0.15	200	nil	380
1080	0.1	330	nil	700
1440	0.1	400	nil	900

be kept a few inches above the sand top and flow adjusted with an outlet valve. If the influent rate is controlled the level on the filter bed will rise as clogging proceeds and the discharge will be nearly constant. If the filter remains unattended it will start overflowing, and the discharge will be reduced but the filtrate quality will not deteriorate. The filter could be cleaned by scrapping the upper layer of sand and replacing it, or by surface jets or by back wash. It is suitable for small communities where low turbidity waters are to be treated.

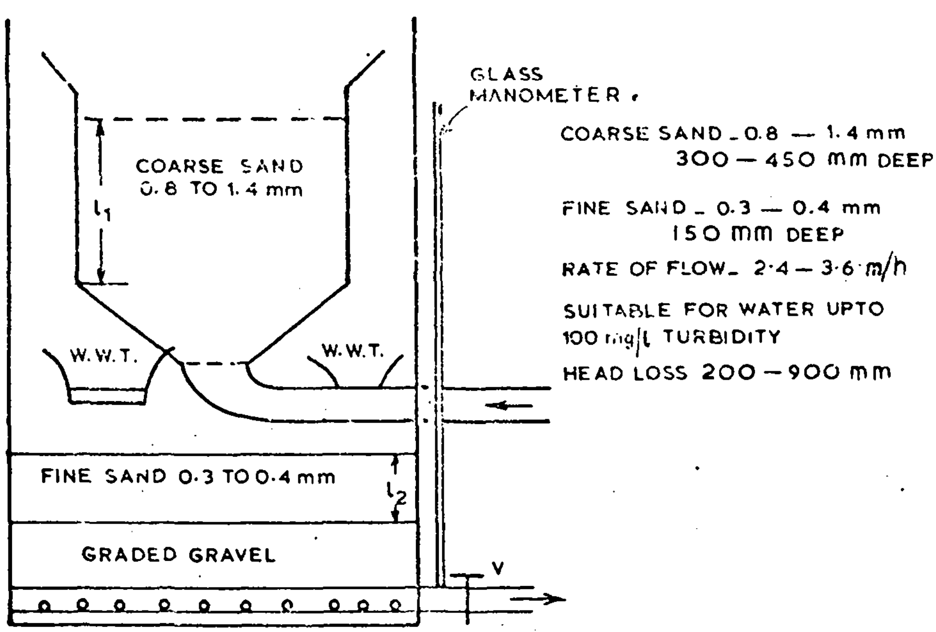
Figure 2 LOW RATE FINE SAND FILTER



Stage Filter (figure 3)

When the turbidity is likely to be higher (up to 100 to 200 mg/l) a stage filter will be more suitable. The coagulated water is first filtered through coarse sand (0.8 to 1.4 mm) and then admitted to a bed of fine sand (0.3 to 0.4 mm). The filter could be operated at 1.2 to 4.8 m/h rate of flow depending upon the turbidity of raw water. A filter of the size of the oil drum (0.6 metres diameter and 0.9 metres high) can give a yield of 10 to 15 l/min. The cleaning is done by back wash process. For coarse sand raw water could be used for back wash. Due to the conical shape of the central drum it is possible to wash the coarse sand at lower pressure and less rate of flow than usually required. This filter gave very satisfactory results during pilot plant studies, giving an effluent of less than 0.5 mg/l turbidity throughout the run of 1440 minutes. The influent turbidity varied between 50 to 100 mg/l and the rates of flow through coarse and fine sand were 6 m/h and 3 m/h respectively. The final head loss in coarse sand was 220 mm and that in fine sand was 250 mm. The coarse sand column acted as a prefiltration unit for a period of about six hours, but after that it acted as a flocculation and settling unit. Good size dense flocs could be seen coming out of the coarse sand bed which were settling on the top of the fine bed. The size of these flocs was of the order of 0.1 to 0.5 mm and they could settle against a vertical flow of 6 m/h. At first the head loss in the coarse sand bed gradually increased up to 220 mm but later on it was nearly constant at this value. Similar observations have been independently reported by Kardile(12).

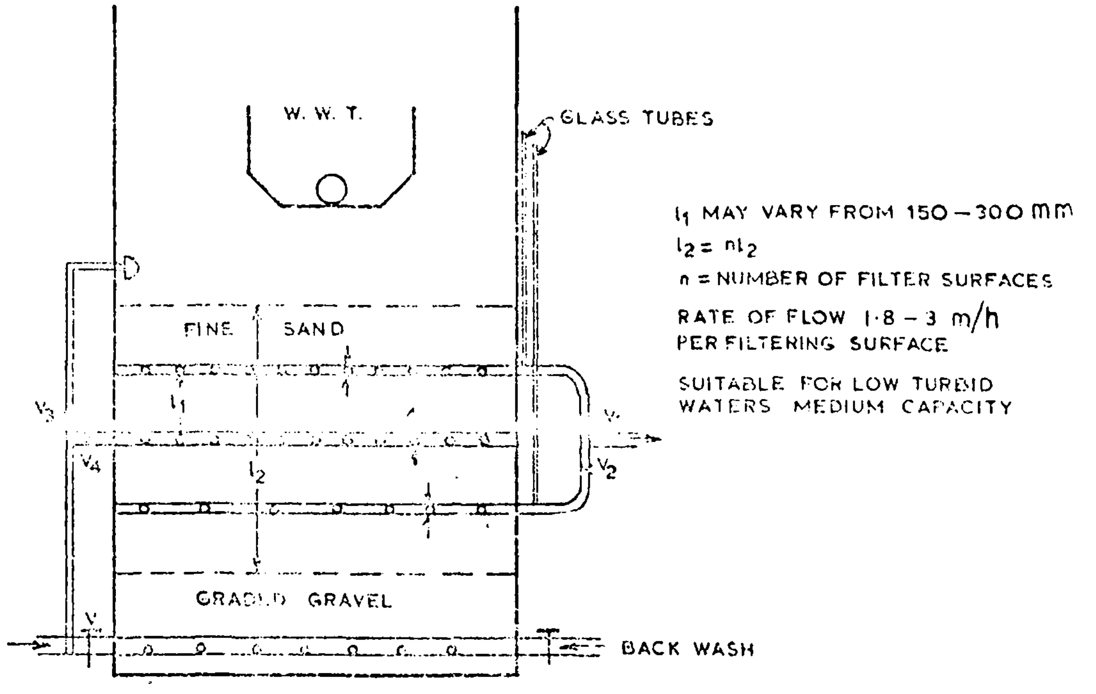
Figure 3 STAGE FILTER



MIMO Filter (figure 4)

When a filter of larger capacity is needed to treat low turbid waters, the MIMO (multi inlet multi outlet) filter is quite suitable. In this case raw water (coagulated) is admitted at different levels in the sand bed and filtered water is also withdrawn at different levels. Though the filtration rate is low, the yield per square metre of occupied area increases with increase in depth. Due to a lower rate of filtration better quality filtrate is obtained. The head loss could also be kept at any desired level. In pilot plant scale studies (0.4 Ml/d) the filter gave very good performance. With an average turbidity of 50 mg/l the effluent turbidity was less than 0.5 mg/l at a rate of filtration of 2.8 m/h. As the filtration area used was four times the plan area the total yield was 11.2 cubic metres/square metre per hour. It gave a head loss of only 450 mm after a continuous run of 27 hours. The filter was also successfully subjected to a shock load of 500 mg/l turbidity for about ninety minutes.

Figure 4 MIMO FILTER



Graded Horizontal Filter (figure 5)

This filter is suitable when higher capacities are needed to treat waters with a medium turbidity load (100 mg/l). In this case the flow direction is mainly horizontal. Table 6 shows the effect of direction of flow on filter performance.

It will be seen that the horizontal flow direction gives better performance than other flow directions. The yield per unit of occupied area could be increased by increasing the depth. Though graded material is used, different types of media are not needed as in the case of multilayer filters. The size of media and grading can be chosen to suit the performance desired and need not depend on back-wash water requirements as in the case of multilayer filters. Thus it will be seen that the horizontal graded filter can have wider applications. A radial horizontal filter named as 'the Simater continuous sand filter'(13) has also been used successfully.

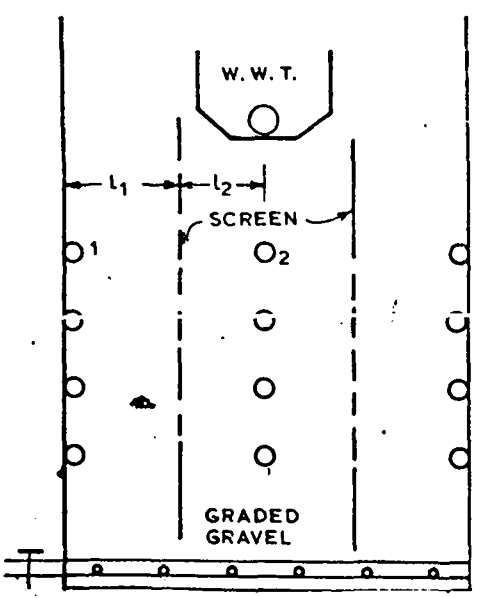
Other types of filters that could be used with advantage are up flow or contact filters, dual or multi-media filters or a combination of pre-filter and a dual media filter. At Ramteek, Nagpur(12) a 2.25 Ml/d capacity plant has been constructed in April 1972 which consists of a pre-filter unit of packed gravel and a dual media filter using crushed coconut shell instead of anthrasite. The crushed coconut shell is much cheaper than anthrasite and will be locally available in most of the places on sea coast areas. It has a specific gravity of 1.4 to 1.5 when soaked in water. It is nearly inert to dilute HCL and the loss of weight after 100 hours of back-wash is less than one percent(14). The plant is giving good performance at a designed rate of 0.77 m/h. It has cost only £6250 (or less than £3000/MLD). It has no costly equipment or controls.

In most of the above filters automatic rate controllers could be dispensed with. Simple glass tube manometers could be used to adjust the desired discharge. These filters could be covered and can be installed in a pressure system. In India amoebic dysentery and other water-borne diseases are still quite common. Chlorination could not be completely relied upon, as much higher bacterial removal efficiency is very desirable. When coagulated water is passed through fine sand beds at low rates a high bacterial removal efficiency is achieved. Hence low rate finer sand and minimum pretreatment should be the key words for filter design in developing countries which are just opposite to the slogan 'higher rate, coarser media and efficient pretreatment' presently adopted in industrialized countries.

Table 6 Effect of direction of flow on filter performance.

	Sand: 0.6 mm diameter Depth: 500 mm Filtration rate: 6 m^3/m^2h Alum: 15 mg/l Initial turbidity, C_o: 60 mg/l				Sand: 1.0 mm diameter Depth: 500 mm Filtration rate varied Alum: 20 mg/l Initial turbidity, C_o: 40 mg/l				
	Head loss			Average filtrate	Filtration rate m/h (m^3/m^2h)				
Flow direction	Initial H_o mm	Final H mm	length of run minutes	turbidity C mg/l	1.2	2.4	4.8	7.2	8.4
					Filtrate turbidity, C mg/l				
Vertical upward	312	1300	500	0.8	0.25	0.39	1.5	7.3	9.8
Vertical downward	317	1800	600	0.3	0.14	0.29	1.0	3.3	5.8
Horizontal	310	1100 1770	600 1000	0.3 0.35	0.1	0.19	0.8	2.5	4.0

Figure 5 GRADED HORIZONTAL FILTER



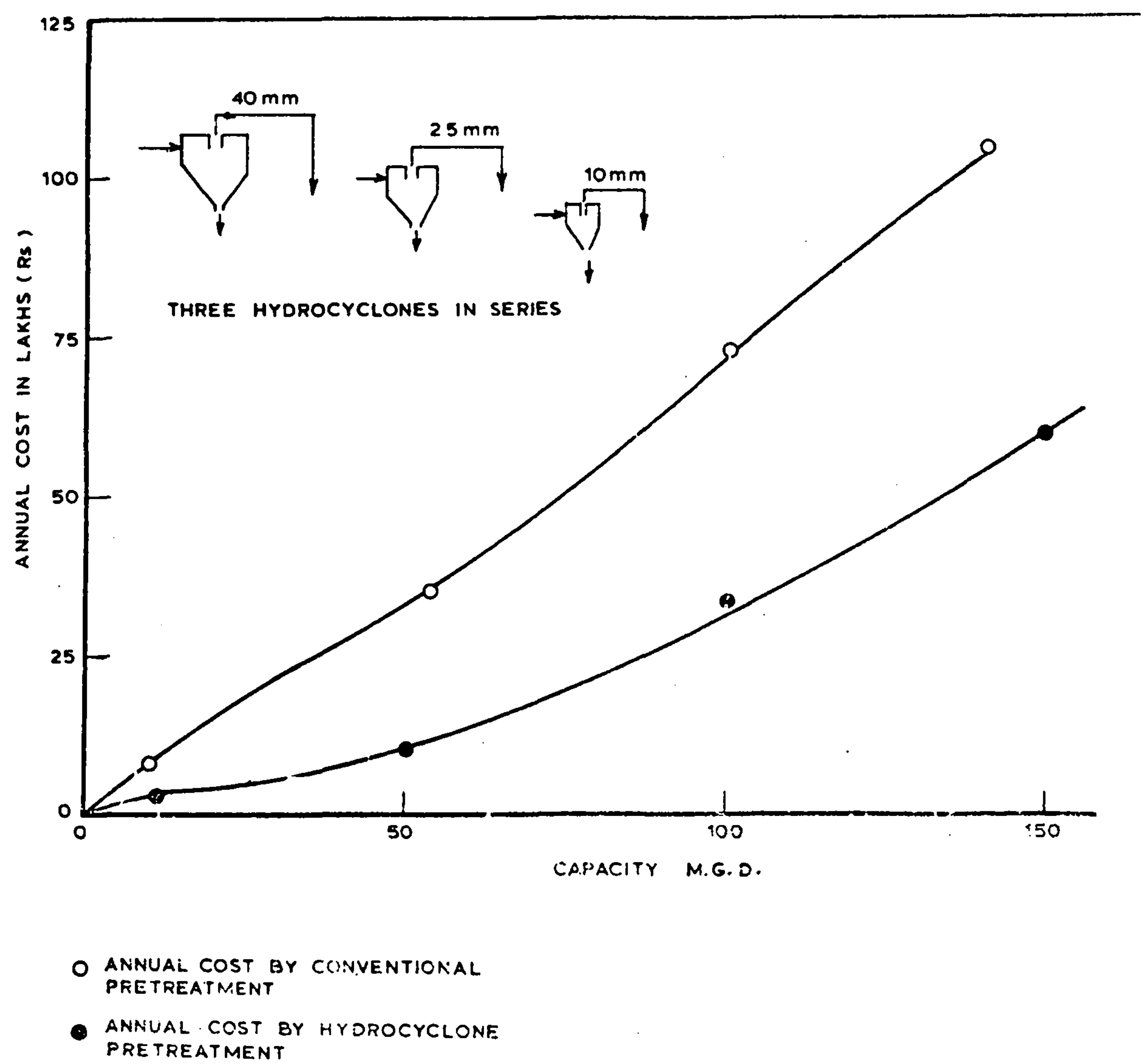
1_ INLET PERFORATED PIPES
2_ OUTLET PERFORATED PIPES
l1_ COARSE SAND 0.8 — 1.4 mm
l2_ FINE SAND 0.35 — 0.5 mm

SUITABLE FOR MEDIUM CAPACITIES
(UPTO 100 mg/l TURBIDITY)

TREATMENT APPROACHES FOR SOURCES IN GROUP B

For the sources in this group high turbid waters are likely to be met with for a few weeks in a year. A complete conventional pretreatment will not be needed for most part of the year. A suitable alternative requiring lesser capital cost should be evolved to deal with this problem effectively. One of the approaches is to use a series of hydro-cyclones as pretreatment units. A hydrocyclone can take a load of 600 to 4200 m/h as compared to 1.2 to 9 m/h in the case of conventional settling units (15,16). Due to such high loadings, capital cost and space requirements are reduced to a substantial extent. Though a hydrocyclone needs a higher pressure (0.6 kg to 1.6 kg/sq cm) no coagulant is needed. It has no moving parts and needs very little maintenance. Experiments carried out at Roorkee(16) showed that particles as small as 3 microns and specific gravity 2.65 could be removed and an efficiency as high as 88 to 90 percent could be achieved by using suitable hydrocyclones in series. Figure 6(16) shows the comparison of annual cost for pretreatment by hydrocyclone and by conventional units. The other approach may be to use shallow depth settling units like tube settlers, with continuous sludge removal arrangements.

Figure 6 COMPARATIVE ANNUAL COST OF PRETREAT



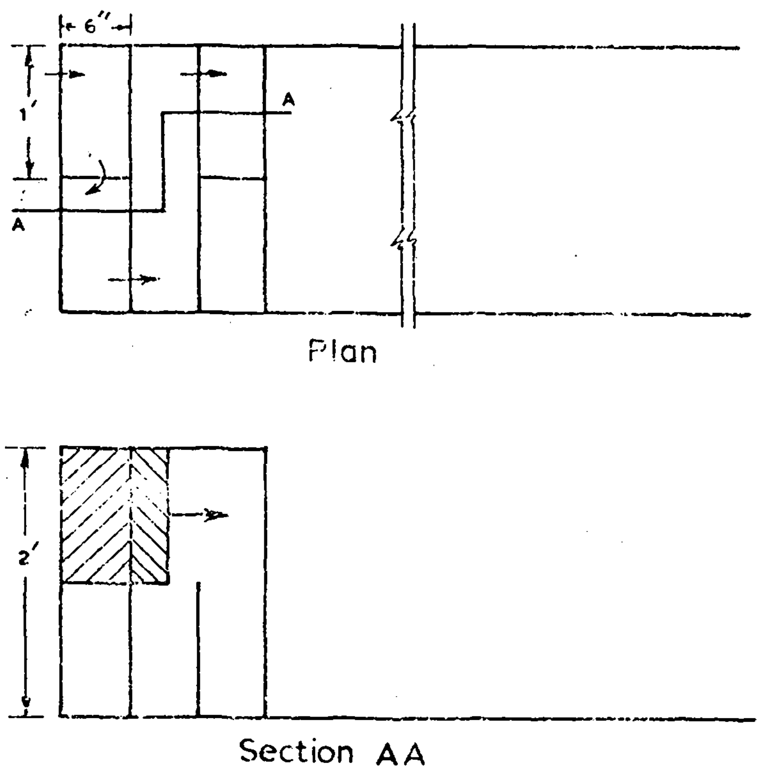
APPROACH FOR TREATMENT OF SOURCES IN GROUP C

In these sources high turbidity and pollution may continue for a major portion of the year, and full pretreatment may be necessary. The mechanism of flocculation is now better understood. Camp(17) showed that if the velocity gradient (r.m.s. value) is kept in the range of 20 to 40 per sec. and if 30 to 40 minutes time is allowed for flocculation good results are obtained. The author(18) has shown that if effort is made to distribute power uniformly over the entire section of the flocculation chamber and if more quantity of water per unit of power consumed is moved in the chamber, the time and power required could be reduced. If baffled channels are designed with this new approach they could be suitable for small capacity plants. A baffled channel flocculator (0.4 Ml/d flow) with a velocity gradient of 20/sec. and a detention time of ten minutes gave satisfactory results (figure 7). Another approach that has been tried is allowing an upward flow of water through a column of suitable solid media. The velocity gradient can be obtained by the relationship

$$\bar{G} = \sqrt{\frac{g\,h}{\nu\,t}}$$

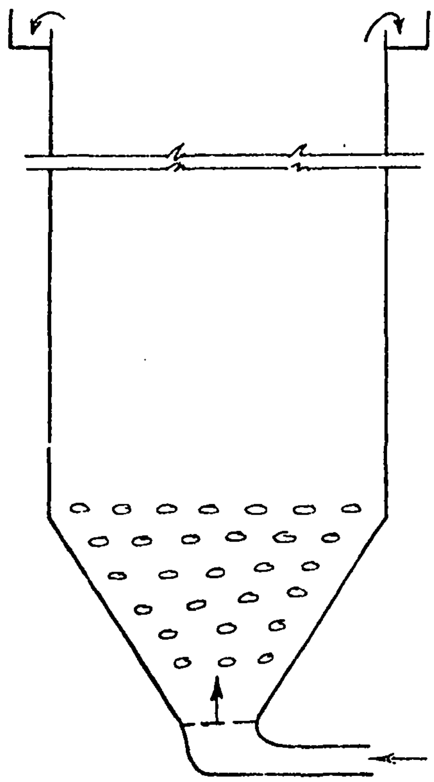
where 'h' is the head loss, 't' is the time of detention and ν is the kinematic viscosity.

Figure 7 BAFFLED CHANNEL FLOCCULATOR (1 Ml/d)



By properly choosing the type of media, its size and flow rate, the desired range of velocity gradient can be obtained. Good dense flocs were obtained by passing pre-coagulated turbid water through a 4 mm gravel bed, 600 mm deep at a rate of 24 m/h. In this case power will be distributed uniformly in the entire chamber. Both these flocculators have no moving parts and will need very little maintenance. These will be suitable for small capacity schemes. If an air compressor is available flocculation could also be achieved by the use of compressed air.

Figure 8 SOLID MEDIA FLOCCULATOR



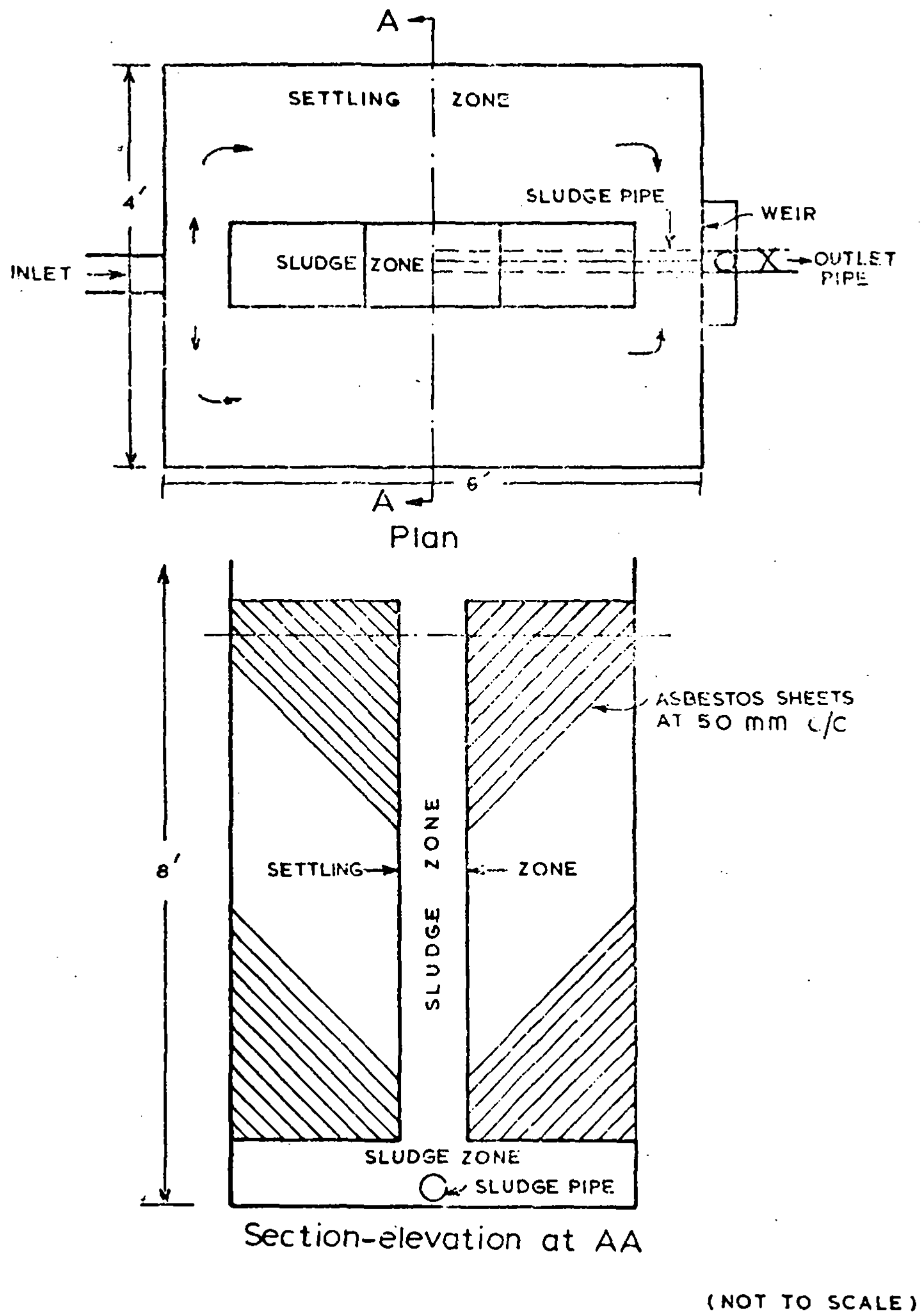
As regards settling units, mention has already been made of hydro-cyclones and tube settlers. Many other designs of smaller depth settlers could also be tried. A "Multi Bottom Settler" (figure 9) was tried both at laboratory scale (six bottoms) and pilot plant scale (36 bottoms). It could achieve an efficiency of about 80 percent with a detention time of six to eight minutes, (19). The sludge could be removed continuously. The unit is very compact and needs no scraper mechanism. It could be used under a pressure system. Any one of the above filters described could be used to treat the settled water.

Chemical Dosing Equipment

In all the above cases coagulation is required to be adhered to and chlorination will also be necessary. The present equipment for alum dosing needs three to four tanks for preparing alum solution, one constant level tank, some weir or valve and a float arrangement to adjust the dose. These units have not proved very successful. Due to deposits of aluminium salts or due to corrosion at higher temperatures the mechanism fails at one or the other point. A simple and sturdy dosing equipment which will need much less attendance and in which the dose will vary with the discharge is needed. It should also have a wide range for dose adjustment. Solubility of alum varies with temperature. It is as low as 55 g/l at 10°C and 90 g/l at 30°C. It should be seen that no error is involved due to this variation in solubility of alum.

The approach that can be tried is the parallel flow approach by using a saturated solution of alum. Figure 10 shows the arrangements that can be used with raw water inlet channels. The jar test will be performed by using the saturated solution from the alum chamber. If still conditions are reached at the raw water inlet of the dosing chamber the dose could

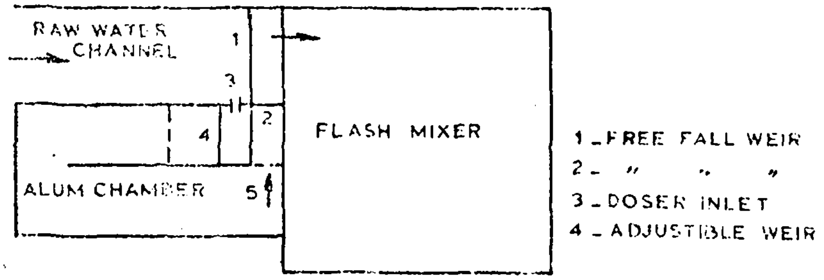
Figure 9 MULTI BOTTOM SETTLER



be adjusted by adjusting the width of the inlet weir. Other arrangements could also be made to control the quantity of water admitted to the dosing chamber. As the dose control is at the inlet it will not be affected by the alum solution. If the flow is stopped the level will go below the sill of the weir and dosing will stop automatically. Once the dose is adjusted it will vary with the discharge. Alum can be dumped into the alum chamber to the desired level and so no accurate measurement of alum will be needed.

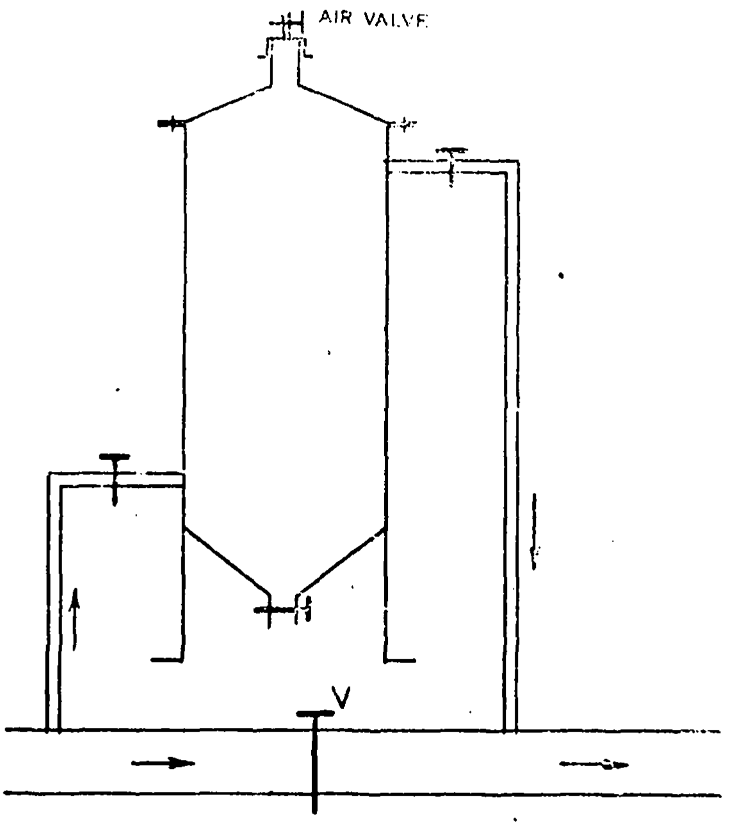
Chlorine dosing may need a different type of arrangement. In small capacity plants the use of bleaching powder is more convenient than chlorine gas cylinders, but it is difficult to obtain saturated solution of bleaching

Figure 10 PARALLEL FLOW CHEMICAL DOSER



powder. Beyond ten percent strength foaming occurs and particles of lime and bleaching powder become suspended. These block the openings used for dosing. Ten percent solution of bleaching powder gives about 30 000 mg/l residual chlorine. The dose of chlorine required is usually very small (0.2 to 0.4 mg/l) and little variation could be permitted in this dose. A pressure doser based on the principle of dilution was tried at Roorkee(20) to chlorinate a tube-well water supply of 90 cubic metres per hour (figure 11).

Figure 11 PRESSURE PARALLEL FLOW DOSER



In a forty eight hours trial the dose varied between 0.2 to 0.3 mg/l. It automatically varied with the discharge. The required capacity of the doser could be calculated by using the following relationship:

$$X_n = \frac{(C - Y)^n}{C} \cdot X_o$$

X_n - minimum concentration of dose to be maintained after 'n' minutes of operation, mg/l.

C - capacity of doser in litres

Y - rate of flow through the doser, l/min

X_o - initial dose of chlorine, mg/l

n - interval in minutes for recharging the doser

After 'n' minutes the doser will have to be recharged with concentrated slurry of bleaching powder. The precipitated lime could be removed from the doser by opening the valve at the bottom.

These dosers could be fabricated at site and are expected to give more reliable performance. Their cost will also be much less than the presently used dosers.

TREATMENT APPROACHES FOR SOURCES IN GROUP D

Very little work has been carried out and reported in India which can be grouped under Low Cost Water Treatment. Every source in this group has its own peculiar problems and a method or approach found suitable for one may not be suitable for the other. However, approaches adopted for some common problems can be discussed.

Due to ample sunlight and uncontrolled pollution of catchments, problems of algal and weed growth are met with at some places. Madras city stores river water in large reservoirs where algal growth takes place and due to decomposition of organic matter, odour troubles were noticed at the slow sand filters(21). Open swimming pools, large settling units, connecting channels, shallow wells and lakes often show abundant algal growths. Due to the poisonous nature and heavy cost of copper sulphate the common method employed is heavy prechlorination. A small preventive dose of copper sulphate and chlorine were tried on Roorkee University swimming pool with some success. At Bhilai in the tanks used for storing and recirculation of cooling water abnormal weed growths were noticed. Use of corrosive chemicals was not possible and Gramoxone and Sodium arsenite were unable to control the problem. Manual weed cutting was also inadequate. An equipment called 'Bengal Chaki' was found to be very useful(22). It consists of a steel pipe with short pieces of small size pipes welded to it at right angles to its major axis. All the pipes are sealed and if necessary, sealed empty drums are attached to the end of the pipe. The chaki was dragged through the reservoir by winch and coil arrangements and brought to the shore a truck load of weeds every time.

Problem of excessive fluoride contents have been reported from certain pockets of Rajasthan, Andhra Pradesh, Tamil Nadu, Maharashtra, Punjab and Haryana. Though extensive survey work has still not been undertaken the information available indicates that the problem is of a serious nature at some places. It is said that a place in Rajasthan has been named Bankaner (Banka - bent, Ner - man) as many people in that area have defective bone structures, probably due to excessive fluorides.

Conventional approaches of using phosphoric compounds, activated aluminia, activated carbon and exchange resins are quite costly and not suitable for small capacity plants. Efforts have been made by some workers(23) to evolve cheaper ion exchangers. Vankatraghavan prepared an ion exchanger by digesting paddy husk in 1 percent KoH solution and then soaking it with 2 percent alum solution. It was tried in some field plants with some success. NEERI, Nagpur(23) has developed an exchanger named Defluoron 2, a sulphonated coal which works on the alum cycle. It has been successfully tried in laboratory and field plants. The cost reported is about 3p per 4000 litres of water treated. The rate of flow used is 5 l/lh. The exchange capacity is about 650 mg of fluorides per litre of the medium (at bicarbonate alkalinity of 160 mg/l and a fluoride concentration of 8.1 mg/l). The exchange capacity decreases considerably with increase in alkalinity and decrease in fluoride contents. NEERI has also developed a simple and cheap chemical technique, called Nalgonda technique. In this, raw water is first treated with lime and then with alum and is then flocculated and settled. The fluorides are reduced to the required level. The cost to treat one cubic meter of water per mg/l of fluoride is about 0.2p. The method appears to be simple, cheap and suitable for small capacity plants.

Another common trouble met with in certain (especially underground) sources is a high content of iron and manganese. A tube-well near Howrah is reported to have iron contents as high as 11 mg/l(24). At certain places dissolved CO_2 is responsible for red water troubles. Some workers (24,25) have proposed some cheaper and simpler approaches for small capacity plants. Raw water is first sprayed over a bed of coke or charcoal so as to give a contact time of 15 to 30 minutes. Then this water is either passed through a coarse sand bed or is stored for a few hours. Finally it is filtered through a fine sand bed at a rate of 0.2 to 1.8 m/h. Such plants are working quite satisfactorily at some places giving 80 to 88 percent reduction in dissolved CO_2 and reducing the iron contents to about 0.1 mg/l.

Provinces like Gujarat, Tamil Nadu and Maharashtra have large areas under saline track. States like Punjab, Rajasthan and Haryana have pockets of brackish water. Villages in these areas have nearly no other fresh water source. The conventional approaches like distillation, ion exchange, freezing etc. are costly and not suitable for small capacity village plants. The counter-current ion exchange technique is reported to be 25 to 30 percent cheaper than the conventional technique(26). A tubular reverse osmosis plant has also been tried to treat dilute sea water(27) but it needs pressures as high as 40 kg/sq cm and special types of membranes. Efforts have also been made to harness solar energy. Solar still plants that were tried gave a utilization efficiency of 30 to 50 percent(28) but the yield is very low, about 2.5 l/sq m per day. The capital cost of these units is nearly prohibitive.

Thus it will be seen that simpler and cheaper methods have been evolved for fluoride and iron removal, but suitable alternative methods have to be evolved to deal effectively with the algal and salanity problems.

CONCLUSION

The discussions and observations presented bring out the urgent need for developing an appropriate intermediate technology to solve effectively the problems of developing countries, especially in the field of water treatment.

The single unit treatment approach suggested for dealing with sources in group A is likely to bring down the cost substantially. The new types of filters suggested are very simple and compact. The flexibility of design and the low rate philosophy will help to achieve better performance and considerable reduction in capital and maintenance cost. All costly controls have been dispensed with. As the height of the filter tank and the head-loss are controllable factors full advantage could be taken of local conditions.

For sources in group B adoption of hydro-cyclone or multi-bottom settlers will eliminate the need for large settling units. These units are very compact and have no moving parts. The use of baffled channel and gravel flocculators for sources in group C will make the pretreatment much simpler. The proposed chemical dosing units are also quite simple and reliable. Thus it will be seen that the approaches suggested fulfil most of the requirements stated earlier.

The work done at present is scattered and lacks proper planning and co-ordination. It will be worthwhile if the developing countries can establish a research centre for evolving an appropriate intermediate technology in the field of water and waste-water treatment.

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discussion

CHAIRMAN: Professor D.J. BRADLEY, MA, DM, FBiol
Director of Ross Institute

The CHAIRMAN felt the first session had left participants with the dilemma of costs of water supplies versus needs. As governments tried to supply more people with water and moved to groups which were poor even by local standards the projects became less financially viable. In most of the countries being considered, except those with oil, the health budget was about 50p per head per year to run the whole of the hospital and medical services. There were the added problems of access to water in many countries as well as quality.

2. The problems of water quality and the treatment of water were as great in India as anywhere in the world and the efforts made in India were more imaginative than in many countries. Professor S.V. Patwardhan had worked at Roorkee University, a hundred miles north west of Delhi, for over twenty years. He was professor and head of the department of public health engineering.

3. Professor S.V. PATWARDHAN said his paper was about low cost water treatment, but by no means low quality water. In developing countries the quality of water had to be given more emphasis than in developed countries, because in developed countries the problem of infections (dysentry etc) was very rare. In developing countries facilities for chlorination were provided but most of the time they did not work, so chlorination could not be relied on as a last line of defence. Therefore the only solution was to try and produce water which after treatment could go without chlorination if necessary.

4. Together with quality and the question of capital cost, the operating cost was equally important and an ideal plant should require low investment and low operating cost. Maintenance too was important: a plant might be installed with so much investment and then found to have been a waste. This was no use: there had to be reliability.

5. There should also be flexibility to adjust to different situations. It should be possible to develop a system which would satisfy all the needs. As a teacher, Professor PATWARDHAN knew it was easy to make a problem more complicated - sophistication was not so difficult: there was greater difficulty trying to simplify a problem.

6. He had divided the paper into four separate parts. First he had listed the problems which existed in developing countries; second was the effect of these problems; third, if these problems and effects were put together it would give the type of technology required; fourth were proposed approaches.

7. The first part had given some of the major problems - not all of them. The basic was investment availability and investment demand. It could be seen from Table 3 that meagre funds existed and often the demand from different sectors was unlimited, and fixing priorities was a very important and difficult problem, decided by conditions. Temperatures varied from place to place from season to season. In one place alone in a particular day the temperature may change by 15-20°C and the effect of this on physico-chemical processes must be considered. In some places 80% of rainfall took place in only two months and this could cause pollution, silting and high turbidity requiring extensive treatment plants. For the next ten months this investment could be lying idle.

8. The third problem Professor PATWARDHAN studied was the group comprising equipment, material and labour. There were inadequate facilities for maintenance, a surplus of labour and shortage of skilled personnel. In a certain town a specific equipment was not working and someone had to be fetched from 300 miles away to fix it, and the whole industry was closed for two days. So servicing of facilities had to be reliable at these places. Then there was large scale unemployment which in many ways affected the planning and design of works.

9. In India 380 000 out of 550 000 small villages had populations of less than 500. Most of the people in these areas were illiterate, poorly informed and superstitious. The question of consumer participation had been discussed during the first session yet this was difficult with these people. They were completely isolated without sanitation or housing.

10. Because of the shortage of capital, the approach was to provide as little water as possible so about 50-75 litres was provided in rural areas and about 100-150 litres per capita for urban areas. The cost of small plants was higher than large plants, i.e. it would cost £5000 per Ml/d for a plant having a capacity of over 50 Ml/d and up to £10 000 per Ml/d if a plant had a capacity of only ½-1 Ml/d. Because of the back-log, water provision facilities had to be provided at a much higher rate than the current demand.

11. Climatic conditions caused problems. Large masses of water exposed to sunlight had a higher temperature than the in-coming water and this caused short-circuiting problems. Another problem was that the temperature rose in the afternoon and sludge particles became entrained with air bubbles making retention difficult, and in many plants water going into settling tanks was better than that going out. Rainfall was another problem and the amount of silt brought by many rivers was so large that these plants sometimes employed about 20 people to clear the channels. The turbidity could go as high as 3000-5000 mg/l. Thus the problems to be faced in developing countries were quite different to those found in developed countries.

12. This then led to certain requirements. Firstly the cost must be brought down to the level of one-third so that for the same allocation there could be three times the rate of construction to catch up on the back-log. Smaller plants must cost less so that the smaller the plant the cheaper it would be: the challenge was how to do it. Secondly it was reported by NEERI that in 80% of plants alum dosing equipment was not working; in 50% of plants chlorine dosing equipment was not working. All these things must be considered when designing a plant. Professor PATWARDHAN said when a plant was installed and visited three years later it was usually not working. Thus he felt a treatment system was needed either where chlorine dosing was not needed or a system where it worked. Reliability and simplicity should always be important considerations because the operator could not always be relied on. There should be minimal mechanical equipment.

13. Mr M.A. AL-HASHIMI questioned the point about the rise in temperature causing the sludge particles to become entrained with air bubbles making retention difficult. He wondered if it could be that the sludge particles collected together, difficult retention being due to the particle size rather than the temperature.
Mr F.W. CROWLEY said this was a common phenomenon. In the Far East there was this tendency to boil up for no particular reason, mostly during the afternoon when sludge tended to come to the top. Various cures had been tried (e.g. covering with plastic table tennis balls) but it was not cured completely.

14. Mr H. MANN said the problem of suspension of sludge was a fairly common problem with tertiary treatment of sewage works effluents, and the kind of sludge deposited from river water in these conditions was probably very similar to the kind of organic material deposited in tertiary treatment lagoons. These lagoons were sometimes replaced by grass plot treatment or the installation of a shallow upward flow pebble bed in the top of the final sedimentation tanks. He wondered whether experiments with shallow upward flow gravel beds in the tops of sedimentation tanks had been contemplated.

15. Mr W.E. WOOD had sometimes found it helpful to sprinkle very finely powdered clay on the water when the floc was rising. This was only a temporary measure but it worked.

16. Professor N. MAJUMDER said he did not think desludging was done as periodically as it should and there could be cumulative effects in the lifting of the sludge. Professor Patwardhan had mentioned a very wide turbidity variation over a short period of time, but this was not typical only of developing countries: it would be true in any country where there was a monsoon or

heavy precipitation spread over a short period of time. The water of the Mississipi also gets very turbid.

17. Professor PATWARDHAN said flexibility in design was very important. Present filters were of standard designs and pretreatment was adjusted to suit the raw water quality requirements. Pretreatment cost was quite high and sometimes higher than filtration costs. If special flexible filters were developed their design could be adjusted to suit the raw water quality. At present, however, more work was being done to improve pretreatment for using high rate filters. He wished to reduce pretreatment as much as possible. This could only be achieved by adopting optimum rates of filtration to ensure reliability in output quality. To develop such filters it was essential to have a thorough understanding of filtration phenomena.

18. The approach discussed in the paper enabled filter efficiency to be predicted more accurately, and therefore a sound base was available for adopting flexibility in filter design. He had tried to analyse the possible types of source, as there was no one solution for all conditions. The first group of sources was the one where turbidity was generally below 20 mg/l and only occasionally rose to 50 or 60 mg/l. For this group he suggested single stage filtration. Different types of filters depending on the plant capacity could be used for the purpose, and details were given in the paper.

19. The second group was where the turbidity went up for a few weeks. The first approach was to use a series of hydrocyclones as pre-treatment units. It was found that particles as small as 3 microns and specific gravity of 2.65 could be removed and an efficiency as high as 88-90% achieved using suitable hydrocyclones. The surface area required was very small because it could take 200 times the surface loading. So small compact units and less capital investment were required. Figure 6 showed a comparison of cost for treatment by hydrocyclone and conventional units. The only cost was pumping, but no alum was required. The pump was required only for two months.

20. The third group was where turbidity was usually higher than 100 mg/l. For this group the solution was flocculation. If the velocity gradient was controlled better results were obtained. Less power was required. A flocculator was designed for a pilot plant with ten minutes retention time and gave good results. A second approach was the gravel flocculator. With this the flocs were smaller with better density and could be easily settled into a deep settler. Then there was the multi-bottom settler, which was a very compact unit which needed no mechanical equipment.

21. Another important consideration was chemical dosing equipment which had 80% failure. Usually the approach was to use 1-2% alum solutions in tanks. This caused precipitation and it had to be stirred. The lever provided for alum dosing always broke and after six months the dosing was out of use. What Professor PATWARDHAN suggested was shown in Figure 10. Alum solution coming out had a strength of 8-9%. Temperature had no effect on dosing. The unit required much less space, and no skilled operation. All that was needed was to dump the alum at a particular level. It was found in small plants that bleaching powder was most convenient for chlorination and a doser for this was shown in Figure 11. 10% strength was the maximum because above this particles became suspended and blocked the dosing openings. The dose varied between 0.2 and 0.4 mg/l.

22. In the fourth group the sources contained fluorides, irons and saline. He felt the approaches suggested for this group tried to achieve reliability, simplicity, less cost and easy operation.

23. Mr AL-HASHIMI agreed it was a good design for filters. Professor Patwardhan had mentioned the importance of flocculation of particles. The use of channels for flocculation was not efficient because the velocity gradient varied and so the size of flocs also changed and this affected the filters. Mr AL-HASHIMI knew there was a shortage of technicians and difficulty of maintenance but mechanical flocculation would maintain the flocs the same size and increase the efficiency.
Professor PATWARDHAN said modest flocs could easily be produced. The previous flocculators failed because they were not designed for changing velocity.

24. Mr M. SATHIAMOORTHY asked how often the fine sand filter should be cleaned by scraping. Professor PATWARDHAN said if the rate was adjusted to about ten times the slow sand filter rate it was possible to run the filter for about three days and then remove about 200 mm depth of sand, which could be placed in another tank, washed and returned.

25. Dr I.C. AGARWAL referred to the mathematical formula

$$\lambda_o = \frac{\log_e c_o/c}{L} \quad .....(1)$$

and suggested that the λ_o was related to E.

26. Mr P.S. DURRANT asked the author what work he had done to investigate the grading of local sands for the different types of filters. He believed that investigations in some Middle Eastern countries had not been successful despite a surplus of sand. Professor PATWARDHAN had wanted a particular size to use in the filter. Once the sand size was known it could be put in the equation. Every sand available could not be used because for backwash cleaning sand could not be less than 0.3 mms and most sands have a size less than this. Therefore there were limitations to the use of local materials.

27. Mr DURRANT asked if any cost analyses had been carried out on the proposed designs as against a conventional design with some sort of pre-settlemnnt. The designs were very ingenious but had been approached from the opposite direction to conventional design by accepting widely different qualities of water and still expecting a uniform treated quality. Professor PATWARDHAN said a complete cost analysis had been carried out using a computer. The first cost was about 9 lakhs (£50 000). The first thing was to convince people that it worked.

28. Dr R. PERRY asked if the MIMO or graded horizontal filter had been tried on an extensive basis. Professor PATWARDHAN said they had not.

29. Mr K.G. STRATFORD asked if work had been carried out using locally derived materials for providing adhesion as an alternative to alum. Professor PATWARDHAN replied not at his University but work was going on in India to find cheaper alternatives.

30. Mr B.M.U. BENNELL said he had not quite grasped the extent of the prototype testing on these designs. Had they been tested in field situations? Professor PATWARDHAN said pilot plant studies were being carried out. The last was in and running parallel to the existing treatment plant: it was working well and giving a good output.

I. C. AGARWAL &
G. D. AGRAWAL

intermediate rate water filtration for hot and developing countries

INTRODUCTION

The provision of safe and aesthetically acceptable drinking water to the community is of vital importance for maintenance of public health. The role of public water supplies, that are bacteriologically unsafe, as vectors of enteric and other water-borne diseases has been established by many incidents and investigators(1). The efficacy of water treatment to check water-borne diseases was convincingly demonstrated, among other incidents, by the dramatic results of Altona and Hamburg in Germany during the cholera epidemic of 1892. In this incident, using water from the same source, the Elbe River, Altona, which filtered its water supply, escaped entirely, while Hamburg, which used the water unfiltered, suffered a severe outbreak of disease. Realizing from such incidents the importance of prevention being better than cure, treatment of water before its consumption was initiated on a wider scale, especially in developed nations. Consequently mortality rate due to water-borne diseases dropped to extremely low levels. For example, according to the Manual of British Water Engineering Practice(2) the death rate from typhoid per million people dropped from 150 in 1900 to almost zero around the 1940s in England and Wales. However, primarily due to lower coverage of people by engineered water supply and sanitation schemes in developing countries, the mortality rate due to water-borne diseases is quite high. In Sri Lanka the mortality rate due to water-borne diseases was 102.8 per 100 000 during 1957 while according to a 1962 estimate, 45% of the urban population was covered by water supply schemes(3,4). In India the mortality rate due to enteric diseases is about 360 per 100 000 where 52% of the urban population and more than 55% of rural population were not served by adequate water supply by 1966(5).

To reduce the mortality rate in developing nations almost complete coverage of population by adequate and safe water supply schemes is required which will need enormous financial resources. Because of the imposed constraints of paucity of financial resources coupled with the restricted availability of skilled technical personnel and sophisticated equipment, either new water treatment methods have to be evolved or existing ones modified so that water treatment units can be developed which are cheap, simple and easy to construct, maintain and operate and which do not require either the incorporation of sophisticated equipment or attendance by skilled technical labour.

Among the various unit operations of conventional water treatment, filtration occupies a central and important place. Filtration of municipal water supplies is generally accomplished employing either slow or rapid sand filters. Pressure filters have been used but on very limited scale. Various modifications of sand filters, viz dual-media and multi-media filters, radial, upflow, biflow and horizontal filters, have been developed but have not been adopted on any scale in developing countries due to various operational problems and use of sophisticated equipment. In fact, viewed in the context of the needs of developing nations, the majority of which are hot countries, the rapid sand filter possesses the following disadvantages:

(i) technical supervision and regular laboratory testing to maintain acceptable filtrate quality

(ii) costly operation and complicated hydraulic design

(iii) employment of sophisticated equipment requiring skilled operation and maintenance and workshop facilities.

Slow sand filters also possess many disadvantages, namely high initial cost especially in cold countries where they have to be covered, requirement of large land areas and large labour force for cleaning process, and inability to cope with highly turbid waters. However in hot and developing countries where the disadvantages of high land costs, expensive labour and troubles caused by frost and reduced biological activity due to extremes of cold may be well within acceptable levels, many advantages of slow sand filtration may make it preferable to rapid sand filtration(6). These advantages include

(i) unmatched quality of treated water, particularly bacteriological quality

(ii) low cost of construction and operation

(iii) ease of construction and operation

(iv) conservation of wash water.

In view of these merits, the World Health Organization strongly recommends the use of slow sand filters in tropical and developing nations.

Objective of this study

In order to assign a major role to slow sand filters in hot and developing countries, it is desirable to reduce their disadvantages substantially. The disadvantages of these filters result primarily from the adoption of lower rates of filtration and absence of proper pretreatment to reduce the turbidity of filter influents to low levels. Alum-coagulation as pre-treatment to the influents of slow sand filters has been found by the authors(7,8) to be suitable to reduce the turbidity to acceptable levels. This study was aimed at evaluating the performance of slow sand filters receiving alum-coagulated influents at conventional and higher rates of filtration. A detailed economic analysis was done to arrive at an optimal rate of filtration.

MATERIALS AND METHODS

Experimental filter units

In order to avoid the inherent disadvantages associated with the extrapolation of results obtained on the basis of laboratory-scale studies due to incompleteness of simulation of field conditions and to eliminate the effect of scale and environment on the natural development of schmutzdecke, the entire investigation was carried out at Kanpur Water Works employing either pilot-scale filters, especially constructed for this study, or full-scale existing filters.

The waterworks of Kanpur (population = 1.24 million, latitude = 26°30' N, altitude = 135 m above M.S.L., shade temperature = 3°-48°C) processes 205 Ml of water daily. An over-simplified flow sheet of Kanpur Water Works is presented in figure 1. The treatment given to raw water round the year includes sedimentation, alum-coagulation, flocculation, settling followed by either slow or rapid sand filtration and post-chlorination. However during periods of prolific algal growth on the filter beds occuring during the summer (March to June), copper sulphate at 1.5 to 4.5 mg/l and chlorine at 1.2 mg/l are added to raw water. During periods of high turbidities ($\gtrsim$ 2500 jtu) in the rainy season (July to October) alum is also added to raw water from the Ganges River at an additional point 2 (figure 1).

The full-scale slow sand filters used for this study were of the size 61m x 30.5m operating at a rate of 133 l/m^2h. Their media consisted of 250 mm of gravel and 900 mm of sand with an effective size of 0.3 mm and uniformity coefficient of 3.5. The under-drainage system consisted of the main U-shaped concrete channel and laterals formed by open-jointed bricks. The filters have manually controlled inlet and outlet sluice valves and the filtered water is discharged over the weir into an outlet chamber.

Pilot-scale filters

Two pilot-scale filters with a plan size of 0.92m x 1.83m were constructed in Kanpur Water Works. The media specifications were exactly the same as those for the prototype slow sand filters. The under-drainage system was also similar. The outside walls of the pilot-scale filters, unlike those of the prototype, had five piezometric tappings and five sampling ports each at various depths to record the head loss and to collect filter effluents at different depths down the bed. Both the pilot scale filters could be fed with the same coagulated, flocculated and settled water as that being fed to the prototype slow sand filters or with raw Ganga Water without pretreatment. The rate of flow in the pilot filters was adjusted by a sluice valve and was determined by collecting a suitable quantity of water in a measured time interval. As an additional check and to get a reliable measure of average daily velocities, water meters were installed to record the flow. Figure 2 gives the layout plan of the pilot-scale filters.

Analytical techniques

The following analyses were performed on raw and filtered water sample to evaluate the performance of filters in terms of various quality parameters

(i) coliform density by the multiple tube fermentation technique (presumptive test)

(ii) turbidity measured by using Hellige turbidimeter

Figure 1 SIMPLIFIED FLOW SHEET OF KANPUR WATER WORKS

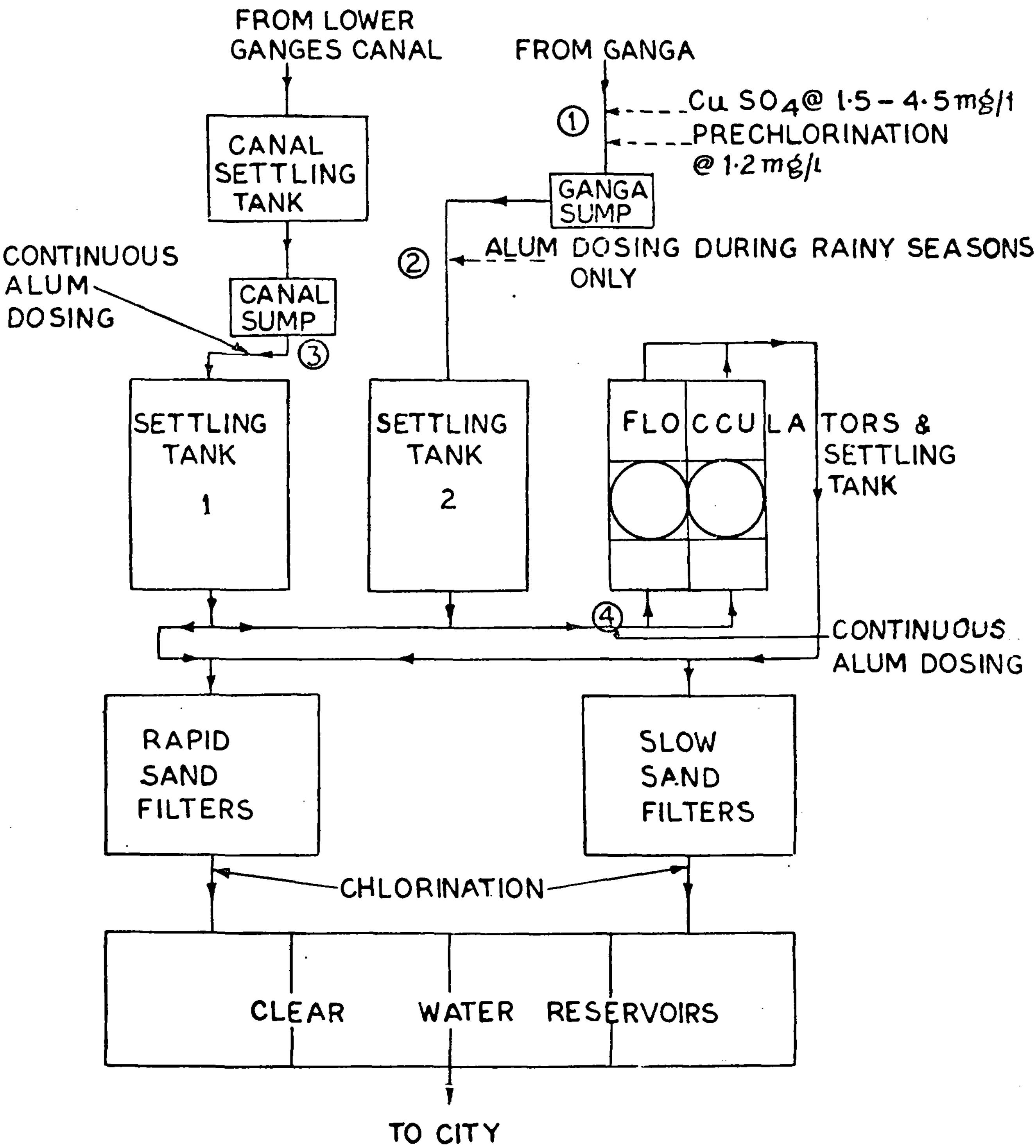
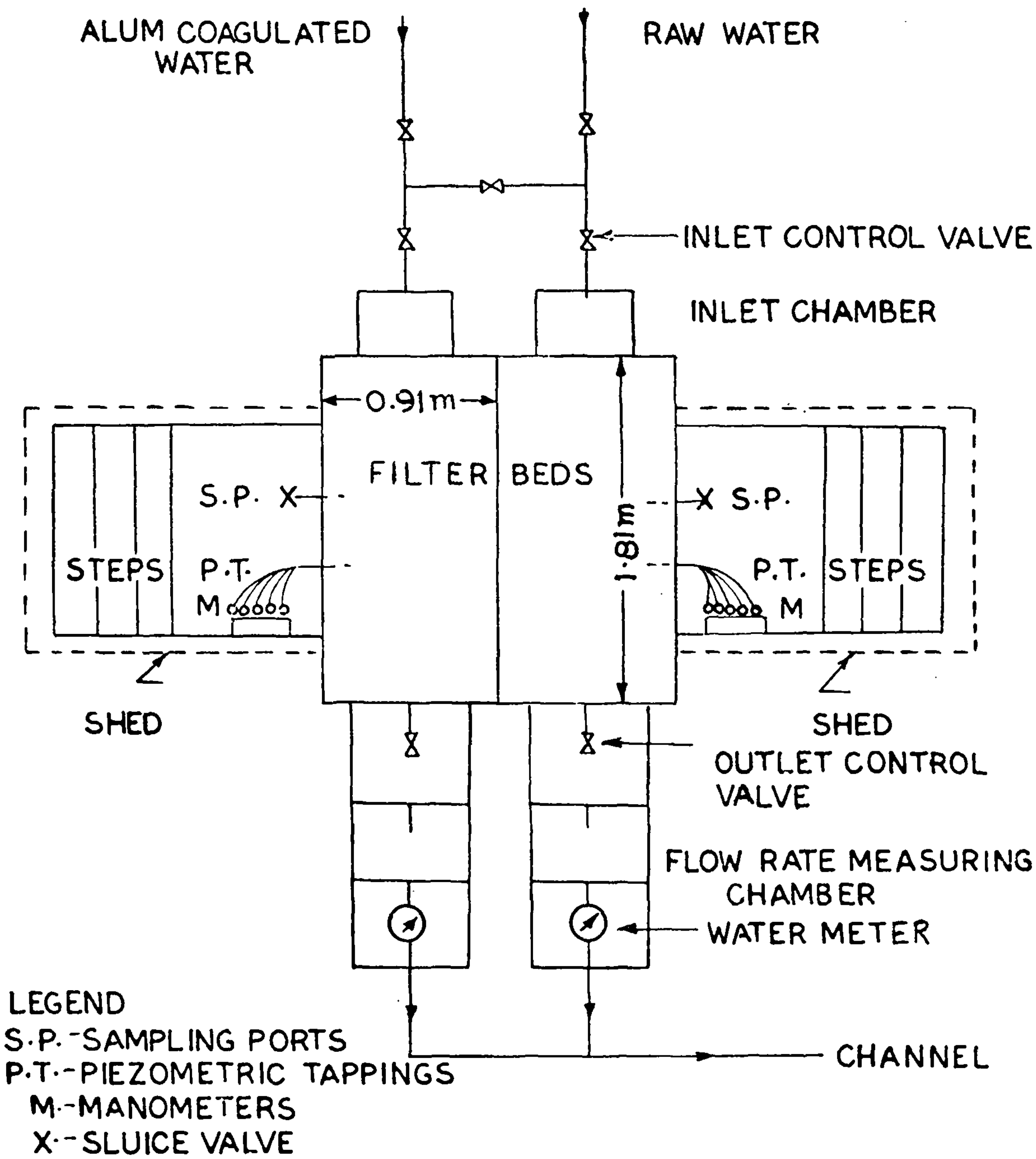


Figure 2 LAYOUT PLAN OF PILOT-SCALE FILTERS



(iii) organic matter indirectly estimated as COD by dichromate reflux method with the modifications in the normalities of potassium dichromate and ferrous ammonium sulphate solutions as suggested by Medalia(9)

(iv) chlorine demand by DPD method

(v) algal content indirectly by chlorophyll extract method(10,11).

Schedule of filter runs

The entire study was conducted in two phases extending over a period of more than one year and consisted of 86 filter runs, 18 on pilot-scale filters and 68 filter runs on prototypes. During the first phase, filters of both types were operated at a conventional filtration rate of 133 l/m^2h to evaluate the performance of slow sand filters using alum-coagulation as pretreatment. In the second phase, the pilot-scale filters were operated at higher rates of filtration, viz 216, 408, 612 and 1000 l/m^2h. The prototype filters were later operated at 612 l/m^2h which was found to be the optimal filtration rate on the basis of economic analysis.

RESULTS AND DISCUSSIONS

This study was conducted to reduce substantially the demerits of slow sand filters which are found to be more suitable for hot and developing nations as these filters can produce filtrate of excellent quality at lower cost in the technological environment as obtainable in such countries. The main disadvantages of slow sand filters are primarily due to the adoption of lower filtration rates and absence of suitable pretreatment reflecting their inability to treat highly turbid waters.

As reported elsewhere(7,8), the authors have concluded, based on extensive experimental evidence, that alum-coagulation can successfully be employed as pretreatment to slow sand filter influents increasing their ability to treat even highly turbid raw waters and thus eliminating one big disadvantage of slow sand filters. This paper presents the effect of alum-coagulation on filtrate quality and the results of operating slow sand filters at much higher than normal filtration velocities so that the other disadvantages of these filters can be substantially reduced.

Effect of alum-coagulation on filtrate quality

As one of the main advantages of slow sand filter is to produce filtrate of excellent quality in comparison to high rate filters, it would be necessary to check that no deterioration in filtrate quality occurs as a result of adopting alum-coagulation as pretreatment. Therefore, several parallel runs of pilot-scale filters were made using raw and alum-coagulated filter influents at the conventional rate of 133 l/m^2h. The filtrates were drawn from different depths down the filter and their quality was evaluated regularly. Besides this 63 concurrent runs on seven prototype filters extending over a year were conducted and their filtrates regularly analysed for turbidity and coliform density besides other quality parameters like COD and chlorine demand which were done occasionally. For the sake of brevity, only typical results are presented in Table 1.

The main quality-parameters for evaluating the performance of a filter are turbidity and coliform-density as filtration aims at removal of suspended and dissolved impurities to improve the physical, chemical and biological (especially bacteriological) qualities of water.

Table 1 Filtrate Quality Parameters for Filters employing Raw Water and Alum-coagulated Water as Influents

Filtrate Quality Parameter	"Raw Water" Filter		Alum-Coagulated Water Filter	
	Influent	Effluent	Influent	Effluent
Turbidity, A.P.H.A.	5-75	Nil	3-15	Nil
Turbidity units	400-1800	0.06-1	10-50	Nil
M.P.N. of E.Coli per 100 ml	150-16 100	Nil-161	23-3500	Nil-21
Chlorine demand, mg/l (one typical value)	0.95	0.49	0.81	0.43
COD, mg/l	0.2-5.1	-	0.2-2.1	Nil-1.0
Algal content, mg/l	-	-	0.5-2.0	Nil

It is observed that though the turbidity of raw water varied over a wide range, both type of filters gave effluents of almost zero turbidity, except in one run of a filter receiving raw water of high turbidity as influent. The reduction in coliform density for raw water filters varied generally between 90 and 100% while that for alum-coagulated water filters ranged most of the time close to 95-100%. In the pilot-scale filters the efficiency of coliform reduction was sometimes poor in both cases, especially with first runs with washed sand possibly due to absence of fully developed schmutzdecke and heterotrophe zone. But the prototype filters which received only alum-coagulated influents mostly produced filter effluents that were almost free from the coliform group of bacteria. Thus it seemed that adoption of alum-coagulation as pretreatment helped in producing filter effluents that are almost bacteria-free.

Alum-coagulation also helped in producing filter effluents of lower chlorine demand in general as indicated by one typical value in Table 1. The low or almost zero values of COD and algal content of effluent from filters receiving alum-coagulated waters indicate good improvement in quality.

Thus in general, it can be concluded that alum-coagulation does not have any adverse effect on the quality of filtrate and on the contrary it may help in improving the overall quality of filter effluent.

Operating slow sand filters at higher rates of filtration

The main disadvantages of requirement of large land areas and consequently of large labour force for cleaning operations and high initial cost of construction result primarily from adoption of relatively very low rates of filtration, average values being around 125 l/m^2h in comparison to about 5000 l/m^2h for rapid sand filters. In the past higher rates of filtration were not adopted lest the schmutzdecke, considered to be a fragile and delicate layer of bacteria and organic matter and mainly responsible for filtration action, might puncture. Later Van de Vloed(12) and others including Huisman and Ives(6,13) explained the mode of action in slow sand filters. The uppermost layers of sand, inhabited principally by actively photo-synthesizing algae and called the autotrophe zone played only the secondary role in the overall purification process while the main role was assigned to lower layers called hetrotrophe zone assisted by the deepest layers termed the mineral oxidation zone. Because of the better understanding provided, higher rates of filtration have been recommended and used. As reported by Ridley(14), filtration rates of 150 l/m^2h, in comparison to 50 l/m^2h used in the past, have been employed as a result of the introduction of micro-straining and roughening rapid filtration as pretreatment. Further, at the Coppermills Water Works, London, the rate of filtration adopted is 250 l/m^2h.

In the light of this discussion coupled with the fact that alum-coagulation as pretreatment produced filter influents of uniform quality and low turbidity, it was thought that much higher rates of filtration could be successfully adopted without seriously affecting the filtrate quality. To explore this, pilot-scale filters were run at rates of 216, 408, 612 and 1000 l/m^2h. Later prototype filters were also operated at 612 l/m^2h. In all the runs, filters received alum-coagulated influents.

Table 2 presents the summary of results of operating the filters at higher rates of filtration. The rate of 216 l/m^2h has been excluded from the list as only one run was made with this rate.

Table 2 Summary of Results of Operating Filters at Higher Rates of Filtration.

Rate of filtration l/m^2h	Length of filter run days	Quantity of water filtered per run l/m^2	Days lost in scraping and recoupment per run*	Effective yield l/m^2h	% reduction in land area required
133	40	128×10^3	3.5	122	0
408	15	147×10^3	3.5	332	63
612	10	147×10^3	3.5	454	73
1000	3.5	84×10^3	3.5	500	85

* average amount of time lost for prototype filters of 61m x 30.5m size in Kanpur Water Works using manual labour for cleaning and recoupment of sand.

It is seen from the table that by increasing the rate from 133 to 1000 l/m^2h the effective yield increased from 122 to 500 l/m^2h and the land area requirement decreased by 85% though the length of run dropped from 40 to 3.5 days. However, increase in rate of filtration beyond a certain value (around 612 l/m^2h) does not result in concommitant decrease in land area requirements. Therefore to arrive at a rational optimum rate of filtration, a complete economic analysis is essential.

Economics of higher rates of filtration

To make the analysis more meaningful it was decided to consider not only slow sand filtration but also rapid sand filtration. Four rates of filtration were considered in each case. The basis of the cost analysis is presented in the Appendix. The local currency (Rupee has been converted into pounds at Rupees 20 = £1.

Costs of filtration and other items at four different rates of filtration for both rapid and slow sand filters were computed and are furnished in Tables 3 and 4.

Table 3 Summary of Cost Data for Rapid Sand Filtration

Rate of filtration l/m^2h	Length of filter run days	Cost per million litres of water (£)						
		Filtration						
		Cost on interest etc*	Operational cost	Total cost	Power	Alum	Chlorine	Total
5000	1.56	0.59	0.22	0.81	0.02	0.49	0.19	1.51
5880	1.00	0.51	0.30	0.81	0.02	0.49	0.19	1.51
8820	0.52	0.35	0.40	0.75	0.02	0.49	0.19	1.45
11 760	0.31	0.29	0.55	0.84	0.02	0.49	0.19	1.54

* Includes cost on interest, depreciation and maintenance and repairs.

The total cost of water treated is nearly the same for rates of 5000 and 5880 l/m^2h, while it is least for the rate of 8820 l/m^2h.

Table 4 Summary of Cost Data for Slow Sand Filters

Rate of filtration l/m^2h	Length of run days	Cost per million litres of water (£)						
		Filtration						
		Interest etc	Operational	Total	Power	Alum	Chlorine	Total
133	40	0.64	0.11	0.75	0.01	-	0.15	0.91
133	40	0.64	0.11	0.75	0.01	0.49	0.15	1.40
408	15	0.26	0.11	0.37	0.01	0.49	0.15	1.02
612	10	0.19	0.12	0.31	0.01	0.49	0.15	0.86
1000	3.5	0.21	0.26	0.47	0.01	0.49	0.15	1.12

A comparison of data presented reveals that the overall cost of filtration employing slow sand filtration is always less than the cost for rapid sand filtration for conditions as obtainable at Kanpur Water Works. Further, the cost of filtration is lowest for rapid filtration at the rate of 8820 l/m^2h and for slow sand filtration at the rate of 612 l/m^2h. It is seen that at optimum conditions of operation slow sand filtration at a rate of 612 l/m^2h is 51.2% cheaper than optimal rapid sand filtration at a rate of 8820 l/m^2h, both employing alum-coagulation as the pretreatment. Based on a saving of 51.2% the actual amount of money saved for a filtration capacity of 100 Ml/day would amount to £1788 per annum or £89 400 for the design life of 50 years for slow sand filters.

To find out the optimal rate of filtration both for rapid and slow sand filters, the cost response curves for both the cases are presented in figures 3 and 4. It is observed that rates of 8100 and 625 l/m^2h can be assumed to be optimal rates of filtration for rapid and slow sand filters respectively in conditions as obtainable at Kanpur Water Works.

Figure 3 COST RESPONSE CURVES FOR RAPID SAND FILTERS

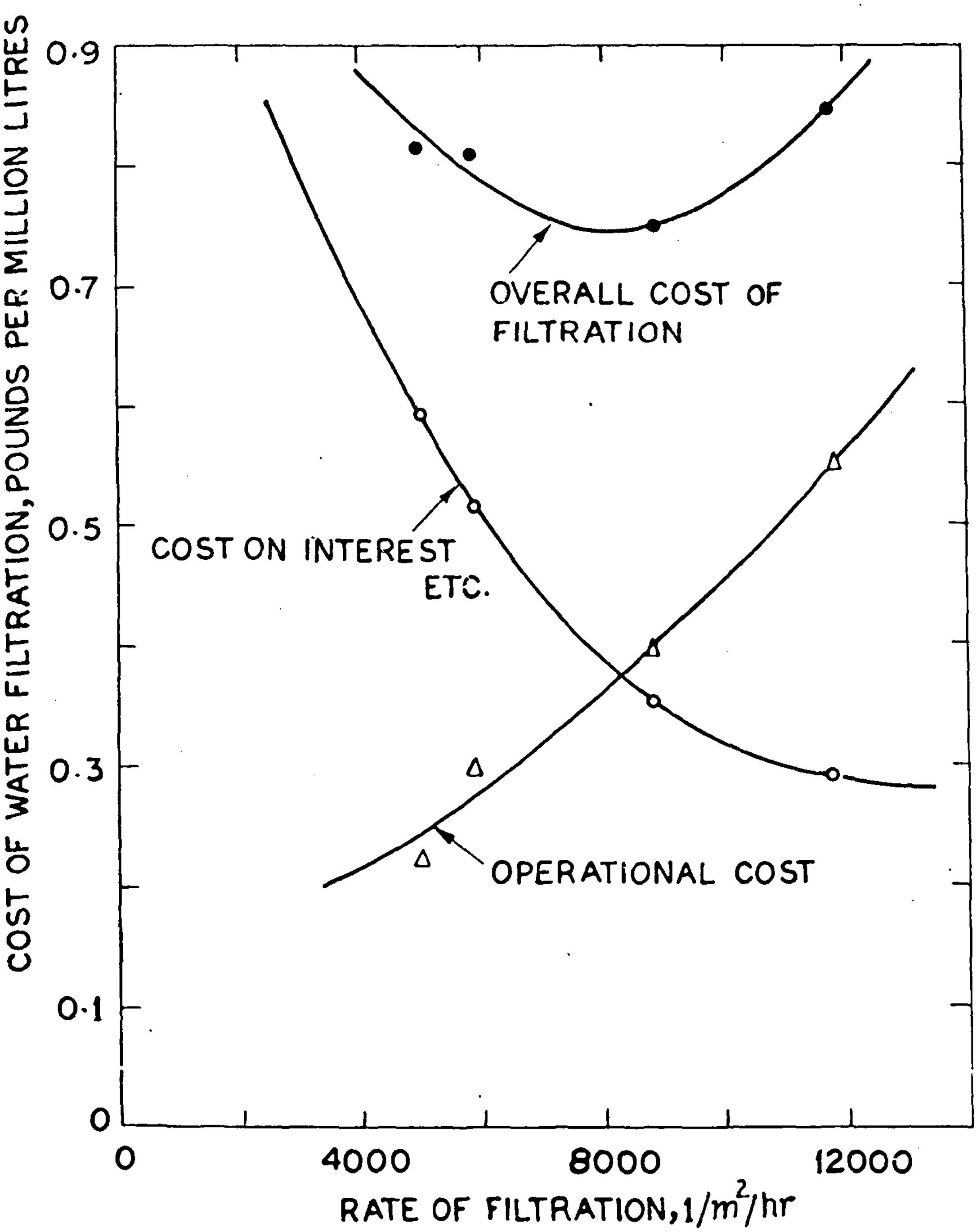
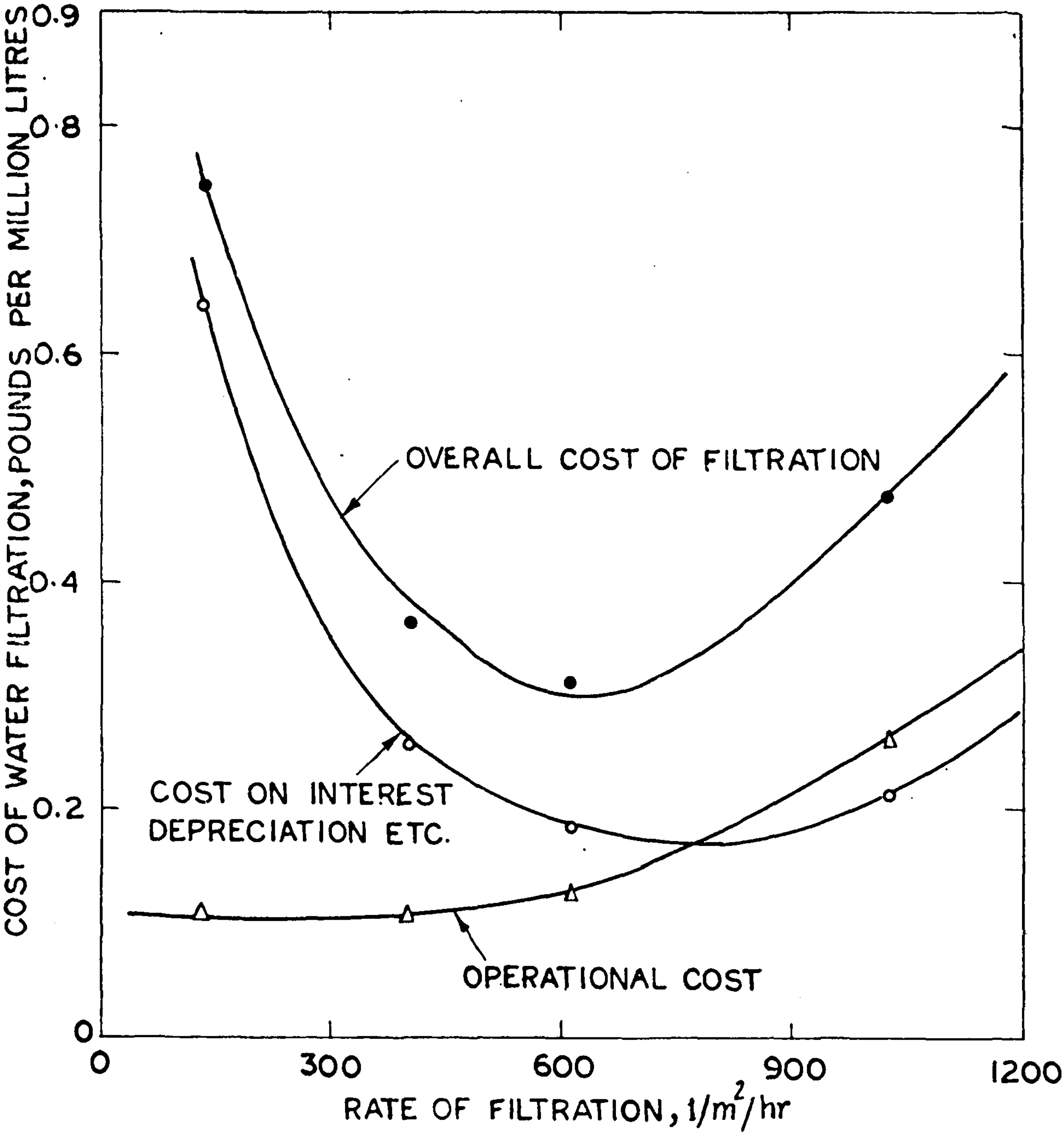


Figure 4 COST RESPONSE CURVES FOR SLOW SAND FILTERS



Distribution of removals and head loss along depth at higher rates of filtration

Though higher rates of filtration will be highly desirable as they substantially reduce the land requirements and cost of treatment, but it should be ensured that the removal of impurities and hence build-up of head loss is confined to the top layers of sand. If the impurities travel deep down in the bed because of increased rate of filtration, the quality of the effluent will deteriorate and head losses in the lower layers of the bed will progressively increase and scraping will not be effective in removing the impurities to restore the filter.

To check the distribution of removals and head loss the variation of filtrate turbidities and head loss build up along the depth of bed are plotted in figures 5 and 6 for four rates of filtration, namely 133, 216, 612 and 1000 l/m^2h.

Figure 5 VARIATION OF EFFLUENT TURBIDITY WITH DEPTH AT FOUR RATES OF FILTRATION

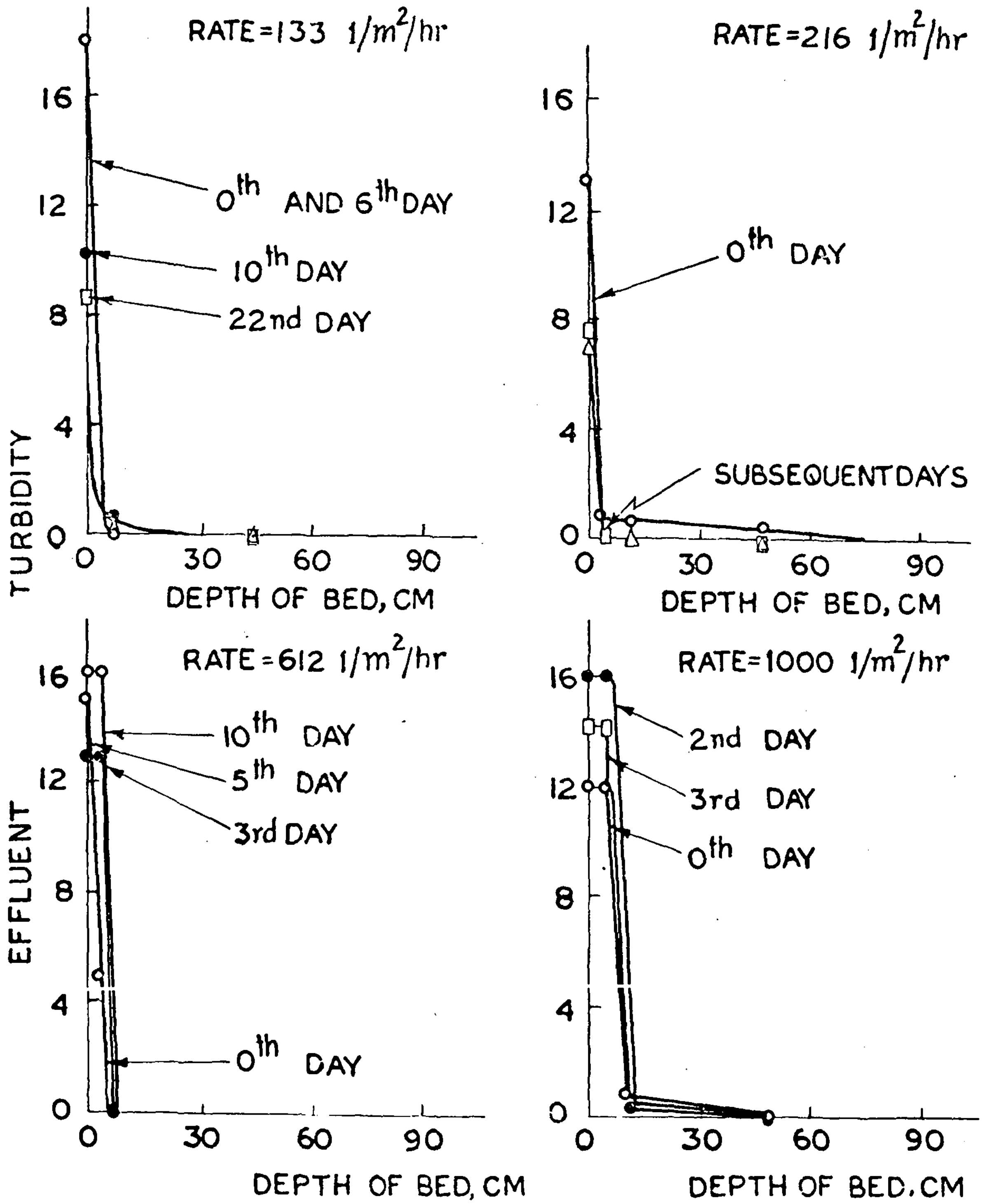
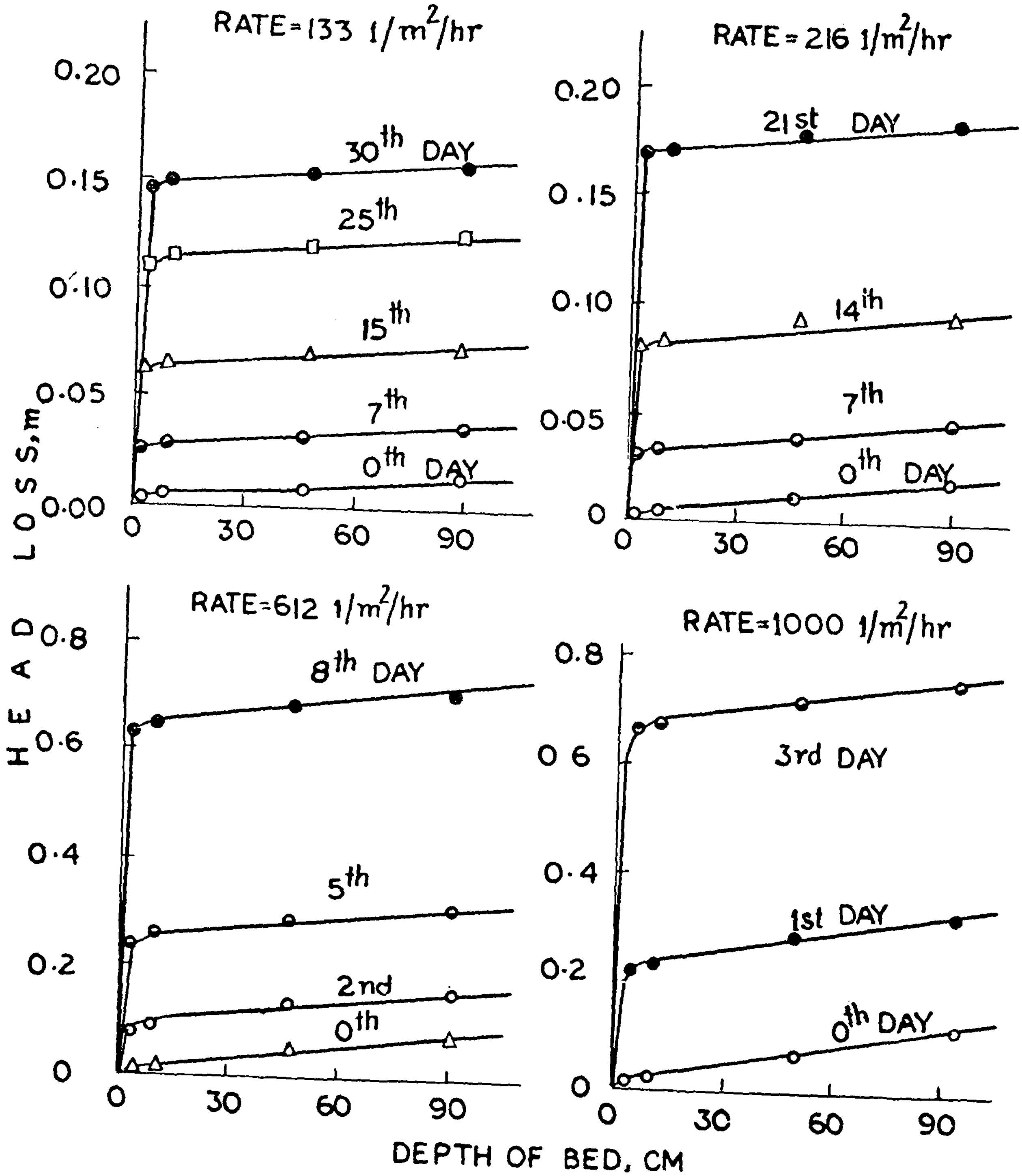


Figure 6 PATTERN OF HEAD LOSS DISTRIBUTION AT FOUR RATES OF FILTRATION



The nature of the curves confirm that with alum-coagulation pretreatment, as proposed by the authors, almost all the removals are distributed in the top 100 mm or so and little impurities penetrate deeper in the bed even at the highest flow rates. From figure 5 it is observed that the effluent contained little or no turbidity almost from the start of the filter run at all the rates of filtration. Determination of non-filtrable residue also confirmed that filter effluents contained little suspended solids.

The pattern of the head loss curves in figure 6 indicates that the majority of head loss occurred in the top 50 mm or so. The head loss in the lower layers remained constant as evidenced by the substantially parallel portions of the head loss curves for lower layers and the head loss in lower layers was close to the values computed from the Kozency-Carman equation for clean and unclogged bed of porous media. Thus from *figures 5 and 6 it is established that little impurities travelled deeper* into the bed even at the highest rate of filtration till the last day of the filter run.

Effect of higher rate of filtration on filtrate quality

Partly because of the importance of rate of filtration of 612 l/m^2h, being close to the optimum value, and partly with a view to present the typical and representative trends, the effect of only this rate of filtration on filtrate quality is discussed. The results of various analyses performed on influents and effluents of filters operating at a rate of 612 l/m^2h are presented in Table 5.

Table 5 Performance of Filter at a Filtration Rate of 612 l/m^2h.

Quality parameter	Influent	Effluent
Turbidity, APHA Units	7-15	Nil
M.P.N. of E.Coli, per 100 ml	39-3500	15-93
COD*, mg/l	4.8	1
Algal content*, mg/l	0.9	Traces
Non-filterable residue mg/l	5.22	Traces

* one typical value only

Comparison of results of Table 5 with those at the rate of filtration of 133 l/m^2h in Table 1 shows that except in coliform density, the effluent at the higher rate is similar in quality to that at the lower rate of 133 l/m^2h. Because of the compulsory practice of post-disinfection even a higher coliform density of about 90 per 100 ml against up to 35 at conventional rates can be accepted, especially when effluents from rapid sand filters having an M.P.N. of E.Coli of 161 and greater are found entirely acceptable at Kanpur Water Works.

Advantages of operating slow sand filters at higher rates of filtration

From the results presented, it is observed that the following advantages result from operating slow sand filters at rates of filtration much higher than the conventional rates.

(i) Reduction in land area requirement: by operating filters at 612 l/m^2h, the land area required is only one-fourth that at the conventional rate.

(ii) Increase in quantity of water filtered: the effective yield of the filter per unit area per unit time increases 3.7 times by increasing the rate from 133 to 612 l/m^2h.

(iii) Overall economy in cost of water treated: the cost per million litres of water treated is £0.86 at near optimal rate of slow sand filtration compared to £1.45 for near optimal rate of rapid sand filtration, indicating an overall saving of about 51%. It may be mentioned that treatment cost for slow sand filtration using uncoagulated influents is £0.91. This leads to the observation that adoption of higher rates of filtration more or less offsets the additional cost incurred in alum-coagulation. This advantage is in addition to the very important advantages of filtering much more water per unit area per unit time even when the turbidity of raw water fluctuates within an extremely wide range which is unacceptable in case of conventional slow sand filters.

(iv) Effluent quality: the effluent quality at higher rate of filtration is not adversely affected. Though the coliform density may be somewhat higher at higher rates, it is still much less than that of the effluents of rapid sand filters.

(v) No need of backwashing: since almost all the removals and head loss occur in the top few centimetres of sand bed even at the highest rate tried, the scraping effectively restores the filter. Therefore, there is essentially no need of backwashing the filters. This is a very important advantage as backwashing requires sophisticated equipment, complicates the hydraulic design of filters and is comparatively very costly.

(vi) Absence of taste and odour: as a result of reduced length of run at higher filtration rates, there is little possibility of disintegration of algae and consequently no taste and odour are detected in the effluents. On the contrary, the problem of taste and odour in effluents has been reported at conventional filtration rates by Ridley(14).

(vii) Reduction in growth of filamentous algae: again, as a result of reduced length of run of 10 days, there is little time for the excessive growth of filamentous algae which starts growing profusely after about 10 days according to Ridley. As a result, scraping and cleaning of the sand is more easy and quick and may be more advantageous economically also.

It is observed, therefore, that as a result of using alum-coagulation as pretreatment before slow sand filters, intermediate rates of filtration (in between those adopted for slow and rapid sand filters) can be successfully employed. This intermediate rate water filtration, as proposed by the authors, results in many advantages and is highly suitable for hot and developing countries. Intermediate rate filters retain the advantages of slow sand filters, namely simplicity in construction, operation and maintenance, efficiency and cheapness, while they eliminate or reduce the disadvantages of slow sand filters substantially.

CONCLUSIONS

On the basis of this study extending over a period of more than a year employing pilot and prototype filters in Kanpur Water Works, the following conclusions may be drawn.

1. Alum-coagulation can be successfully adopted as pretreatment to slow sand filter influents without any adverse effect on the overall quality of filter effluents. This will enable the slow sand filters to treat even highly turbid waters.

2. As a result of adoption of alum-coagulation as pretreatment, slow sand filters can be operated at filtration rates much higher than conventional. Four filtration rates, namely 216, 408, 612 and 1000 l/m^2h were tried. Filtrate quality at all the four rates was acceptable.

3. Because of the adoption of higher rates of filtration, intermediate rate filters would require much less land areas and capital investment on construction (including the costs of land and filter media) would be substantially reduced. At a rate of 612 l/m^2h these filters would require only one-fourth of the land area required by slow sand filters operating at the rate of 133 l/m^2h to filter the same quantity of water.

4. The cost of treatment of water employing intermediate rate filtration at near the optimal rate of 612 l/m^2h is 51.2% cheaper compared to the cost of treatment using rapid sand filtration at near the optimal rate of 8820 l/m^2h in conditions as obtainable at Kanpur Water Works.

5. The intermediate rate water filtration, besides possessing all the above mentioned advantages, would not require the use of imported and sophisticated equipment. Being simple and cheap to construct, operate and maintain, it is highly suitable for hot and developing countries being labour-intensive rather than equipment-intensive.

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A P P E N D I X

Basis of Cost Analysis

To compare the costs for the slow and rapid sand filters, cost per million litres (Ml) of water treated has been taken as the basis. The cost per Ml of water treated is calculated by dividing the annual cost per filter by its effective annual yield. The total cost of filtration per filter per annum, C_T, is given by

$$C_T = C.\ r + C\ d + C.m + O \qquad \text{(i)}$$

where C is the capital cost per filter; r, d and m are the annual rates of interest, depreciation and maintenance and repairs. O is the annual operational cost per filter unit and includes the cost of sand backwashing/ scraping, recoupment and overhauling of filters and the cost of manpower involved in the actual operation and supervision of the filter.

Table 'A' presents the rates of land power, water alum and chlorine along with annual rates of interest, depreciation, maintenance and repairs adopted for calculations. Table 'B' provides the cost data for both types of filter in accordance with equation (i) to obtain the cost of filtration per filter unit per annum for prototype filters at Kanpur Water Works at late 1972 prices. Table 'C' includes sample calculations for the actual quantity of water filtered per unit per annum for the rates of filtration adopted for rapid and slow sand filters at Kanpur Water Works.

In all the tables original values in local (Indian) currency of Rupees have been converted into English currency at the rate of Rupees twenty equal to £1.

Table 'A' Various Rates Employed For Computations

Sl. No:	Item	Rate	Comments
1.	Land cost	£2.38 per square metre	Rate of compensation paid by Kanpur Municipal Corporation for acquired land
2.	Interest on capital	7% per annum (p.a.)	Normal rates of interest charged by State Government on loans to Corporations.
3.	Depreciation		
	(i)	2% p.a.	For civil works of slow sand filter with design life of 50 years.
	(ii)	3% p.a.	For civil works of rapid sand filters with design life of $33\frac{1}{3}$ years.
	(iii)	4% p.a.	For mechanical equipment used in rapid sand filters.
4.	Maintenance and Repairs:		
	(i)	1%	For slow sand filters
	(ii)	2%	For rapid sand filters
5.	Power	£0.5 per 100 kWh)	Rates at which Kanpur Water Works purchases/sells the particular item.
6.	Water	£8.0 per Ml)	
7.	Alum	£14.0 per ton)	
8.	Chlorine	£7.5 per 100 kg)	

Table 'B' Cost Data on Slow and Rapid Sand Filters

S.No.	Item	Slow Sand Filter (Size 30.5m x 61m)			Rapid Sand Filter (Size 7.6m x 7.6 m)		
		Capital Cost £	Annual cost on interest, depreciation and maintenance etc. £	Annual operational cost £	Capital Cost £	Annual cost on interest, depreciation and maintenance etc. £	Annual operational cost £
1.	Land	4444	311	-	145	10	-
2.	Civil works	9648	955	-	6300	756	-
3.	Mechanical equipment	50	6	-	5400	702	-
4.	Sand						
	(i) Scraping/backwashing*		-	80	-	-	566
	(ii) Recoupment	-	-	64	-	-	109
5.	Operation	-	-	67	-	-	147
6.	Supervision	-	-	5	-	-	33
	Total	14 142	1272	216	11 845	1468	855

* Includes cost of scraping and carting to sand washing machine in case of slow sand filter and cost of power on pumping air and water and cost of backwashing water (2% of filtered quantity) for rapid sand filter.

Table 'C' Sample Data on Quantity of Water Filtered and Cost of Filtration for Slow and Rapid Sand Filters

S.No.	Item	Type of Filter (Conventional Rates)	
		Slow	Rapid
1.	Quantity of Water Filtered		
	(i) No. of days lost in scraping/backwashing and overhauling, days/filter/year	32	14.4
	(ii) Total quantity of water filtered, Ml/year/filter	1980 (@ 133 l/m^2h)	1863 (@5880 l/m^2h)
2.	Cost of Filtration		
	(i) £	1488	2323
	(ii) £/Ml of water	0.75	0.81
3.	Other Costs all in £/Ml of water		
	(i) Alum (av.dose = 35 mg/l)	0.49	0.49
	(ii) Chlorine	0.15 (av.dose = 2 mg/l)	0.19 (av.dose = 2.5 mg/l)
	(iii) Extra power cost for lifting the water to average value of head loss	0.01	0.02
4.	Total cost of filtration		
	(i) without alum-coagulation	0.91	-
	(ii) with alum-coagulation	1.40	1.51

discussion

CHAIRMAN: Professor D.J. BRADLEY

The CHAIRMAN introduced Dr Agarwal who had worked with Professor Agrawal on various aspects of slow sand filters.

2. Dr I.C. AGARWAL read some of the most important portions of his paper. It was known that adequate water treatment reduced illness. In developing countries the money and skills were so limited that simple and cheap water treatment units had to be used. Filtration was the most important treatment process. Comparison of rapid and slow sand filtration showed that slow filtration was most suitable for developing countries. It had two main disadvantages: the adoption of very low rates of filtration and the inability to deal with highly turbid water. Ives, Huisman and others had found that the use of alum coagulation as pretreatment was prohibitive, but the extensive study by the authors at Kanpur Water Works on prototypes and pilot-scale filters had shown that alum-coagulation could be used successfully for slow sand filter influents.

3. The prototype and pilot-scale filters used the same filter media and underdrainage system. Either alum-coagulated water or raw water could be fed to the pilot-scale filters, which had sampling ports and piezometric tappings on both sides and a simple arrangement for increasing the through rate. The entire study consisted of 86 filter runs, 18 on pilot-scale filters and 68 on prototype filters. During the first phase, filters were operated at conventional rates of filtration (133 l/m^2h) to evaluate the performance of slow sand filters using alum-coagulation as pretreatment. In the second phase the pilot-scale filters were operated at higher rates of filtration i.e. 216, 408, 612, and 1000 l/m^2h.

4. The turbidity of the effluent from alum-coagulated influents was almost nil even if the turbidity of raw water varied from 5-1800 APHA. Regular and extensive monitoring of coliform density showed that alum-coagulation as pretreatment had no adverse effect on the performance of filters in purifying water.

5. A summary of the results of operating slow sand filters at higher rates of filtration was given in Table 2. It could be seen that by increasing the rate from 133 to 1000 l/m^2h the effective yield increased from 122 to 500 l/m^2h and the land area requirements decreased by 85%, though the length of the run shortened from 40 to 3.5 days. For Kanpur Water Works the results of an economical analysis, which were given in Tables 3 and 4 revealed that the overall cost of filtration employing slow sand filtration was always less than the cost for rapid sand filtration. Further, the cost was lowest for rapid filtration at the rate of 8820 l/m^2h and for slow sand filters at the rate of 612 l/m^2h.

6. With these higher rates of filtration it was important to ensure that the removal of impurities was confined to the top layers of sand. If the impurities travelled deeper into the bed, scraping the filter would not restore the filter. Consequently head loss variation and turbidity variation along the depth were plotted. It was clear that most of the impurities were arrested in the top few centimetres of the sand and there was no necessity of backwashing the filter. Backwashing had been avoided because it complicated the hydraulic design and required sophisticated equipment like air compressors.

7. Dr AGARWAL then summarised the advantages of operating slow sand filters at higher rates of filtration. The area could be reduced to one quarter (at 612 l/m^2h) and there could be 50% saving of cost. In addition, the dangers of deterioration of taste and odour and of prolific growth of filamentous algae with long runs (mentioned by Ridley) could be avoided.

8. The CHAIRMAN had been interested to get some idea of how widely applicable the concept of intermediate rate filtration was. Was the optimum stable or precarious? Quite often when systems were optimised it made them more liable to catastrophes.

9. Mr JOHN PICKFORD said that presumably in allowing for the change of cost in the capital cost Dr Agarwal had allowed for the reduction in the land area and yet this had been claimed as an additional advantage: had the advantage of saving land been counted twice? Dr AGARWAL confirmed this. Besides a saving of land cost, reduction in land area requirements might be a big advantage in some cases.

10. Professor S.V. PATWARDHAN asked whether the figures had included the entire cost of pretreatment, and what additional costs were included for rapid filtration. Dr AGARWAL said the operational cost of pretreatment had been taken into account, but capital costs were not. For rapid sand filters more skilled labour and other things were needed for the backwash.

11. Mr E.L.P. HESSING said in the paper Dr Agarwal had said "though the coliform density may be somewhat higher at higher rates, it is still much less than that of the effluents of rapid sand filters", and asked for details of the biological reliability of the water. Dr AGARWAL said Table 5 showed the effluent at higher rates to have an E.coli density of 15-93 per 100 ml. The rapid sand filters at Kanpur Water Works had an effluent with a concentration of the order of 160. Post-chlorination was an essential practice to safeguard against contamination.

12. Mr HESSING said by applying post-chlorination one of the biggest advantages of slow sand filters was lost. Dr AGARWAL said in his opinion post-chlorination was important because there may be variation in the quality of water received. The distribution system, especially of developing nations, might not be maintained well, and if the quality deteriorated in the distribution system, then there was no check on post-chlorination.

13. Professor N. MAJUMDER agreed with Dr Agarwal that post-chlorination was essential. Whatever operational rate was used it was impossible to depend upon the quality of the water.

14. The CHAIRMAN suggested that no-one would dispute that when it was possible it was a good thing to chlorinate water. The question was whether it broke down so often in practice that it was impossible to rely on it being there. He felt it depended very much on where one worked. If it broke down frequently it might be more dangerous to rely on it than to assume it was not there. There were three separate factors: desirability, cost and maintenance.

15. Professor MAJUMDER said it was not a question of relying on chlorination. It was something that must be there to follow the slow sand filtration or rapid sand filtration. Maybe it would break down occasionally, but that should not be an excuse for dropping the entire system. The CHAIRMAN repeated that if the chlorination system broke down frequently for reasons beyond control, then the pre-chlorination quality of the water became important. Dr AGARWAL quoted Professor Huisman who said slow sand filter was a complete treatment device provided it was operating at low rates of filtration. Thus if there was a possibility of chlorine equipment breaking down then perhaps lower rates of filtration should be used. At low rate filtration there was no risk as far as coliform was concerned.

16. Mr H. MANN noted from Table 2 that the quantity of water filtered per run was slightly improved by increasing the rate to 408 l/m^2h and also to 612 l/m^2h. The run was reduced from 40 days to 15 - 10 days. There were still 3.5 days between runs while the filter was being scraped and recouped. Had Dr Agarwal considered any measures to reduce the 3.5 days between runs? Dr AGARWAL said as far as the economic comparison was concerned it had not been taken into consideration. Mr MANN said that only a small part of the 3.5 days was occupied by scraping and the rest of the time was for the Schmutzdecke to re-establish and settle down. Could the time for this be shortened? Dr AGARWAL suggested that the role of the Schmutzdecke was not very significant. The time of ripening had been defined as that necessary to give 50% reduction in turbidity and half day or so was needed to ripen the filter when using alum-coagulated influents.

17. Mr W.E. WOOD said he would be a little afraid of the long-term effect of this on the filter. Within the filter there was a series of colonies of changing forms of life that operated under different chemical and bacteriological conditions. He fully agreed that 125 l/m^2h was too low a rate; the optimum rate was perhaps two or three times that. But as the rate increased these colonies were driven deeper into the bed because the water was not in contact with the upper layers for so long. Normally with slow sand filtration there was periodic scraping of the top, but after 12-18 months it was necessary to change the sand over and throw back, because otherwise micro-organisms would pass into the sub-drainage system. This turning up of the bed was a major and very expensive business. Under slow rates it might be two years or more before this needed doing; under medium rates it might be about 18 months.

18. Dr AGARWAL said the filters were run for one year. Biological life could adapt itself to changing characteristics. The top 300 mm was assumed to be responsible for removing most of the organic matter and for bacteriological purification of water. If a depth of filter was maintained which was always greater than this, then Dr AGARWAL thought the bacteriological quality would not suffer much. He had operated it for one year and found no trouble.

19. Mr WOOD said that purification was affected by the time with which the water was in contact with the various layers of biological life. Obviously if the rate were increased the natural life of the filter would adapt itself to deeper layers to enable it to be in contact so much longer. Had the bed been analysed in depth at the end of the year to find out how the life was adapting itself? Dr AGARWAL replied that they had analysed some of the sand layers and found that a very rich biological life existed. There were comparable runs; one receiving raw water and the other coagulated water. On analysis there was no difference in biological population.

20. Mr HESSING said that from a technical point of view the optimum would be somewhere about 500 l/m^2h, but he felt that from the point of view of reliability and easy operation, and maybe also with a view to avoiding the usual chlorination, the real practice optimum would be lower i.e. 200 or 300 l/m^2h. Dr AGARWAL said the economics varied with the local circumstances. The rate of around 600 l/m^2h gave an optimum at Kanpur. A low rate gave better quality, but higher rates could be adopted if post-chlorination was used, providing the post-chlorination was reliable. Mr HESSING said he could imagine especially in remote areas that the delivery of chlorine could not always be guaranteed.

21. Dr AGARWAL said that in developing countries slow sand filtration was cheaper. One of the biggest disadvantages of slow sand filtration had been that it could only be used for influents with a turbidity less than 100 mg/l or so. By using alum-coagulation as pretreatment, that range could be widened and any type of water could be treated. In reply to a further question from Mr Hessing, Dr AGARWAL said local sand with a high uniformity co-efficient (2-3) could be used for slow sand filters. Rapid sand filtration required sand with a uniformity coefficient of 1.5 or even less. Slow sand filters might be cheaper by using local sand, and the walls could be constructed with bricks. Lime joints with a minimum of cement could be used.

22. Mr P.A. OLUWANDE considered that post-chlorination was very important especially in some areas of Nigeria where many of the people got water from public taps for storage in houses. In such a situation the water was exposed to contamination. Mr HESSING asked whether the consumer liked the taste of chlorine, and Mr OLUWANDE said that during the cholera outbreak of 1970 water was provided with a chlorine content of 11 mg/l. The people abandoned the water because they thought it was poisoned. However, chlorination up to 1 mg/l was quite satisfactory. Dr AGARWAL suggested that health was more important than taste.

23. The CHAIRMAN thought it depended on the community. Unless they believed in the germ theory of disease, taste was more important than health, because they would think that the taste was going to injure their health more. Health education was very important, although he thought more than health education was needed to get people to drink 11 mg/l of chlorine!

24. Mr F.W. CROWLEY was worried about the whole concept. Basically a slow sand filter was a biological filter. Dr Agarwal's proposal to alum-coagulate up-stream of the slow sand filter gave a risk of aluminium carry-over which would retard the biological action. This showed up in the results given for the E.coli figures which were very high for any slow sand filter. It seemed that efficiency of the slow sand filter had been sacrificed

for the sake of higher filtration rates using alum-coagulation. Dr AGARWAL said that in Table 1 it had been shown that the E.coli were almost nil. He had also written that prototype filters receiving alum-coagulated influents produced filter effluents which were almost bacteria-free. This was found to be in contrast to a simple filter receiving raw water. This fact was observed in comparative results obtained from a raw water filter and alum-coagulated water filter.

25. Mr CROWLEY asked for a scientific explanation because it went against all the concepts of water treatment. Dr AGARWAL did not agree that slow sand filters were only biological filters, because there were other processes that were equally important. Bacteria could be considered as micron particles removed by mechanisms other than biological ones. There was something between the pure biological filtration and rapid sand filters, where physical and chemical processes were predominant. Of course, quality deteriorated at higher rates of filtration but not to the extent of being unacceptable.

26. Mr CROWLEY said the point was that the head loss figures shown were fairly consistent but if there was aluminium carry-over there would be rapid head loss build-up near the top of the filter. The experiments had been done under fairly controlled conditions but at a waterworks there could easily be aluminium carry-over if dosing was not controlled accurately. The CHAIRMAN said that carry-over was more likely to occur at a large plant.

27. Dr R. PERRY asked if the sand was analysed for aluminium at the end of the experiments. Dr AGARWAL said the water filtrate was analysed for aluminium and it was found that most of the aluminium flocs remained at the top.

28. Mr J.E.J. GOAD said that the figures given in Table 1 did not seem to show convincingly that using alum-coagulation was better. Did Dr Agarwal have any other data? Dr AGARWAL said there were two quality parameters, turbidity and E.coli. This Table showed the turbidity and E.coli loads and it could be seen that alum-coagulation was to the good. Mr GOAD said the improvement was not very significant using alum, bearing in mind that the filter had a worse effluent. Dr AGARWAL said pretreatment reduced turbidity before it got to the filter. Without alum-coagulation the filter choked up and the run was uneconomically short even at conventional rates. Alum-coagulation was therefore necessary for highly turbid waters if slow sand filters were to be used.

29. The CHAIRMAN thought the discussion illustrated a great dilemma for water treatment. There was a well establishdd technology which had been running for a long time, which by western standards was relatively cheap and which had been optimised slowly over a long period. The hazards of water supply systems failing were very great, and therefore there was great pressure towards conservatism in the approach. Yet because of the extreme economic pressures in developing countries, people tried to find cheaper ways. Nearly all the comments for variations came from people who were entirely concerned with developing countries. No British consulting engineer had suggested a major departure from what was recognised as orthodox. He suspected that for someone from abroad going into a less well developed country there was a tendency to play for safety and orthodoxy.

30. Mr P.S. DURRANT said the engineer was paid for producing something that would work, not for an experiment. The CHAIRMAN suggested that the institutional structure within which advice from outside came led to this situation. There were strong reasons for developing powerful experimental departments within developing countries. An outsider was hired to do one project, but projects should be looked at ten years after they were built to decide which were best.

31. Dr PERRY said that in India universities found it extremely difficult to get funds for research. Research of the type reported by Professor Agrawal and Dr Agarwal was often published and forgotten. The organization of a central research establishment with the backing of government who were prepared to see research innovated in the universities was essential. Currently there was room for a great deal more co-operation between central research establishments and the universities. The CHAIRMAN said this took a long time to grow up. Nigeria had established medical research councils which were beginning to forge links between government and universities.

32. Professor MAJUMDER wondered whether anyone present had done experiments by speeding up slow sand filtration in the U.K. Mr K.G. STRATFORD said the Metropolitan Water Division of the Thames Water Authority had carried out extensive trials into the relative merits of slow sand filtration, rapid gravity filtration and various forms of settling tanks using a Thames river water after storage. The investigations were allied to the complementary problem of sludge disposal arising from rapid gravity filtration with coagulation. The results

of those investigations confirmed that the practice of using primary rapid sand filtration without flocculation followed by slow sand filtration was the most efficacious insofar as the London works were concerned. The subsequent large installations at Ashford Common and Coppermills took account of those results although micro-straining was also incorporated at Ashford. Details of the trials have been published in the Metropolitan Water Board's Annual Reports of their Director of Water Examination. Professor MAJUMDER said that in India there were quite a lot of slow sand filters. As demand increased it was necessary to decide whether to put in new rapid sand filters or increase the rate of filtration of the existing slow sand filters. Instead of investing large sums on new plants it might be better to increase the rate of filtration of the existing ones. Dr AGARWAL thought the rate operated by the Coppermills Waterworks was 250 l/m^2h using reduced depths of sand and gravel.

33. The CHAIRMAN thanked Professor Agrawal and Dr Agarwal for their paper which had promoted a lot of discussion and hoped that they would be encouraged to continue their experiments with a view to optimising systems.

H. R. WASMER

wastes management as a world problem

INTRODUCTION

Nobody needs to be told that pollution is a world-wide problem. To most people this means that certain pollutants like pesticides have become widely distributed within the natural cycles in water and in the atmosphere; indeed, compounds like DDT are found in the most remote places on earth.

Traditionally, waste management was restricted to the technical, organizational and economic aspects of waste handling. Emphasis was given to wastes from point sources such as effluents, stack emissions or municipal refuse. Thus, most activities and particularly most financial investments were concentrated on the construction of treatment facilities. This so called end-of-pipe approach was successful insofar as the environmental situation would have deteriorated even further without such treatment. However, evaluations of cost/benefit relations were not carried out for alternative approaches to waste management. The question remains open whether we have chosen the optimum solution.

In order to evaluate waste management activities it seems appropriate to clarify terms such as efficiency and effectiveness: The process of policy making leads to the formulation of objectives. In the case of environmental protection, this means a description of the state of the environment to be achieved or maintained. By quantifying these objectives it becomes necessary to work with tolerance levels and to set limits to the residual load on the environment. Setting these limits is based, on the one hand, on our scientific knowledge, and, on the other, on philosophical considerations i.e. our ethics regarding the biosphere. Once such objectives are set, our aim will be to reach these goals by the most effective and economical means. The term efficiency can be applied to the quantification of such endeavors (waste management). However, here again, the important point has to be stressed. It is the residual load on the environment that has to be taken as a reference and not just the amount of pollutants removed.

The limited effectiveness of end-of-pipe measures becomes evident in the face of pollution from non-point sources (lead discharged into the atmosphere by internal combustion engines, freon from spray cans as a threat to the ozone layer in the atmosphere). When dealing with these kinds of pollutants, waste management plays an important role in the initiation of any materials flow, i.e. the design of manufacturing processes, produce specifications, or even in non-technical fields such as legislation, taxation etc.

The aspects of waste management described so far are more or less restricted to the national level. The following attempts demonstrate that waste management plays an important role on the international scene as well and that the traditional approaches to waste management are inadequate for pollution control on a world-wide basis.

Objectives

The objectives of this paper are

- to elaborate parameters that could be used for the description of pollution potentials on a world-wide basis;
- to demonstrate that there exists a transfer of environmental problems even if pollutants are not transported across political boundaries;
- to identify and describe the constraints on waste management and to show the limits of pollution control measures.

GNP/Energy Consumption as a Measure of National Pollution

It has been proposed by Goldberg(1) to use the GNP/area ratio as a measure of the potential pollution of a country. While the gross national product is incontestably related to the flow of materials within a society as a result of its industrial, agricultural and domestic activities, Goldberg's approach has some severe limitations:

a) It does not take into account that only part of the area is cultivated or otherwise used for civilisatory activities;

b) It does not consider the various types of activities that combine to make up the GNP.

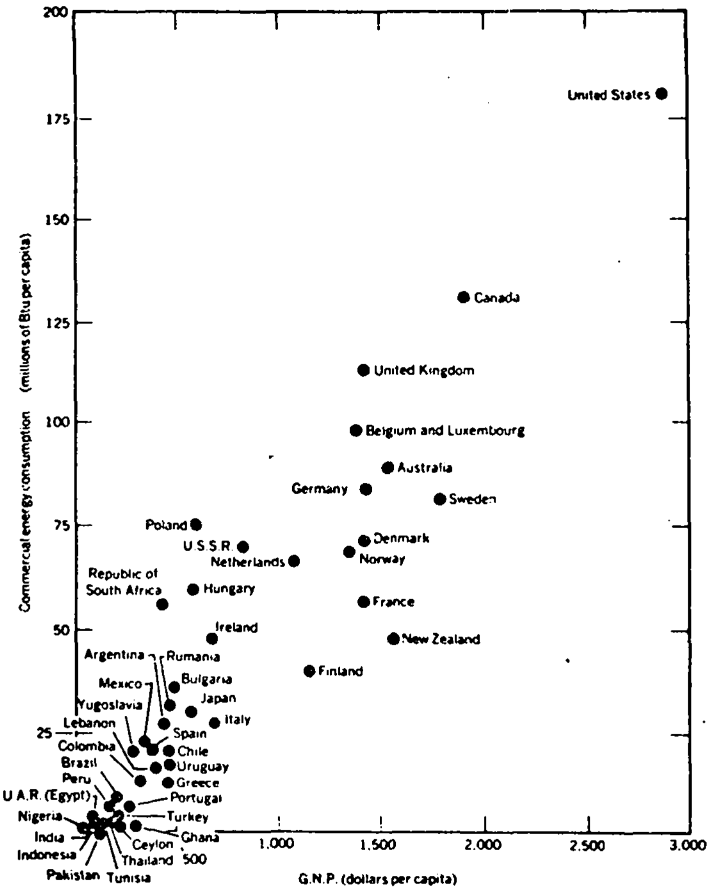
Gambel(2) investigated the relationship between GNP/capita and consumption of fossil fuel energy for different countries. In general, high per capita energy consumption is a prerequisite for high output of goods and services. Figure 1 shows this well known pattern, with the industrialized countries demonstrating peak values while a cluster of points, indicating various developing countries, are situated at the opposite end. The question arose how the distribution pattern of GNP/capita vs energy/capita could be explained. For this purpose more recent data(3) were elaborated and the ratio of GNP/energy consumed determined (i.e. the slope in Gambel's presentation).

This ratio varied considerably as shown in Figure 2. The following conclusions can be drawn from these data:

1. GNP/energy is an indication of the type of activities for which energy is used to produce goods and services.

2. GNP/energy consumption is a criterion for quantifying the specific pollution potential for the overall activities of a country. The absolute pollution potential would then be the produce of specific pollution potential times total GNP. The relevance of such a figure

<u>Figure 1</u> COMPARISON OF FOSSIL-FUEL CONSUMPTION AND INCOMES FOR DIFFERENT COUNTRIES.



could be further improved if it would be corrected by the factor total land area/cultivated or "used" area.

3. It has been proposed that the costs for pollution control be incorporated as externalities in the price of consumer goods. Even more important, however, is that these externalities be included in the price of primary materials.

4. The international implications of the waste management problem are more far-reaching than we used to believe; national waste management policies (or legislation) should consequently be based on the nature of environmental problems rather than on available pollution control technologies.

The statements made above need further explanation.

<u>Statement 1 and 2</u>

Several authors(4) have proposed to use the following equation for the description of environmental loadings U :

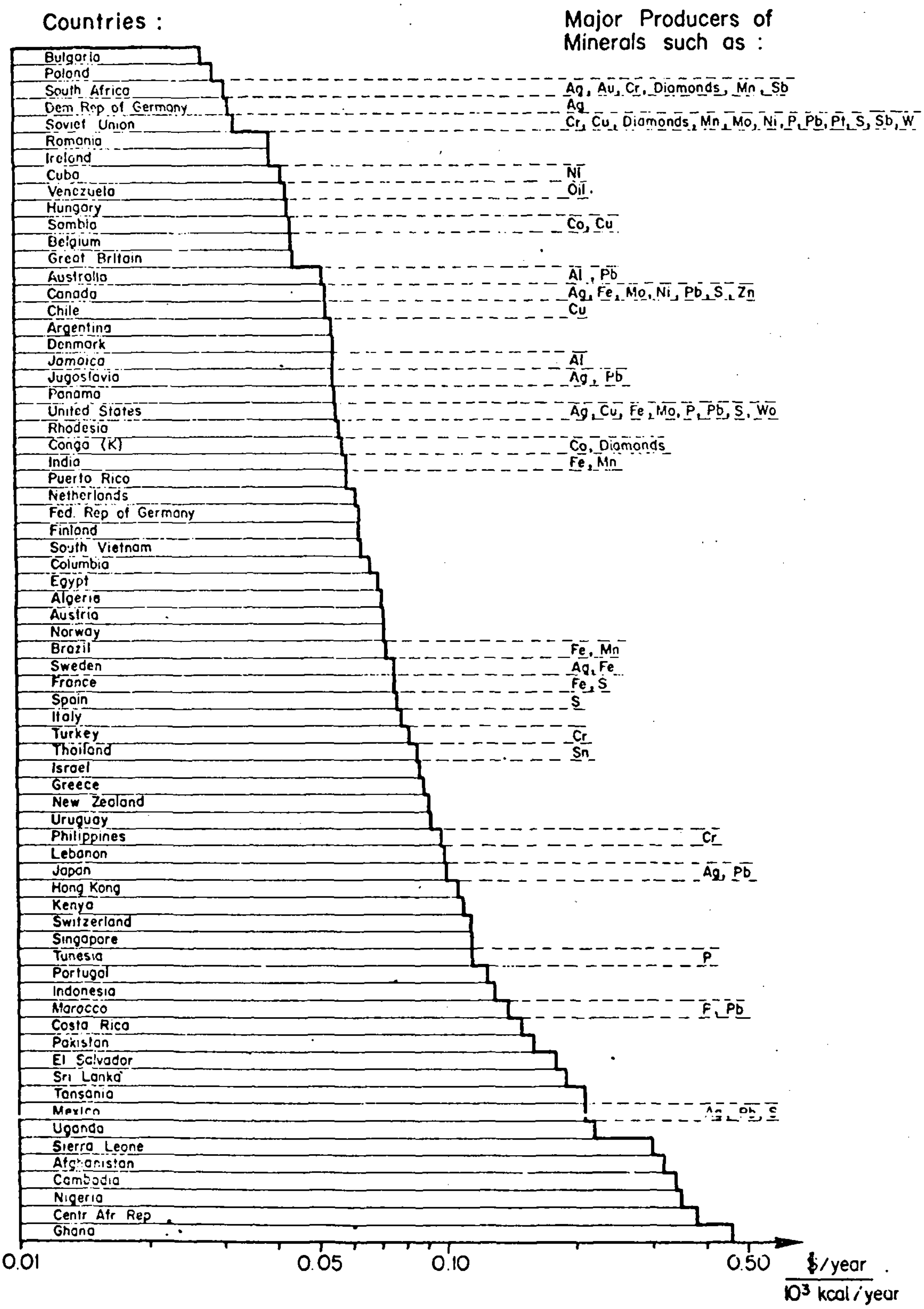
$$U = \frac{GNP}{Area} (1-\eta)$$

where η is a descriptor for the efficiency of activities.

Figure 2

RATIO of GNP/ENERGY CONSUMPTION

$\left(\frac{\$ / year}{10^3\ kcal/year}\right)$



Could the differences in the GNP/energy ratio be explained by the efficiency by which energy is used?

The variation in the ratio of GNP/energy consumption can only be partially explained by the efficiency of energy use. Figure 2 does not take into account the various forms of energy; i.e. no distinction is made between electricity produced in hydromechanical plants and electricity produced by the combustion of fossil fuels.

The geographical distribution of the various countries shows that the more "efficient" energy users are located in warm climates. Conversely, the "inefficient" energy users need considerable amounts of energy for heating which does not directly contribute to the growth of the GNP.

Figure 2 shows some very interesting facts that should consequently be considered in the definition of waste management policies. Countries with an economy based on the production of primary raw materials will undoubtedly have a lower ratio of GNP/energy used. The ratio per se is given by thermodynamics. To illustrate the importance of primary production, the major producers of metals are also listed in figure 2. Countries that are active mainly in the tertiary sector (i.e. no heavy industry but raw material imports and high quality goods production, with emphasis on services, tourism etc.) show relatively high ratios.

Although "efficiency" should not be used as a qualifying term, it nevertheless indicates that low GNP/energy ratios are due to energy intensive activities. Metal ores mining and processing are examples of energy intensive activities (for one ton of copper about 600 tons of waste materials are produced).

Statement 3 and 4

Countries whose activities lie mainly in the tertiary sector are actually living at the expense of those countries that produce primary materials. There is a hidden trade of waste management problems, since the countries importing primary materials are exporting pollution problems to the primary producers. The extreme case would be a country that imports all primary materials including food and energy and exports high quality goods and services. This country does not have to deal with any of those waste management problems that are related to the production of the imported raw materials.

Bound by more stringent pollution control legislation, producers in industrialized countries can no longer consider the quality of air, water and soil a free and unlimited resource. Expenditures for pollution control are included in costing and are ultimately passed on to the consumer.

It seems obvious that such considerations should not be limited to the manufacturing level but should include the level of primary production as well.

It is beyond the scope of this paper to discuss the various implications for the international trade of primary products if the cost of pollution control were included in the price of primary products. To reach international agreement will not be an easy task, but world-wide concern for the state of our environment gives reason to believe that the common interest of mankind will be respected.

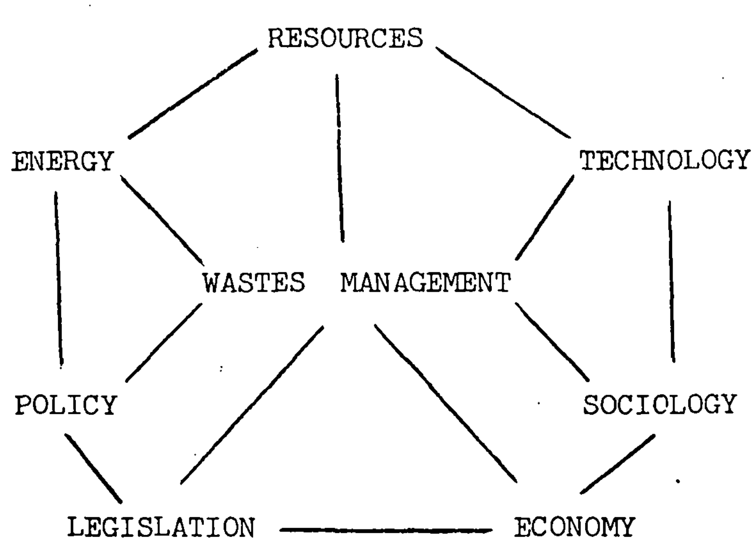
Some comments on legislation: All legislation on pollution control mentions as one of the objectives the state of the environment that should be maintained. In the case of water pollution control legislation, the only workable basis is to set up criteria for the condition of the receiving water bodies. Quite often such standards are taken over from other countries' legislation. Such practices can lead to situations where the ultimate goal, protection of the environment, is only partially achieved because the boundary conditions were not duly taken into account. It would certainly be most unfortunate if a country active mainly in the tertiary sector (services) would adopt the same criteria as another country that produces mostly primary materials.

It also shows the inherent fallacy of the philosophy that the extent of pollution control should be determined by technological fixes, i.e. "the most practicable means", or "best available technology". This end-of-pipe approach leads to a series of standard technical solutions for most waste management problems. One could agree that there is too much emphasis on technology transfer with regard to waste management compared to the transfer of problem analysis.

Constraints and Limits to Waste Management

The various aspects of resource conservation, pollution control and environment cannot be considered out of context. The complex interactions within the materials cycle, the direct correlation between energy and minerals production, the effects on industry and the consumer, and the inter-relationships of national and international policy all need to be taken into account for the formulation of objectives. Figure 3 shows these inter-relationships in a schematic form.

Figure 3 INTER-RELATIONSHIPS IN WASTES MANAGEMENT



The following paragraphs are an attempt to describe the technological limits to waste management. The non-technical (socio-economic) aspects will not be discussed further because this would go beyond the scope of this paper.

The lack of available waste treatment technology is not the principal barrier to pollution control. The basic technology is known for the control of most problems, although engineering applications may not, as yet, be developed enough to meet the demands of practice. Waste management is primarily an economic and political problem that was left with the engineers. While technology can do much towards conserving resources it cannot do everything. Those who argue that technology has always come up with an answer tend to ignore that the so called "solved" problems have always had their social, environmental or economic costs.

The limits to technical measures for waste management can easily be shown by a mathematical model.

CONCLUSIONS

As the use of resources continues the world trend towards inter-dependence will become more pronounced. There will be occasional fluctuations like the recent oil crisis. The long range goal of countries should, however, not go in the direction of independence with regard to raw material supplies; this would be impossible. Policy-making at all levels should recognize inter-dependence within the materials cycle among nations and among the various users of resources. "Above all we should adopt a conservation ethic that is determined to avoid wastage, make more efficient use of materials and practice waste management on a rational basis."(6)

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discussion

CHAIRMAN: B.M.U. BENNELL, BSc, FICE,
Ministry of Overseas Development

The CHAIRMAN said the session would deal with a subject of world-wide interest - the problem of waste management. He felt no subject had aroused more interest and concern over the past decade as this. Its most serious form touched upon the livelihood and even the lives of everyone in all corners of the earth.

2. The Conference was fortunate to have Dr Hans Wasmer to guide discussions on this vital subject. It seemed entirely appropriate that Dr Wasmer should be from Switzerland, a country regarded by many as amongst the world's leaders in both political sanity and public order. Dr Wasmer was Deputy Director of the Institute of Water Resources and Water Pollution in Zurich. He took his first degree in engineering at the Institute of Technology in Zurich and then worked with consulting engineers on the problems of disposal of solid waste and waste water treatment. He took a second degree at the University of California and again worked with consulting firms in the U.S. He had occupied his present post since 1972. He also taught at the Swiss Federal Institutes in Zurich and Lausanne and lectured on behalf of WHO at Rabat in Morocco.

3. After Dr Wasmer's introduction the discussion would be divided into these sections:

a. Operation and maintenance
b. Constructional facilities and treatment technology
c. Regional waste management systems
d. Development of concepts
e. National goals.

4. Dr H.R. WASMER said the role of the engineer in society was very important. He wondered whether educational programmes and universities produced engineers who were fit for the task of working and operating in the five areas mentioned by Mr Bennell. The public health engineer was unlike the conventional civil engineer or mechanical engineer as he worked on a completely different level. For example a civil engineer might get an assignment to build a bridge and have the choice of whether to build an arc bridge or a suspension bridge, but at least the decision would already have been made that there should be a bridge and where it should be built. The mechanical engineer might produce a turbine or something else, but the public health engineer was involved right after leaving school in decisions that had far-reaching consequences. Dr WASMER felt so far, most educational programmes failed to prepare the student for this decision-making task.

5. Dr WASMER intended to deal with the engineer's task on these various decision-making levels.

a. He would not go into details of operation and maintenance.
b. Constructional facilities and treatment technology were beyond the scope of this Conference as they involved all aspects of the best technology for a given problem in a given geographical area.
c. He would say a little about regional waste management systems.
d. Development of concepts, pollution control strategies and executive orders: by this he meant the upper levels. If there was legislation how was it to be

implemented? For example, should phosphorus be prevented in detergents? Was there a substitute? Was the technology available?

e. The engineer was involved in national goals and pollution control legislation.

6. Even on international levels there were waste management problems which people did not usually consider in their everyday lives. It was possible to develop a pollution potential for various countries and there was a transfer of environmental problems, even if pollutants were not transported across political boundaries.

7. When the gross national product was plotted against energy consumption (as shown in Figure 1) it provided a measure of national pollution. This approach had limitations and did not take into account that only part of the land was cultivated nor the various kinds of activities which combined to make up the GNP. From Figure 2 the differences in what the various countries produced and the energy they used was surprising. Countries with an economy based on the production of raw materials had a lower ratio of GNP/energy used. This ratio was given by thermo-dynamics. To illustrate the importance of primary productions, the major producers of metals were listed in Figure 2. Dr WASMER had put the mining of metals as primary production. This was according to the definition he felt everyone was familiar with - primary meant agriculture, secondary meant processing and manufacturing, and tertiary would be only services etc. If a country's economy was based on the primary sector it would never reach a high ratio because it needed a lot of energy to produce some goods. It would be tempting to say that the countries at the top of the list were wasting energy and countries at the bottom of the list were making good use of their energy, but this would be an over-simplification.

8. Countries whose main activities were in the tertiary sector were exporting pollution problems to the primary producers. It could be asked why pollution should not be included in the cost of primary resources.

9. Many developing countries were taking over legislation, particularly for water pollution control, from industrialized countries. This was a practical way of doing it but it did not make much sense. A study should be made of what the country could do and what the particular problems of the country were. The same legislation and the same river standards should not be expected from countries at the bottom or at the top of the list given in Figure 2.

10. The interaction between resource conservation and pollution control, the correlation between energy and minerals production, the effects on industry and the consumer, and the inter-relationships of national and international policy all needed to be taken into account.

11. Waste treatment technology was known for the control of most problems, although engineering applications might not yet be sufficiently developed to meet the demands of practice. Waste management was primarily an economic and political problem left for engineers. Technology could do much towards conserving resources, but the so-called 'solved' problems always had their social, environmental or economic costs.

12. Mr P.A. OLUWANDE, referring to what Dr Wasmer had said about ratios shown in Figure 2 and national goals, feared that some policy makers in certain developing countries might be over-optimistic, thinking that because they had high ratios there was no pollution problem. Nigeria, according to the graph, had a very high ratio, which meant there was little or no pollution. However, there were isolated serious pollution problems resulting from the consumption of fuel by the numerous vehicles in the cities and from domestic and other wastes. Dr WASMER said if Nigeria scored high it meant they produced a lot of GNP related to energy: it did not mean they did not have any pollution problems. This presentation showed intensive activities and if this was multiplied with the total GNP it gave a total pollution potential. It also did not take into account what kind of energy was used. This was merely an attempt to scale the various problems.

13. Professor N. MAJUMDER asked how the ratio of GNP to energy consumption could be related to pollution. Dr WASMER said it was only a measure to give an indication of pollution potential, but agreed with Professor Majumder that a less industrialized country could have a high ratio and therefore less potential pollution. He was unable to account for India's high pollution problems with little industry.

14. Dr R. PERRY said most road vehicles in Switzerland were comparatively new and many were controlled. In India vehicles were a lot older and there were no controls at all. Thus the emissions from road vehicles in India were a lot worse than those in Switzerland. That sort of analogy could be stretched to many industrial processes operating in India compared to those in Switzerland, and the emission level in India was greater than in Switzerland. On the

other hand, as Dr WASMER pointed out, there were more vehicles per unit area in Switzerland than in India.

15. Mr W.E. WOOD said that the problems of India were not affected by whether they were higher or lower on the list. He could not see where this was leading. Dr WASMER said the objective was certainly not to develop a hit parade of the efficient energy users. It was an attempt to qualify the pollution problems on a national level: to try and make some comparisons: to see where, and what kinds of problems existed.

16. Dr S.M. ROMAYA said this did not give where the problems were or what kind they were. It just gave a rough guide in a sort of league table of a very complex issue: the contributory factors and results could be complex. It seemed to Dr ROMAYA to be more sensible to treat it as a complex issue rather than to try and simplify it in a crude way. It would be better to tackle each aspect of the physical measurements, identify them and make comparisons, whether with energy, noise etc.

17. The CHAIRMAN said it seemed important that if politicians and public opinion should be aroused there should be some measure of comparing the dangers of pollution in different countries.

18. Mr JOHN PICKFORD felt the crux of the matter was the extent to which energy consumption was a real measure of the pollution potential. Dr Wasmer had given the GNP/energy scale but to what extent did this affect pollution? Was it only a very small part of the pollution potential or, as Dr Wasmer seemed to be suggesting, a major part? Mr PICKFORD considered that it was a very small part. As far as developing countries were concerned, the majority of pollution was derived from sources other than those which used energy. Dr WASMER asked Mr Pickford whether he was talking about a health problem or a pollution problem. Mr PICKFORD replied that surely the major pollution problems of land, water and air involved health. Pollution of faecal origin was the greatest concern to developing countries, but this was not included in the equation. Professor MAJUMDER added that the type of pollution in India had no bearing on energy consumption; he referred to human excreta on the ground and open wastes.

19. Mr M.I. ALDRED asked for details of the mathematical model which showed the limits to technical measures for waste management. Dr WASMER said it was derived from thermodynamics. A certain amount of pollution could be reduced by pollution control and by doing this energy was used and the total energy consumption would increase. Somewhere there would be an optimum of pollution control versus energy used.

20. Mr J.E.J. GOAD said the GNP/energy ratio took into account food production which would be reflected in the GNP. Subsistence agriculture was efficient in terms of this ratio since there was a low energy consumption for the production of food.

21. Dr WASMER said he was in total disagreement with Mr Pickford and asked what alternative there was to energy as an indicator of pollution. Dr ROMAYA said there was a series of alternatives. Energy was one factor in a complex subject. Admittedly it was an important factor, but where there was little energy consumption, as in India, it became of minor effect and other pollutants would assume more importance.

22. Dr WASMER felt this was a problem of definitions. He was an environmentalist and not a health engineer. Professor MAJUMDER asked for Dr Wasmer's definition of pollution and Dr WASMER said pollution was influences that disturbed the ecological stability and also included limitation of resources. He suspected Professor Majumder's definition would be directly concerned to the impact on man. Mr PICKFORD thought a commonly accepted definition of water pollution was that given by Dr Key that pollution was anything which was added to water which affected directly or indirectly man's use of that water.

23. Mr D.M. TURNBULL thought Figure 2 was most misleading and Figure 1 was more useful. The consumption of energy was directly related to the amount of materials used and in particular what was discarded, i.e. waste. Dr WASMER agreed that pollution was a consequence of waste. There was still the problem of how to qualify pollution on a national scale. He thought the problem had been dealt with on a national scale: it could go further. In Switzerland environmental pollution control legislation had been drafted in 1974: it was discussed and ended up in the waste basket. Someone had said in an earlier Conference session that engineers should do what politicians decided, but Dr WASMER thought politicians did not take many decisions: things just happened, and the engineer should take the chance to get involved.

24. Another speaker thought Dr Wasmer had shown clearly how difficult it was to assess this problem because of the diverse

waste and method of dealing with waste in different parts of the world. In Britain there had been problems with china clay mining when all the streams coming from it were polluted. The Thames was returning to something like normal because fish could now be caught up to Westminster Bridge.

25. Professor MAJUMDER commented on the three aspects of air, water and solid waste in India. The management of water pollution was not very well organized, and the water pollution laws had not been properly enacted. Checks were made on the type of waste discharged into water courses and once it was found that pollution was beyond limits, the industry responsible was required to undertake proper treatment. Bills for control of air pollution were before the government and it was expected that laws would be enacted before long. For solid waste there was no such law. The CHAIRMAN asked if the laws were at state level or national level. Professor MAJUMDER said parliament passed a bill and then it became obligatory on the states.

26. Mr OLUWANDE said in Nigeria an attempt had been made to persuade the government to enact a pollution control act, but this had not been successful. Thus industrialists were free to discharge pollutants into the streams. People thought air pollution was no problem, whereas traffic problems were worse in cities in Nigeria than in London. Solid waste created problems in the cities, where refuse stockpiled at public collecting depots tended to block the streets because refuse disposal was often left to local authorities.

27. Mr P.W. ROYDHOUSE suggested that pollution should be considered against the degree of urbanisation that had been experienced; a town of a million people had far more waste and pollution problems than any small village of say a hundred persons. Dr WASMER said it depended on what questions were asked. For example this approach would certainly create some difficulties with regard to rural areas and by separating industrialized areas from residential areas. Mr ROYDHOUSE said any industry that established itself in a rural area would bring with it a measure of urbanisation. He felt it should be possible to measure the degree of pollution against the density of population in any country. Dr WASMER said he was not measuring the degree of pollution but was developing some yardstick for indicating pollution potential.

28. Dr PERRY thought that the legislation currently acceptable in the West was not necessarily acceptable in developing countries. Nor could developing countries afford politically acceptable legislation that led to further technical problems, an example of which can be seen in the phosphate problem. The problems of eutrophication had been known and legislation against phosphates in the United States was instituted as a result. Subsequently it was shown that alternatives like N.T.A. had problems arising from carcinogenic degradation products. Further N.T.A. could lead to solubalisation of metals from sewage works into receiving waters which could bring additional problems. This sort of legislation, which was largely for political advantage, should not be introduced into developing countries. Again, in the United States vehicle emission control had led to as much as 18% increase in fuel usage, which was non-acceptable to a developing country.

29. Dr WASMER referred to Public Law 95/200 which was the pollution control legislation in the United States. There it said "zero discharge by 1980". To do this pollution control was to be introduced by the most practical means by 1973 - the 'most practical means' being the most economical. By 1978 control should be by "the best available technology". However there was no legislation to provide the money required. The Swiss legislation for pollution control said that the load on the environment should not increase and the legislator did not decide what should have priority, economic development or the environment.

30. Professor S.V. PATWARDHAN felt the biggest problem was implementing legislation. Many industries wanted to reduce the pollution load but in many cases they were not in a position to produce the desired standards.

31. Mr GOAD said one way of controlling the emissions of factories or municipal authorities was to make them buy the rights to discharge waste to a river or lake. They bought the capacity of the receiving body to take pollution bearing in mind that the river or lake could only take a certain amount. They could pass on the costs to the consumer. Dr WASMER said this was a possible solution but it depended on the national legislation. It would be a dangerous approach as things could get out of control, because everybody would sit on their rights and say "it's my river, I'm going to do what I want with it. I don't want any fish and I think it's better as a sewer".

32. Mr E.L.P. HESSING was more interested in the effects of pollution on the human being. Was it possible to apply the criteria being discussed on pollution arising from domestic waste which influenced public health?

33. Dr ROMAYA said one of the problems in developing countries was to make the investment attractive to industrialists. If someone who was interested in starting an industry was told that it was necessary to have this, that and the other as controls - such as a very limited amount of effluent could be discharged to a river and that only certain gases could go into the air - then he would be frightened away. Dr WASMER agreed. At the Stockholm conference someone from a developing country said "we would like to have some of your pollution - together with the industry that produces it". The CHAIRMAN feared that many large industrial concerns exported their pollution by setting up in countries which did not have pollution control legislation. It was important to recognize that this was happening and not to let it happen by accident.

34. Professor M. DANBY asked whether good national waste management included control of packagings. Developing countries did not have this problem, and he feared that as economic development continued they would import the wickedness of the packaging industry. Dr WASMER said if energy was used as an indication of pollution potential, it would be seen that packaging was a very important problem.

the OXFAM emergency sanitation unit

35. The CHAIRMAN said that in dealing with pollution in the developing world one of the many daunting problems was the galloping cost of conventional treatment of human waste. He introduced Mr J.C. Howard from OXFAM who would describe a rather novel and inexpensive solution to these problems based on his experiences recently in Bangladesh.

36. Mr J.C. HOWARD said he was a trained public health engineer. OXFAM was a large British charity which raised around £4-5 million per year from the public which made it one of the biggest fund raisers in the world. They worked in various countries. One of the main problems was how to spend the money they raised wisely. They had consultations with governments overseas but liked to try and decide for themselves how to spend the money. It was difficult to decide whether to use it in family planning, agriculture, water resources, irrigation etc. and each was an attractive field, particularly to donors. For example, to dig a well and say that 50 acres of land would be irrigated was very nice; to say that a latrine was to be put up did not seem quite so attractive.

37. In June 1971 Mr HOWARD flew from Britain in a VC10 which was full of water, taking 25 tons of saline water to Calcutta to treat cholera. That consignment cost nearly £30 000. When they arrived, there were a hundred refugee camps from the East Pakistan war each with about 100 000 people. The immediate problem was sanitation, water and feeding. The saline water was flown out because cholera patients needed something like two litres an hour to rehydrate them.

38. In refugee camps, slums and difficult urban conditions, thousands of people lived with no sanitation and no hope of sanitation. A cholera patient excreted about two litres an hour with around 2000 infective doses of cholera an hour. This lasted for about 36 hours and then he would either die or start to recover. In rural India and in Bangladesh with untreated cholera there was 40-50% death rate. The same patient would also excrete all his worms and a female round worm would lay 100 000 fertile eggs a day. This was the sort of problem on the ground which made a lot of the discussions about environment very insignificant. In Bangladesh about half a million lived in refugee camps. They were mainly slum dwellers recently evicted from Dacca. As over 1500 mm of rain (60-70 inches) fell it was no wonder there was 12% death amongst infants under one.

39. When Mr HOWARD returned to Britain in 1971 he spoke to everyone who might be able to help: the army, the Imperial College, London School of Tropical Medicine. They were asked what could be done for large numbers of people who had no sanitation and it was raining and waterlogged. Could OXFAM buy something "off the shelf" and put it up? However, there was nothing which could be moved across the world quickly to treat for example a thousand people's soil on a long-term or short-term basis.

40. They found several people, including John Pickford, a microbiologist at Surrey University and James Fraser, a civil engineering consultant, who put their ideas together. The first idea was a percolating filter using plastic media. Finally they

came up with an idea of a large flexible tank of the kind made for the RAF as fuel tanks. This tank provided containment for the excreta.

41. They then built a simple package. There were two 5000-gallon tanks which could be rolled up and packed with 20 squatting plates and pipework into a 1.8m x 1.8m x 0.9m (6' x 6' x 3') crate weighing 500 kg when full. The crate could be used for the latrine superstructure. The cost was about £1000 and it was hoped it would serve around 500 people. Investigations at Surrey University showed that the cholera vibrio, which was an aerobic bacteria had a break point of around six days when retained under the anaerobic conditions in the tank.

42. Mr HOWARD showed photographs taken recently in a refugee camp in Bangladesh. The usual latrine put up by government was a concrete squatting plate over a hole. Once the hole was full everyone was surprised that the excreta was treading all over the place. People stopped going there and went back to their usual place of excreting along the banks of the river.

43. In the camp OXFAM sanitation units had been erected in the last two or three months. There was a full-time operator to keep the place clean and a clerk counting the people going in so it was known who used the place. The units were erected with a little supervision by a totally local team and the problem was not acceptability but over-usage.

44. In trials at Dacca in October/November 1974 the drains at the cholera hospital with 3000 cases of cholera were blocked. All the sewage from the hospital was passed through a similar unit and they found about a thousand-fold reduction in cholera vibrio. About 99% of the round worm were settled out.

45. Mr HOWARD said engineers needed to give more answers to the worldwide problem of how to provide sanitation for poor people. They did not want electrically operated equipment because there was no electricity; they did not want chemicals as they could not store them; they did not want chlorine treatment because they could not get chlorine. They wanted a simple biological gravity-type system.

46. The field worker of the local community had a lack of engineering skill or advice. This was one of the reasons why a package was required. There was always a shortage of craftsmen and materials and there was always uncertainty of the costs and financial input required. With a package sewage treatment unit the costs were known and it took simple technology to put it together and run.*

47. Mr OLUWANDE asked whether the tanks previously used at the Dacca refugee camps were watertight. Mr HOWARD said they were not watertight but they became full of solids.

48. Mr OLUWANDE asked whether there were any problems with the local people not wanting to share the OXFAM units with people from other parts of the country, and what sort of treatment was used. Mr HOWARD said there had been no problems. The clerk had to motivate people to use the units. The tanks were only dealing with excreta; there was no washing water or soap or detergents. For each person using the latrine six or seven litres of flushing water was added to the two or three litres/day of sewage. In the first tank there was massive precipitation of solids which were held for three months. When the tank was half full with sludge retention time was lost and then they desludged. The first units were installed in March 1975 and the first desdudging had already been done. The sludge was put in a desludge trench and there had been no interference except for an inordinate interest by local chickens. They maintained that if it was left in the trench for a further three months making a total of six months, it could then be applied to land.

49. Professor PATWARDHAN asked if the tanks were closed at the top. Mr HOWARD replied that the tanks were like rubber pillows. There was a gas vent on the top and this was another problem to be solved - what to do with the gas because the gas vent was going like a steam engine all day.

50. Mr ALDRED said the size and distribution of these units was obviously fundamental because it affected cost. In the short time the units had been in operation had it been possible to establish the optimum size of unit and the distance that people were prepared to walk to them rather than go to the bush or river? Mr HOWARD said at present it appeared that three other sizes of unit were needed: a 200-person unit, a 1000-person unit and a 5000-person unit. With regard to distance,

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* Copies of a brochure describing the OXFAM sanitation unit may be obtained from OXFAM, 274 Banbury Road, Oxford, England.

small children still tended to go in the bush and it was a case of shouting at them to go to the unit. Some people were going up to 1½ miles to use the units.

51. Mr M. LANSDELL asked what was done about paper. Did they bring their own or was it supplied? Mr HOWARD replied that there was no paper used, just water. A lota (a brass pot) was provided at the door.

52. Replying to a question from Professor Patwardhan, Mr HOWARD said smaller units were more difficult to maintain and keep clean. There was virtue in a big unit, and he thought to walk a hundred metres was reasonable. He was not suggesting that this was the world's answer to sanitation. However, in places like Calcutta these units could be installed and a reasonably safe liquor could be put into the local surface drain. It would certainly be free of cholera and 99% free of roundworm and whipworm.

53. Mr WOOD asked for more information on the desludging. Mr HOWARD said they tried to elevate the squatting plates four or five feet above the ground, because ideally the tank should sit on the ground. If a trench was dug to the side of the tank, a flexible pipe could be used to desludge by gravity. The trench would take something like half the capacity of the tank - 2500-3000 gallons.

54. Mr WOOD asked if there was any other cleansing on the camp i.e. solid wastes which could be composted with the sludge.
Mr HOWARD said that in this type of community there was little to throw away: it was either burned or used in some other way.

55. Mr R.A.J. SIMKINS said presumably the latrine would have to stay for a reasonable time. Did Mr Howard anticipate any difficulty over the sludge disposal trenches growing in size from the latrine until it was found in due course that there would be some embarassment over disposing of the sludge? Mr HOWARD said that although the latrines were permanent, if at any time the people moved elsewhere the units could be lifted and resited. The material from the desludge trench would be taken away every third month and used as a compost.

56. Mr G.B. RALPH asked if there was a liquor trench to dispose of the liquid.
Mr HOWARD said the effluent passed through a locally made stone filter. Distribution was from perforated pipe only, and a corrugated sheet drilled with holes. They needed more information about the best media for filtration - it might be twigs or plastic media or burned bricks. When running a brick filter in Dacca there was so much build up that slime had to be removed after a week.

57. Mr ALDRED asked what was the population density of these camp sites. Mr HOWARD said there was a house every four or five metres in all directions and each house had something like three to five people, so there were 200-300 people per acre.

58. Mr I.R. BENTON asked about other sanitation facilities on the camp such as showers and washing facilities. Mr HOWARD said there was a river in which people bathed. If it was made more of a settled community he thought a piped water supply would have to be laid on.

59. Mr BENTON asked what the life expectation of the tanks was. Was any deterioration found underneath where they were sitting on the ground? Mr HOWARD said the tanks were made from a double layer of butyl rubber with a nylon bracing. The manufacturers had stated the life to be between ten and fifteen years. It may be necessary to up into better quality if there was deterioration. In the short-term perhaps for a month, a polythene bag might be used with an earth retaining wall.

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60. The CHAIRMAN thought the system described by Mr Howard represented the lowest form of technology to be considered for waste disposal. It was time to consider problems encountered in more sophisticated surroundings. Operation and maintenance problems for water supply had aroused a good deal of interest earlier in the Conference. He wondered if there were any experiences which could be shared on the sewage and sewage disposal side.

61. Professor PATWARDHAN felt that in developing countries it might be better to have a decentralized system in case of failure. Dr WASMER said in Switzerland there was a population of about six million and about 60% of the population were not connected to sewers. According to some cost comparisons five times as much was spent on sewerage as on sewage treatment. This caused some thought on whether there were any alternatives and an interesting figure developed. Switzerland had a lot of cows and in terms of waste each cow was equivalent to about six adult humans. The load from cows was equivalent to about 35-40 million people, yet there was no health problem.

62. Mr OLUWANDE said that in Nigeria most big towns and cities had no central sewage treatment plant. One reason for this was the cost of connecting sewers. Decentralization would save the cost of connecting sewers and the amount of pumping required.

63. Professor MAJUMDER said NEERI had been working on small units for small household units and small communities in decentralized areas. In towns with a central plant all the sewage was treated and discharged to a watercourse at one point. If there was a breakdown there could be serious pollution problems. On the other hand, if there were multiple plants and multiple points of discharge and one of the plants broke down, the pollution would cause less of a problem. However, this multiple point collection and disposal might be quite expensive. Dr WASMER suggested that a concentrate of point source on these rivers was not important. It was a shock load, but it did not create health problems.

64. Mr ALDRED said that a gravity system with percolating filters did not require any electricity supply, although they required about ten feet of head which was not always available. Another alternative was the oxidation pond which took up a fair amount of land but required no sophisticated engineering.

65. The CHAIRMAN felt that in this country we tended to export our preference for concentration, and the question was whether this was always right.

66. Mr LANSDELL said that with long collecting sewers in hot countries it was not sufficient to have a self-cleansing velocity. Because of the trouble caused by sulphides it was necessary to have a self-oxidising velocity. In Venezuela there was considerable corrosion of relatively new sewers by sulphuric acid attack on the concrete. Consequently engineers avoided long trunk sewers connecting up several communities and long rising mains which caused high sulphide concentrations, making sewage difficult to treat.

67. Mr GOAD asked if anyone had had any experience with the vacuum car systems of lifting solids only. Mr PICKFORD said they were being proposed for Belize. The CHAIRMAN said they were installed in the Bahamas with varying success.

68. Mr B.M. DUMBLETON said his firm had recently costed a vacuum piped system as an alternative to a water-borne sewerage system and came to the conclusion that whilst there was not a great deal of difference in terms of capital cost, the vacuum system was marginally more expensive. The inherent problems with it would be spares and breakdown and difficulty with equipment, which would not be encountered with a conventional system. They came to the conclusion that the vacuum sewer system was only suitable for places where there was a very sophisticated society which would be able to adequately deal with any failures in the system.

69. Mr GOAD said he had referred to the collection of solids by a vacuum car. This might be a horse-drawn sewage collection system as proposed for Belize where the solids were collected from a tank at each house in carts. He believed this was already done in the Far East.

70. Mr PICKFORD said that in Belize houses were built on stilts and had a tank underneath. The cart came along, connected up, sucked it out and carried it away - it was a type of cesspit system. The Japanese accompanied it with quite sophisticated treatment processes including Zimco wet oxidation, which was going from one extreme to the other.

71. The CHAIRMAN asked how this compared on capital cost. Mr PICKFORD said the Japanese claimed it was only one-third of the cost; it saved digging up roads to lay sewers, and that it was a sensible method because large masses of water were not added to the waste; a fairly concentrated waste material was treated. The CHAIRMAN asked why this was not adopted on a more widespread basis. Mr PICKFORD felt that the danger of vacuum cars breaking down would be great. There was always more likelihood of mechanical failure with specially made equipment.

72. Mr DUMBLETON said that there were problems which made it unsuitable for undeveloped areas. However, it did avoid the high cost of laying gravity sewers particularly in solid rock. In reply to a question from the Chairman, Mr DUMBLETON said the reduction of water use had been included in the cost analysis.

73. Professor MAJUMDER said this system had been considered for the unsewered areas of the bigger towns in India. The system of collecting human excreta from existing service privies was laborious and unhygienic. The night soil was collected and disposed of either by composting or trenching.

74. Mr DUMBLETON said that another deterrent was the high capital cost of installing a vacuum toilet in property. With a completely new development where the vacuum toilets could be put into the houses as they were built, it would be a more viable proposition.

75. Professor MAJUMDER asked Dr Wasmer whether he felt waste management should be the responsibility of engineers or the medical administration. It was a question repeatedly posed in India. Dr WASMER said that by tradition in industrialized countries management was mainly with the engineers: if they built the system they should operate it. It would not be a bad thing if the medical community had more influence in management. Engineers ought to be able to cope but they needed some background of biology, chemistry and medical know-how.

76. Professor MAJUMDER made his question more specific: who was responsible for solid waste? Dr WASMER said that in Switzerland, Germany and France, management of solid waste was with the engineers. Mr PICKFORD said that in Britain practice varied before reorganization of local government in 1974. In some places responsibility was with the medical officer of health and in others the engineer. Now there were separate solid waste departments of the county council.

77. Mr OLUWANDE said in Ibadan a board had been created with the responsibility of disposal of solid waste and other aspects of protecting the environment. Doctors and engineers worked together on the board.

78. The CHAIRMAN asked Dr Wasmer to explain some of the work his Institute was doing at the WHO International Reference Centre for Waste Disposal. Dr WASMER said he was from the Swiss Federal Institute of Technology - the Institute for Water Resources and Water Pollution Control. They were affiliated and collaborated with WHO by acting as a host Institute for the International Reference Centre for Waste Disposal. This was the sister of the IRC located in the Hague for water supply. There had been a meeting a couple of years ago which dealt with the operation of the International Reference Centre. The International Reference Centre for Waste Disposal was part of the programme of WHO in the waste disposal field. It was established following the recommendation of a WHO scientific group for the treatment and disposal of waste in the late 1960s. WHO made budgetary provisions for the establishment of such an International Reference Centre. The functions and responsibilities were very broad and included:

a. Information management - selection, collection and dissemination of technical and scientific information on the collection and treatment and/or disposal of liquid and solid waste.

b. Stimulation and co-ordination of research and development; conjunctive research and development of investigations and experiments in waste disposal practices.

c. Training functions: the training of research and other personnel; the preparation of guides, codes of practice and training manuals; organization of courses and seminars particularly for participants from developing countries.

This was what they were supposed to do but they only received 10 000 dollars per year from WHO for this. The main function now was in training. Each year about twenty or thirty WHO fellows stayed with them either for a day or two, or for two or three months.

79. The CHAIRMAN thanked Dr Wasmer for his paper and for taking part in the discussion.

P.A. OLUWANDE

development of the aqua-privy for urban sanitation

INTRODUCTION

The majority of the hot countries are also developing countries. The term 'developing countries' is often used euphemistically to describe all those countries which are not developed. While the environmental problems confronting the developed countries are those resulting from developments, those facing the developing countries are those due to lack of developments. These are characterised by poverty, ignorance, limited availability of technical know-how and inadequate research. Table 1 illustrates how poor certain developing countries are (Szego, 1973).

Table 1 Poverty in the Developing Countries (1972) Compared with Certain Developed Countries.

Countries	Per capita GNP (US $)	Population (1972) millions	Birth rates per 1000 of population	Annual population growth rates per cent	Infant death rates per 1000 live births
Namibia	40	0.7	44	2	-
Malawi	55	4.7	49	2.5	182
Nigeria	75	58	50	2.6	148
Guinea	100	4.1	47	2.3	216
India	110	584.8	42	2.5	139
U.K.	1890	56.6	16.2	0.5	18.4
Sweden	2920	8.2	13.7	0.4	11.7
Kuwait	3320	0.8	43	8.2	39.0
U.S.A.	4240	209.2	17.3	1.0	19.2

In addition to these defects, many developing countries often get their priorities in the wrong order, with the result that prestigeous projects which are 'eye catching' and 'vote winning' are often embarked upon in place of simple schemes which will benefit the majority of the people. The old popular saying that 'there is no vote in sewage' is still very appropriate in the developing countries, with the result that up to 90% of the diseases which doctors see in hospitals and clinics are due to poor, inadequate or absence of sanitary conditions.

The sanitary conditions of many developing countries may be visualised by considering the situations in Nigeria, a very urbanised country with a population of about 70 million. In 1975 there is not a single town or city with a central sewage system though we have all types of modern sewage treatment plants serving institutions, housing estates and army barracks. Table 2 gives the housing conditions in eight major cities in Nigeria (Federal Office of Statistics, 1973). An observation of column 6 shows that even in main cities and towns, the majority of the people do not have a water carriage toilet system. In smaller towns and rural areas where more than 80% of the entire population live, the flush toilet is almost totally absent.

Table 2

1	2	3	4	5	6	7
Cities	Population	% of household occupying one room	Average no. of persons per room	% of houses with tap water	% of houses with flush toilets	% of houses with electricity
Lagos	850 000	72.5	3.8	71.7	43.5	93.2
Porthacourt	230 000	51.5	2.4	75	18.6	81.4
Benin	130 000	48.0	2.2	24.9	14.0	59.3
Warri	70 000	59.9	2.6	62.4	10.9	89.7
Kaduna	190 000	63.9	2.1	40.3	14.1	53.3
Kano	380 000	69.1	2.4	26.1	1.8	69.1
Ilorin	270 000	23.9	1.6	30.7	10.3	56.1
Ibadan	800 000	47.3	2.1	33.4	25.2	56.1

This paper therefore discusses the great potentials which the aqua-privy system has for the provision of safe sewage disposal in the developing countries. A very simplified approach to its construction at the village level will also be discussed.

2. COMMON SEWAGE DISPOSAL METHODS IN THE DEVELOPING COUNTRIES

In many developing countries, the methods of excreta disposal which the majority of the people use are

(a) deposition on surface of ground in surrounding bush

(b) bucket latrine

(c) the pit latrine.

As already indicated in table 2, only a very small percentage of the people use flush toilets which employ the septic tank system. Unfortunately, the aqua-privy system, which is a convenient intermediate system between the pit latrine system on one hand and the septic tank system on the other, is almost unknown. In Nigeria, the aqua-privy has just been introduced in Ibadan for public toilets and in comfort stations. It is not yet being used in private toilets.

The health hazards of depositing excreta on the surface of the ground in the bush and open field around the houses are grave indeed. The spread of diseases like typhoid, cholera, shigella and amoebic dysentries is enhanced. Many publications have been written to show this (Moore et al, 1965; Schliessmann, 1959; Kourany and Vasquez, 1969; and Cvjetanovic, 1971). These diseases are still causing epidemics in many developing countries. Other worm diseases like ascariasis, hookworm, trichuris and Schistosomiasis are also very common in communities where faeces is disposed of in an insanitary manner (Sanders and Watford, 1974; Schliessmann et al, 1958). The bucket latrine is very cheap to start but it involves many operational problems. Improved forms of it reported by Pradt (1971) and CPHERI (1969) can be adopted when the system has to be employed for faeces disposal.

Though the pit latrine is the simplest and cheapest method which can be made sanitary, the vast majority of the people in the developing countries do not like it. It is impossible to operate it without smell and flies, although it is possible to keep odour and fly breeding to a minimum by good construction and correct maintenance (Oluwande, 1969). The septic tank system which the people often use when they feel too sophisticated for the pit latrine is more expensive than the aqua-privy to construct and maintain. It requires that water must be available to flush faeces into the septic tank, and to avoid blocking, toilet paper must be used for anal cleaning. These two conditions are often very difficult to satisfy by many families in the developing countries.

3. THE AQUA-PRIVY

As illustrated in figure 1, the aqua-privy is an intermediate method between the pit latrine on one hand and the flush toilet system of the septic tank on the other. Among its advantages over the pit latrine are:

(a) It operates odour-free as long as the tip of the inlet pipe is inside water

(b) It operates fly-free as long as the inside of the inlet pipe is maintained clean

Its main advantages over the septic tank system are:

(a) It does not require water to carry faeces into the tanks, so houses in communities without piped water supply as well as those in communities with piped water supply but who cannot afford private water connections, can employ it.

(b) It can withstand rough use because it cannot be easily blocked. Therefore, families which find it difficult to buy toilet paper may use materials like pieces of wood, newspaper and cobs of maize for anal cleaning. The only danger is that these types of materials will make the tank full prematurely.

(c) It is cheaper and simpler to construct and maintain than the septic tank.

Table 3 gives the costs of providing the three systems in the Ibarapa division of Western State of Nigeria in March 1973. The cost of the pit latrine and aqua-privy could be much smaller if the family is prepared to use self labour and local material for the super-structure.

Figure 1: PIT LATRINE, AQUA-PRIVY AND SEPTIC TANK SYSTEMS COMPARED

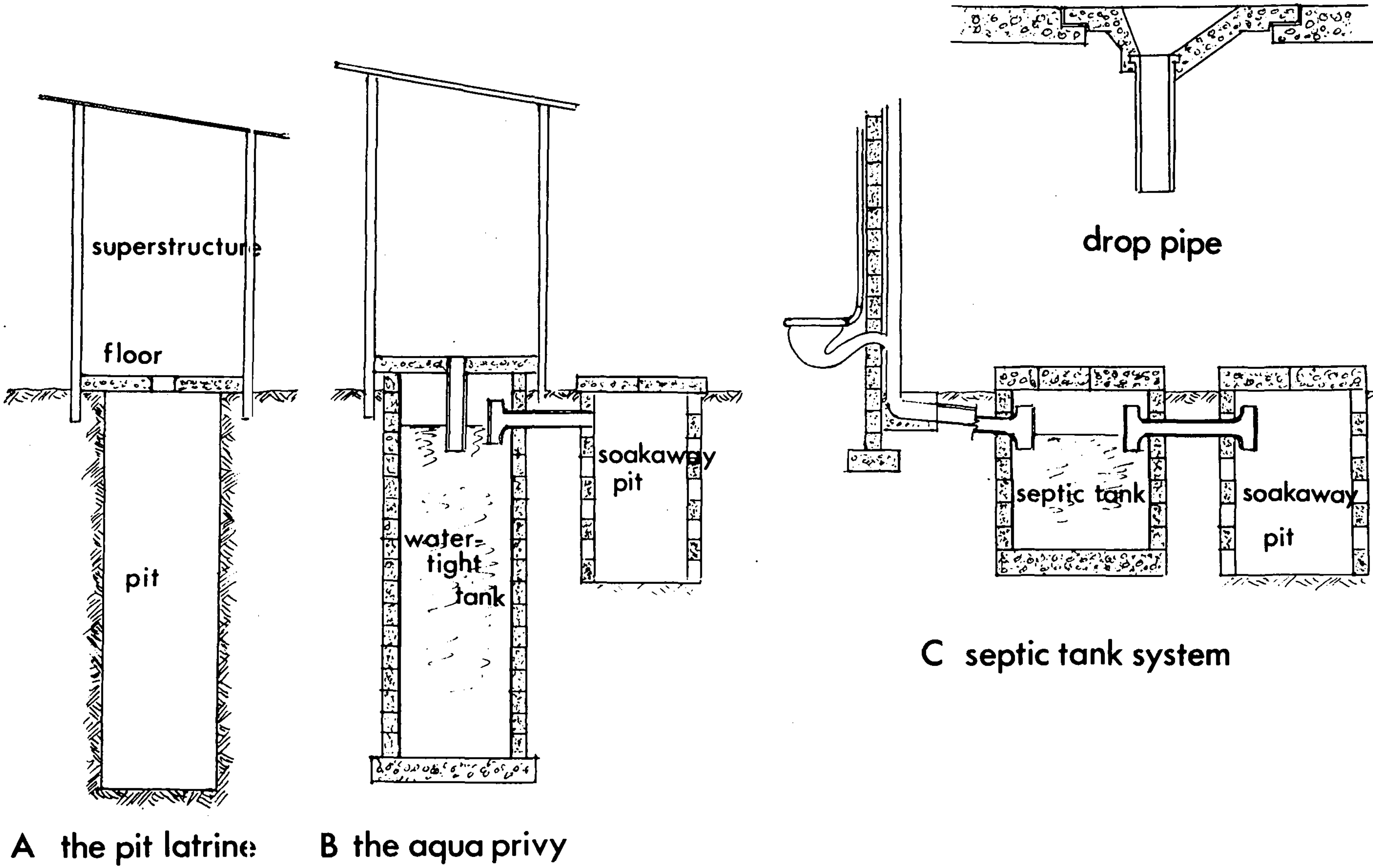

Table 3 Costs of Pit Latrine, Aqua-privy and Septic Tank Systems

Items	Pit latrine ₦	Aqua-privy ₦	Septic tank ₦
1. Labour for digging	16	30	30
2. Cement	2	30	30
3. Gravel	2	6	6
4. Sand	1	8	8
5. Bricklayers labour	4	18	24
6. Pipe fittings	-	6	35
7. Water closet flush tank and seat	-	-	42
8. Plumbers labour	-	-	15
9. Super-structure	20.50	20.50	20.50
Total	45.50	118.50	210.50

Note: ₦1 = 1.5 U.S. dollars

4. CONSTRUCTION OF AQUA PRIVY

Much has been done and written about the aqua-privy - its construction, and maintenance. Wagner and Lanoix (1958) discussed its different aspects in some detail including dimensions of its components. Marais (1973), Vincent et al (1961), McDonald (1952), Maclaren International Ltd (1970) and McGarry (1975) discussed various aspects of its construction and maintenance including how other domestic wastewater may be discharged into it to ensure that the free end of the inlet drop pipe is constantly beneath the water level. They also discussed how the aqua-privy tanks can be made to form a primary treatment unit in a central sewage system of a community. Sewers which convey effluent from such aqua-privies can have very gentle gradients since the bulk of settleable solids will settle in the aqua-privy tanks. Such sewers will therefore be cheap to construct.

One very important aspect of the aqua-privy construction which has not been discussed much in the literature is how to incorporate simply the inlet drop pipe into the floor slab. The devices suggested in many publications involve the use of moulds which are very difficult to construct (see figure 1D). This aspect differentiates construction of aqua-privy from that of a simple pit latrine and that of a septic tank system. Three simple approaches have been employed by the author for casting the floor slab for the aqua-privy (Oluwande, 1974). These are:

(a) the trench method

(b) the hole method

(c) the raised platform method.

Only the trench method will be described briefly in this paper. There are four steps involved in this trench method:

(i) A trench about 150 mm deeper than the length of the inlet pipe and 750 mm wide is dug. The length of the trench will depend on the number of slabs to be cast at a time.

(ii) Planks about 25 mm thick and 300 mm wide are cut into pieces one metre long. Four such pieces will be required for a floor slab 900 mm long by 900 mm wide. The pieces are placed side by side on the trench and a circular hole 200 mm diameter is cut through the two pieces in the middle to accommodate the inlet pipe.

(iii) A piece 675 mm long is cut from a 150 mm diameter pipe. An asbestos cement pipe is preferable because it can be easily cut. Four holes with diameters big enough for 100 mm long nails are made equally spaced on the circumference of the pipe. The centre line of the four holes must be about 25 mm from the end of the pipe. Nails 100 mm long are passed through the holes with their big ends inside the pipe.

(iv) The platform planks are arranged over the trench and sheets of newspaper or cement bags are laid over them. The portion of paper over the middle hole is removed. The free end of the prepared piece of pipe is passed through the central hole until the pipe is supported on the platform by the nails. The steel reinforcing rods for the floor slabs are arranged so that they pass under the nails. A special wooden cover is made for the hole of the pipe. The main mould for the slab is placed in position and 1:2:4 concrete mix is used to cast the slab.

Another aspect of the aqua-privy construction is the provision of an aqua-privy system with the tank above the ground level. This will enable people in areas with a high groundwater level and other riverain areas to construct the aqua-privy tanks cheaply and simply. Any watertight container may be used as the tank for the aqua-privy system. As discussed previously, a large proportion of money used for the construction of an aqua-privy system is spent on construction of the aqua-privy tank. Huge savings can be made in construction cost if materials like wood, membrane bags filled with sand (ITDG, 1969) and other locally produced materials which are very cheap are used for producing the watertight tanks.

5. AQUA-PRIVY AND COMFORT STATIONS

The comfort station as introduced to Ibadan in Western State of Nigeria is a communal convenience owned by a compound of many houses and consisting of latrine, shower and clothes washing apartments. The comfort station was designed to solve sewage disposal problems of houses in core areas of the city where houses are so closely built without any order that there is no space for individual toilet facilities. It is also impossible to provide sewers. The general plan of the comfort stations in Ibadan is given in figure 2. The size of each station depends on the population of the compound which the station serves. The number of toilet compartments is determined by allowing one compartment for 15 people, the shower compartments are decided by allowing 20 people for one, while the size of the clothes washing space is fixed by allowing 25 people per unit. For ease of maintenance, each household is allocated a toilet and a shower compartment.

The comfort stations built so far in Ibadan have been provided through aided self-help. The families provided land and part of the labour, while the World Health Organization provided materials and the Government provided technical supervision. Each comfort station similar to that shown in figure 2 cost about ₦5200 or $7800. The annual maintenance cost including cost of water, electricity, salary of a maintenance attendant and other miscellaneous charges is ₦708 or $1062. Up to date ten comfort stations have been built and 24 others are under construction.

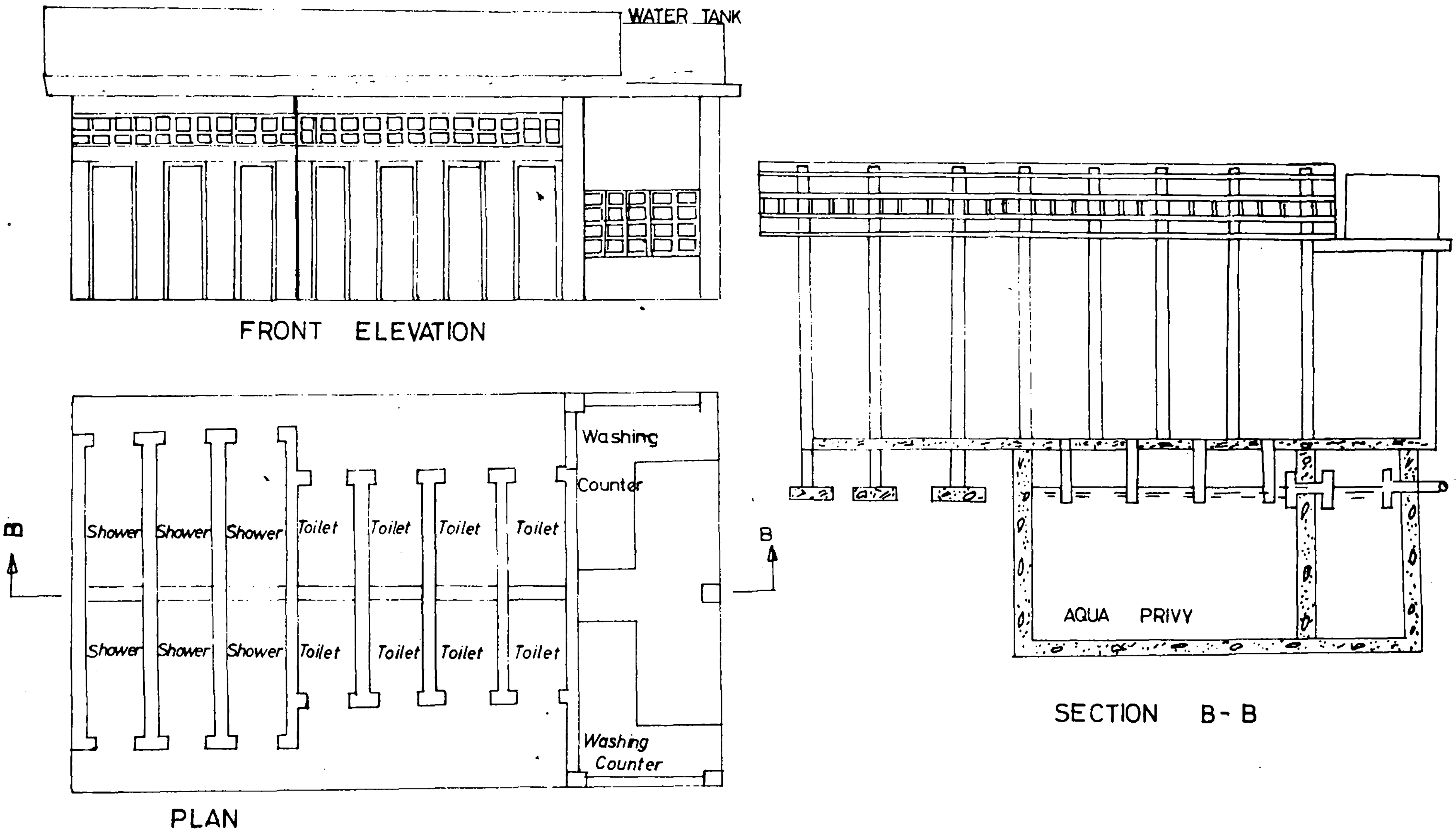

Figure 2: LAY-OUT OF THE COMFORT STATION

6. OPERATIONAL OBSERVATIONS

The performance of the comfort stations is being monitored under a special programme financed by the World Health Organization. Observations so far highlight certain important operational difficulties which are vital for the success of the system as a method to be adopted in built up areas of the cities of developing countries. Some of these observations are:

a. Effects of 'Dual Living Pattern'

The majority of the people using the comfort stations have houses in Ibadan and in villages near their farms. They live long periods in the village houses while they only come to the houses in Ibadan for special occasions like big traditional and religious feasts. During these short periods they stay in Ibadan, they mess up the comfort stations.

b. Inability of the People to Pay Water and Electricity Bills

The comfort stations make water readily available to the people who used to obtain water from more distant public taps. This increases the daily water consumption rate of the people considerably. Since water for the stations is metered, there is a perennial problem of the people being unable to pay for water and electricity used. Electricity to the stations is being disconnected and only the generosity of the State Water Corporation prevents disconnection of the water supply to the stations.

c. Inability of the People to Employ Competent Attendants

When the comfort stations were designed, it was intended that there would be a paid attendant in charge of each station to carry out routine maintenance and repairs. Absence of these attendants makes the stations poorly maintained.

When the research on the operation of the comfort stations is concluded much will be known about this method of providing safe sewage disposal in built up areas. At the moment the effluent from the stations, which is similar to septic tank effluent, goes either to rivers or soak-away pits. It is intended that when central sewage treatment plants are built for Ibadan, the effluent from the stations will be discharged into the central sewers.

7. CONCLUSIONS

The aqua-privy has great potentials for cheap safe sewage disposal in the developing countries. Efforts should be made to introduce it since at the moment many countries that can benefit from it do not seem to know about it. Its construction can be considerably simplified and its cost can be drastically reduced by using local materials.

ACKNOWLEDGEMENT. The opportunity offered by Ibadan Waste Disposal Board to visit the comfort stations and to collect all the information required is greatly appreciated. The author also thanks Ibadan University and Loughborough University of Technology for the opportunity offered to attend this Conference.

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discussion

CHAIRMAN: Professor N. MAJUMDER
Director, NEERI, India

The CHAIRMAN said he attended a number of seminars, conferences and symposia. At most of these there was hardly any time for discussion by the time the papers had all been presented. He thanked Mr Pickford for arranging this Conference where there was plenty of time for discussion.

2. Unfortunately, human excreta collection and disposal was a very neglected area of sanitation activity in the majority of developing countries. Sophisticated programmes were discussed but not much thought was given to the collection and disposal of night soil. So entire communities were being exposed to serious hazards.

3. He introduced Mr Oluwande, who was a senior lecturer at the University of Ibadan in Nigeria. He did his post-graduate studies at Imperial College in London in 1965-67 and subsequently visited several countries in S.E. Asia and the Middle East. Although his paper was primarily about the aqua-privy, undoubtedly the subject of excreta collection and disposal as a whole would be covered.

4. Mr P.A. OLUWANDE said most of the items contained in the paper had been reported by many other authors but he hoped that the presentation would encourage discussion on the situation that he had noticed in many developing countries. When engineers, architects, doctors and planners wanted to provide sanitary facilities for low-income housing programmes, they often turned to pit latrines or the bucket system. As could be seen from Table 2 of the paper, flush toilets were very uncommon in the major towns and cities of Nigeria and this was typical of the situation in many developing countries.

5. Methods common in many developing countries were deposition of excreta on the surface of the ground, the bucket latrine with all its complications of operation and the pit latrine which people did not like to use. A modification to the bucket system was the use of vacuum carts to empty faeces from concrete vaults at houses. NEERI had developed a wheelbarrow to avoid the common practice in developing countries of collectors carrying faeces on their heads from one part of the town to another. In Nigeria some modifications had been found necessary to encourage people to use pit latrines. They had discouraged the communal pit latrine and encouraged each family to have its own unit.

6. The aqua-privy had great potential in both rural and urban areas of developing countries. It was an improvement to the pit latrine which created odour no matter how well it was maintained. Compared with the septic tank, the aqua-privy was very good for unsophisticated people because it could withstand rough use. When people used cobs of maize, pieces of wood or newspapers for anal cleaning it was impossible to use a flush system. It was also cheaper than the septic tank system. The cost of constructing a pit latrine and aqua-privy could be less than was shown in Table 3 if families used self-labour for digging and if local material was used for the tank of the aqua-privy and the superstructure. There was little that could be done to reduce the cost of a septic tank.

7. Aqua-privies could be used for the primary treatment of sewage from individual houses. The effluent could be discharged

through inexpensive small diameter sewers with gentle slopes as suspended particles had been removed. The cost of constructing sewers to convey sewage to a central point scared governments in developing countries. Mr OLUWANDE thought many developing countries would be encouraged to have sewage treatment if the cost of sewerage was reduced.

8. An aqua-privy could be constructed in villages where there was no-one who could make sophisticated moulds or where there were no bricklayers by incorporating the drop pipe into the floor. Savings could be made by using materials like wood, membrane bags filled with sand or other local materials. It was important that the tank was watertight and this was not always easy in developing countries unless construction was closely supervised.

9. The central part of many towns in Nigeria was completely built up: houses were so close together that it was impossible to reach them with a cart and there was no space for individual sanitary facilities for every house. However, occasionally there was an open space which was used communally for deposition of faeces on the ground or there might be a pit latrine not being used very well. In a situation like this a comfort station, as shown in Figure 2, could be used. It included facilities for toilets, showers and laundering. Each family was responsible for the maintenance of a particular unit. Fifteen people were allocated to each toilet, twenty to each shower and twenty five to each washing space. The comfort stations were normally built through family effort (provision of land and labour), Government help (technical supervision) and WHO help (imported materials not available locally). So far ten comfort stations had been built and twenty four others planned.

10. Certain observations had been made on the operation of the system. The first was the effect of the 'dual living pattern' i.e. where people had houses in the towns as well as in villages. When these people moved into their town houses for traditional or religious celebrations they tended to spoil the system. The second observation was the inability of the people to finance operation of the system. Originally it was expected that the users would pay for electricity for the comfort stations. There were also problems with water. People using the stations were mostly those who had previously used public taps and as water was readily available at the stations the consumption increased and people were not prepared to pay for this water. Thus electricity to the stations was being disconnected and the only reason why the water was not disconnected was because the Water Corporation belonged to the State Government. It was also difficult to employ competent attendants. When the comfort stations were being considered it was hoped that one of the families using the station would be employed to look after it, but it was found they were not able to do this, and the stations were not being properly maintained.

11. Mr OLUWANDE quoted the conclusion of his paper: "The aqua-privy has great potentials for cheap safe sewage disposal in the developing countries. Efforts should be made to introduce it since at the moment many countries that can benefit from it do not seem to know about it. Its construction can be considerably simplified and its cost can be drastically reduced by using local materials".

12. The CHAIRMAN said Mr Oluwande had highlighted the construction features of the aqua-privy. These were very pertinent because sometimes drawings were not always understood by those in the field. The author had indicated the cost which was an important factor for this sort of programme, and he had indicated how local materials could be used, maintenance and the method of financing.

13. Mr M.I. ALDRED asked if the aqua-privy would be desludged like a septic tank, and the sludge taken to another place for treatment. Mr OLUWANDE said it had to be desludged some time. Modern houses in cities used the septic tank system and aqua-privies could be emptied by the same method. In rural areas where septic tank emptiers were not available, people could remove sludge manually and chemicals such as caustic soda could be used to reduce the danger of disease. Mr ALDRED asked if it would be necessary to do all this through the drop pipe, and Mr OLUWANDE replied that the whole slab could be removed. If a mechanical septic tank emptier was used the hose could be put through the inlet drop pipe. If a compartment was included so that the slab did not have to be removed for desludging, the construction would be more complicated.

14. Mr H.B. JACKSON wondered if Mr Oluwande was being fair in Table 3 because facilities were provided for the septic tank that were not provided in the aqua-privy. It was assumed that with the septic tank a water closet would be inside the house so there would be a comparatively expensive water

closet unit plus pipe fittings and septic tank. Mr JACKSON was not sure what the difference was between the aqua-privy and the septic tank. Mr OLUWANDE explained that water was required to flush faeces from inside the house into the septic tank outside, whereas with the aqua-privy system the tank was built directly below the slab. Mr JACKSON suggested that there appeared to be scope for several ranges inbetween.

15. The CHAIRMAN added that the distinction between the septic tank and the aqua-privy was not in the tank: the tanks were the same. In one case the excreta was flushed into the septic tank whereas in the other case the down pipe went directly down into the tank and was submerged in the liquor.

16. Mr JACKSON said that in Figure 1 the sectional drawings showed the watertight tank of the aqua-privy as being much longer than the septic tank. Why was that? Mr OLUWANDE said this had been deliberate. For most aqua-privies he recommended a tank about eight feet deep because the people used solids for anal cleaning. By being deeper the tank would take longer to fill. With the septic tank, with plenty of water for flushing, there was no need for the tank to be so deep.

17. Dr S.M. ROMAYA remarked that it was said that a septic tank had to be multi-compartmental to prevent material in suspension passing through to the soakaway and clogging it. Mr OLUWANDE said that the small septic tanks he had designed were not multi-compartmental, although it was important to divide very big tanks into compartments.

18. Mr T.O. EGUNJOBI said the latter part of the paper implied that the people were too poor to pay for electricity and water. He came from Ibadan and felt that it was not a case of them being unable to pay but a lack of determination to pay. They would spend hundreds of pounds on a single funeral or traditional ceremony. Developing countries had their priorities wrong, and because of wrong priorities and ignorance they were not spending their money properly. Mr OLUWANDE apologised if he had given the impression that the people were too poor to afford electricity and water; Table 2 showed that 50% of houses in Ibadan had electricity. However, they could not see why they should pay, as they had the idea that the project would be financed entirely by the government.

19. Mr K.G. STRATFORD assumed that the people who used the comfort stations paid local taxes or rates and felt that to ensure the scheme was a success it would be better for the Water Corporation and Electricity Authority to charge the municipality who could spread the cost out in taxes.

20. Mr OLUWANDE said in Ibadan as far as water was concerned, the consumers could be divided into three groups:

a. Metered consumers - big industries, institutions, universities and hospitals - who had to pay about 35p per thousand gallons.

b. Private people with private water connections who had to pay about £1.50 per flat per month.

c. Those without private water connections who paid for water by general water rates. The rate was about £1 per annum, based on taxable adults: in a family of twelve people there might be only one taxable adult.

Because of this the people were already paying to the Water Corporation, and they did not see why they should pay a double tariff.

21. Mr STRATFORD said the problem was one of collecting money from twenty families (i.e. the number of families using the comfort stations). It was a relatively small sum of money if spread across the whole town. If more comfort stations were to be built it was important to sort out the question of paying for maintenance and collecting taxes before people became disinterested in the whole project.
Mr OLUWANDE said it was only the electricity that was being disconnected. Virtually a free supply of water was being supplied to the comfort stations by the Water Corporation.

22. Mr J.A.O. OLANIYAN felt the operational aspects of the aqua-privy were more important than the technical aspects. Engineers could always devise the kind of technology that would work but it was more important to devise something that would work within a given psychological, cultural and political constraint. Cleaning toilets was usually considered a menial job only fit for a very low class of person, especially when it was communally used (i.e. when someone outside the immediate family circle was using it). It might be better if heads of families signed forms with the local authority or government before the stations were constructed, agreeing to maintain the stations and pay for them. Otherwise he felt it should become a really public facility accessible to everyone, and should be maintained by public employees.

23. Mr OLUWANDE said it was important to differentiate between public toilets and the type of comfort station being discussed. Multi-compartmental aqua-privies were being introduced to replace the old bucket system for public toilets but in comfort stations the compartments were divided out according to the families and each family could actually take charge of its own compartment.

24. Mr OLANIYAN could see no reason why the individual compartments should not be connected to pipes that supplied water into houses and be connected to the domestic electric meter, so individual families could pay the same as for domestic electricity and water. Mr OLUWANDE said the water and electricity to the comfort stations were metered, but the public taps that people had used previously were not metered. With the comfort stations they were getting better facilities, but they did not want to pay.

25. Mr W.E. WOOD said the aqua-privy was a proven engineering solution to a particular problem. In many places, including parts of Nigeria, a constraint to the installation of water-borne sanitation (whether discharging to septic tanks or a sewerage system) was the shortage of private plumbers. Sanitary ware, such as W.C. pans, were seldom made locally and were often not easily available.

26. The new concept with comfort stations was to use an aqua-privy for a group of families. In the past aqua-privies had chiefly been built for communal use, for example in Kano market.

27. Mr WOOD stressed the need to build the squatting slabs under controlled conditions. Drop pipes could be made of locally constructed material - in Kano they were made of earthenware with flared sides so that there was no excreta build-up. Mr Oluwande had mentioned the maintenance and necessity of making the tank watertight: it was necessary initially to keep the tank full to the bottom of the drop pipes. However well the concrete was made it was not waterproof to begin with although it quickly became waterproof as faecal matter filled the interstices. One way of keeping the tank full was to lead roof-water into the tank. The rainwater pipe also acted as a vent which was important to prevent a build up of inflammable gas. Gas could cause trouble and could be explosive. For desludging it was relatively easy to construct a longer tank so that a manhole gave access outside the building.

28. Anal cleaning varied with the religion and habits of the people: some used corn cobs, stones or water. In Moslem countries there should be provision for water, although it was rather dangerous to install taps in the comfort station itself. Mr WOOD felt there should be some health education of the people who would be using these units.

29. Mr OLUWANDE said the drop pipe should not be too big in case small children wanted to see what was happening at the bottom of the tank - bamboo was big enough. Marais and others had suggested that waste-water from bathrooms in houses could be discharged into the aqua-privy to make sure the level was constant.

30. Mr JOHN PICKFORD said that 'comfort stations' had been advocated in the past three or four years as being something new. Nearly twenty years ago in Ghana he had built about a dozen latrines which were then called "septic tank latrines" but which were in fact aqua-privies. Many had a bathroom incorporated although water was usually brought to the bathroom in buckets. As far as Mr PICKFORD was aware there was never any trouble due to the water level dropping. Desludging was done infrequently. Some were in use for five or six years without any necessity for desludging; others had to be desludged after about three or four months. There was a manhole for desludging in the entrance. He doubted the wisdom of having a rainwater pipe from the roof going into the tank as Mr Wood had suggested, because with tropical rainfall there would be a surge into the overflow system. Mr Oluwande had mentioned the work of Marais and Mr PICKFORD felt this was one of the greatest possibilities for the use of aqua-privies. In Zambia latrines were built at the junction of the compounds of four houses. The latrines had separate cubicles for each of the four houses with a single aqua-privy underneath. The overflow went through a 100 mm pipe which could be laid at quite a flat gradient giving a velocity of only 0.3 m/s. The discharge was treated in an oxidation pond system where there were two 7-day tanks followed by one 14-day tank.

31. Mr R.A.J. SIMKINS asked for an indication of how long the aqua-privy would last before needing emptying. Was there a possibility that desludging would give rise to considerable problems when aqua-privies came into general use? Mr Oluwande had mentioned that desludging could either be

done by hand, which was an unpleasant task, or by a cesspool emptier, which was a fairly expensive and sophisticated machine. He asked how many towns in Nigeria were operating cesspool emptying services. Did the private owner of the aqua-privy pay for emptying and were there likely to be difficulties with this payment? In Britain people who had to pay for emptying septic tanks often put it off to the last possible moment.

32. Mr OLUWANDE could not state the duration of operation before desludging because most of his aqua-privies were constructed around 1973, but some idea could be gained from septic tanks. Septic tanks with crude designs were being used all over Nigeria. However, there were also properly designed septic tanks which did not require desludging often because the only type of waste going into the septic tanks was faeces. Some septic tanks operated for twenty years without being desludged. In Nigeria all towns maintained a septic tank emptying system although private owners were charged for this service. There were also some contractors who were licenced for emptying septic tanks. Therefore he could not foresee a problem.

33. Mr G.B. RALPH said that due to the depth and the need for it to be watertight, the tank should have some structural stability. The minimum necessity for this was cemented masonry blocks and he was rather intrigued that the paper suggested that materials like wood and membrane bags filled with sand and other locally produced materials could be used. Mr OLUWANDE said wood and similar materials should only be used for private aqua-privies, and the pit would not be deep. With tanks about eight feet deep, solid blocks were used. It was important that the blocks were cured properly and also that the excavated soil around the tank was replaced gradually in steps of about two feet to make sure that water did not seep behind.

34. Professor M. DANBY asked what happened to the wastewater in the showers and the washing counter of the comfort stations. Mr OLUWANDE said the wastewater went into the aqua-privy, and as soon as the water level got up to the outlet level of the tank it went out automatically.

35. Mr R.P. WHITING described a glass fibre type of aqua-privy fabricated in Botswana. There was a kiosk on top and a tank underneath. A small factory had been set up and the skills for making the glass fibre kiosk and tank were readily learned. Resin and fibre had to be imported, but there was a saving in cement and to some extent in pipe fittings. The shape of the kiosks and chambers enabled them to be nested and a lorry could take twenty or thirty at a time to villages. Mr WHITING showed some slides of these.

36. The CHAIRMAN said in India, particularly in rural and semi-urban areas, pit latrines were built with the latrine superstructure two feet away from the pit. A water-sealed hand-flushed squatting plate was provided. Aqua-privies had been used in a limited way. In many railway stations where there was limited water, the aqua-privy worked well and was the only type of privy recommended. However, it had not been found to be as good as septic tanks, because mosquitoes bred in the drop pipes. Sludge was not removed manually. In some installations a sludge pit was provided adjoining the tank and sludge was discharged from the tank under the hydrostatic head through a two inch diameter pipe, which did not get clogged. After a few months the sludge became humus which was used in the fields.

37. The CHAIRMAN thanked Mr Oluwande for presenting his paper which was of topical interest, particularly in countries like India, where excreta disposal demanded a lot of attention.

C.G. WEBB

comfort and ventilation in an equatorial climate

INTRODUCTION

The equatorial climate, harmless and even pleasant in itself, provides a background of some difficulty for the ventilation of crowded buildings. In the absence of wind, which might give relief in fairly small buildings though it can hardly help in large ones, the only means of natural ventilation which can be relied on is the stack effect. A choice has to be made between this and air-conditioning in urban circumstances. The alternatives are discussed.

This subject was first considered by the writer in 1957, and what follows is no more than a belated postscript, hopefully overtaken by events. It seeks to define the purpose, scale and mechanism of natural ventilation in an equatorial climate, specifically that of the west coast of Malaya although similar conditions prevail elsewhere in low latitudes. Perhaps it may still serve as a starting point for discussion in spite of the lapse of time.

The climate and what it feels like

The equatorial or 'doldrums' climate, which is characteristically windless, warm, equable and moist, occurs over a belt several hundred miles wide which migrates with the sun's declination as far north as the Gulf of Iran and as far south as Australia. The daily pattern of warmth is that it feels neutral about an hour after sunrise, then warm with a peak of warmth about two hours after noon until it is neutral again at midnight. Finally it is cool in the early morning being coolest at sunrise. In the occasional sudden and brief squalls, convective by day or katabatic by night, it can feel really cold.

Outdoors in the shade the climate is enervating but harmless. Indoors, in a well-sited, well-designed and well-run bungalow with access to an open garden it is pleasant if monotonous. However, when people are crowded indoors, whether for entertainment, for shelter, or by force majeure, there is a warmth problem; one which would of course yield to adequate air-conditioning, flexibly controlled, if it were available. When air-conditioning is unavailable or inadequate the problem can become serious and the worst cases occur when numbers of people are casually and unexpectedly assembled with restricted access to the open air.

Frequently one comes across flats which are disliked by their occupants, and which become impossible if they try to hold a party. In the extreme case there are occasional incidents like that at Kosti in Sudan in 1958, when 300 rioters were locked up for the night, without serious over-crowding as it was thought, and by midnight 200 were dead. As far as the writer knows nodody has seriously considered large-scale deep shelters against air attack in S.E. Asia or India.

The permissible rise of temperature

The temperature itself is never extreme in an equatorial climate, the normal shade maximum being about 35°C. High humidities, however, begin to matter at about 25°C, are increasingly important in the 30 to 40°C range, and are finally dominant, saturation at 42°C being rapidly fatal. Relative humidities outdoors in an equatorial climate range from 70% to 100% by day, and saturation is general by night. Indoors the air is no drier.

The temperature rise accompanied by saturation which is bound to occur in a crowded building is at best unpleasant when the place is already warm; and a rise which in a cooler or drier climate would be thought moderate can here be potentially dangerous. With less than 10°C scope to reach the endurable limit obviously every degree counts, and one can usefully assume that the maximum permissible rise of temperature with saturation which can be accepted during the warm part of the day or evening is only about 2°C.

In the early morning hours the situation is different, and larger temperature rises are permissible, and even desirable. Probably few would complain if the bedroom temperature at dawn were 5°C above that in the street or garden outside.

The thermal function of a building

The thermal function of a building for human occupation in an equatorial climate is accordingly different from that of a similar building in a cooler or drier climate. Ideally it should on the one hand exclude almost all extraneous 'wild' heat viz. short-wave (solar) radiation whether direct, reflected or scattered. It should also exclude long-wave radiation from heated walls, roofs and the ground, and from cooking, laundry, artificial lighting and industrial appliances.

On the other hand the building must permit the dispersal of the body-heat of the occupants by ventilation, by refrigeration, less usefully by storage in the fabric, so that the temperature rise is limited to about 2°C.

Natural ventilation requirements by day and in the evening

As regards the warm period from about 9 am to 10 pm, it is possible to consider the effect of ventilation by itself, supposing that wild heat has either been excluded or is balanced by thermal storage. The ventilation task is then to remove about 100 watts per occupant by convection into the ventilating air without raising the air temperature by more than 2°C. The amount of heat to be removed will range from ½ kilowatt in the case of a family sitting quietly, through 1 megawatt for an excited audience at a badminton championship, to 10 megawatts or more in a packed covered stadium.

The necessary rate of air flow is surprisingly large viz. 10 000 cubic feet per hour per person and upwards. Such massive ventilation is rare indoors in other climates, and it obviously overrides the more familiar criteria of dispersing body-odour, cigarette smoke etc.

Except in the quoted family case, horizontal ventilation by wind or by fans is out of the question. Vertical ventilation by the stack effect is, however, available and can be very effective. To remove the warmed air from the vicinity of the occupants at the required rate needs an air velocity of only a few centimetres per second, which apart from its cooling effect is imperceptible.

It is tempting to compare rates of air-change, and in those terms the rate would be about one change per minute, but the air-change concept must break down if there is not time for the air to be thoroughly mixed throughout the space to be ventilated. For the same reason it is necessary that the ventilation should be uniform all over the occupied space, without dead spots and unventilated corners. Again since the air movement is upward the temperature will be higher at head level, and this will necessitate a somewhat higher rate than otherwise.

If the stack effect is doing the job then wind may not help. The arrival of a light breeze can only give a slight bonus of extra ventilation on the windward side of the building, and it may hamper and reduce the stack flow. It can even in a certain case oppose and prevent stack ventilation.

To encourage the stack effect large openings are required, on a scale of 10 square feet per person or more, half the area of opening being in or through the floor, or at least very close to floor level; there should be minimal obstruction to uniform vertical flow; and the upper openings should be high.

The natural ventilation requirement of bedrooms

The ventilation requirement of a bedroom is more modest. Most of the daytime forms of wild heat are absent, body-heat is at a minimum of 60 watts per person, and a temperature rise of 5°C is desirable by dawn. Squalls need to be excluded, and ventilation should be by stack effect only, at not more than 3000 cubic feet per hour per person. In the past bedrooms have often been designed to be over-ventilated, to the extent that the occupants have been driven to block up the ventilators.

There is the complication that some, e.g. children, the sick and those who merely keep early hours, will be in bed during the evening or the day. Bedrooms should be sited for daytime coolness, and there is a case for air-conditioning to be switched off and the ventilators opened at midnight.

The area of the ventilation openings need be only 2 square feet per person.

The traditional solution

Traditionally the designed buildings, with their very large but heavily shaded ventilation openings, were quite successful thermally. Colonial-period buildings copied many of their features in more permanent materials, and were reasonably so. Both are out-moded for modern urban living, but it may be useful to consider how they worked thermally, whether one aims to increase comfort or to economise on air-conditioning in the modern equatorial city.

The traditional style of building, of which the fisherman's or rice-farmer's dwelling and the older of the sultan's palaces were examples, was clearly designed to minimise the entry of wild heat and to encourage ventilation by the stack effect. The floor was several feet above ground level, so that the incoming air would be relatively dry and cool, and was itself permeable to air. The living space was high, and opened without ceiling into a high sloping roof also permeable to air. There were louvred openings at floor level, under the deeply overhanging eaves, and in the gables and the ridge. In the larger buildings rattan blinds hung from the eaves in place of walls, while in the smaller the walls were thatched, plaited or loosely boarded, and had small windows shaded by a thatched, plaited or louvred shutter. No glass was used.

There was a core of bedrooms etc. surrounded by a wide verandah, the eastern end of which was preferred for sitting. The whole plan was orientated on an east-west axis to minimise the overall solar load, and if possible sited on rising ground open to the south. Cooking and laundry were done outside the house, in the open or elsewhere.

Measurement of the openings showed that the stack effect would be quite adequate for any probable number of occupants.

The urban situation

In a modern equatorial city there is a change in the balance of advantages and disadvantages, the fundamental ventilation problem staying the same as before. Solar heat is often more difficult to exclude by shading, and there may be cooking and laundry to be done inside the dwelling. There may be only one or two outside walls on which to site ventilation openings, ceilings are low, and the ventilating air may be quite warm. On the other hand buildings are higher, have a higher thermal capacity and better insulation, and air-conditioning is more readily available.

So there is a greater need for ventilation, and what there is is less effective. It would be fortunate if air-conditioning be used to supplement and improve the effectiveness of ventilation, as it can in desert climates, but this is not the case. A choice has to be made, and there is much to be said for air-conditioning in cities.

There have been two questions in the mind of the user of air-conditioning: how cool should the conditioned room be; and what does one do when the conditioning fails, or is overpowered by the entry of a lot of people. There seems to be no basic reason why it should be much cooler than the environment found to be thermally neutral locally at an hour after sun-rise, or at about midnight. And in a building designed for conditioning there is no prospect, when it fails, of restoring comfort by natural, or even forced, ventilation. The only immediate answer is to go elsewhere or out of doors.

Taking the two questions together, there seems to be a case for a double installation, comprising a small plant for lenient conditioning when the building is sparsely occupied and a large back-up plant for when it is occasionally crowded.

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discussion

CHAIRMAN: Professor M. DANBY, AADipl, RIBA
Professor of Architecture, University of Newcastle upon Tyne

The CHAIRMAN said Mr Webb was a pioneer in the field of thermal comfort in an equatorial climate, and of its relation to ventilation. He was a physicist who started his professional career at the Building Research Station. He then went to the University of Singapore for 27 years where he became head of the physics department and became involved in field studies and research into comfort. After leaving the University he returned to the Building Research Establishment and published a number of papers.

2. Mr C.G. WEBB said that in cool climates thermal comfort was achieved by house heating, with a minimum of ventilation designed to be adequate to keep the indoor air fresh. In an equatorial climate it was possible simply to substitute air-conditioning for house heating, with the same minimum ventilation. Now half a century old this solution was a familiar one, but it had snags. Apart from questions of efficiency, reliability, expense and taste there was that of flexibility: many buildings were normally sparsely occupied, and then on rare occasions became really crowded. The air-conditioning could be overpowered by the increased heat and moisture load, and the design of the building was such that it was found impossible to fall back on natural ventilation. The alternative, and traditional, solution was natural ventilation on a copious, but controlled, scale; the absence of wind required natural ventilation to be driven by the stack effect. Equatorial buildings had evolved over the centuries on this principle, and their performance had been at least satisfactory. After half a century of air-conditioning the alternative solution deserved a backward look as it still had something to teach.

3. Not so long ago a young man, in Malaya for instance, could in a few weeks cut materials from the edge of the jungle and build himself a small family house, the cost being minimal. The result was flimsy and would probably last less than five years, but it was reasonably satisfactory from a thermal-ventilation point of view. This was the basic Malay house; there were bigger and more complicated houses, more permanent houses, and some bungalows and palaces all in the same style. (Several slides showed these by photographs and measured drawings). They had common features: the floor was five feet from the ground and was sievelike, allowing air to flow through; the roof was large and overhanging and of thin thatch so that air could again flow through; there was no ceiling; rattan screens hung from the eaves. Cooking and laundry were done elsewhere and the sun was totally excluded. The metabolism of the occupants would set the stack effect going, drawing cool air in through the floor and keeping the house cool and pleasant.

4. This style of building became impossible in an urban situation. It was very expensive in land, especially if the fire risk and hygiene were taken into account; and even the materials were unavailable. The inevitable multi-storey buildings in brick and concrete, superior in many ways, were often less comfortable thermally. People found them hot by day and too cold at night; and if they gave a party the result was almost suffocating. There were four respects in which the modern dwelling in an equatorial city was at a disadvantage:

a. There was a tendency to design ventilation in U.K. terms, whereas the ventilation requirement in an equatorial city was on quite a different scale.

b. It was difficult to exclude wild non-metabolic heat when cooking and laundry were done at home, and complete shading from the sun was often impossible.

c. Multi-storey building discouraged the stack effect by demanding low ceilings.

d. The ventilation provision, which was inadequate by day, could not be reduced sufficiently when late at night people were apt to feel cold.

5. Mr WEBB illustrated this by the equation:

$$\text{Rate of heat removal by ventilation} = \text{rate of heat production}$$

$$= \text{metabolic heat} + \text{wild heat}$$

$$V\rho \; Cp \; \Delta T = Q \quad = \quad Nq \pm X$$

V = rate of air flow in litres per second

ρ = density of air

Cp = specific heat at constant pressure

ΔT = rise in temperature of the ventilating air

Q = rate of heat production

N = number of people

q = metabolic rate in Watts

X = wild heat (which could be refrigeration and therefore negative)

From this equation

$$\left(\frac{V}{N}\right)_{1/s} = \frac{100}{\Delta T_c}\left(1 \pm \frac{X}{Nq}\right)$$

It was possible to calculate how much air was needed to prevent the temperature rising too much. For instance with normal U.K. ventilation and in the absence of wild heat,

i.e., X = 0.4 $\quad \frac{V}{N} = 10$ litres per person

then $\Delta T_c = 10°C$

Conditions could be compared thus:

U.K.	Equator
T = 10°C → 20°C R.H. 50% No sweating	T = 30°C → 40°C R.H. → 100% Sweating copiously
In relation to the endurable limit of	42°C & 100% R.H.
O.K.	Not O.K.

6. Thus it was clear that there needed to be much more ventilation in equatorial conditions than in U.K. by probably a factor of 10. But this was in the absence of wild heat and was only a start. To go back to the original equation, supposing the designer allowed 1 m^2 of sunshine per person i.e. one window letting the sun in

$$X = 1 \text{ kiloWatt and } \left(1 \pm \frac{X}{Nq}\right) = 11$$

7. To sum up, under equatorial conditions ventilation should be generous by day especially if any sunshine got in or cooking or laundering was done indoors. If possible, all wild heat should be excluded, but ventilation still needed to be massive. The only way of producing ventilation on that scale was the stack effect, unless some refrigeration could be put in to cancel the heat that really should not be there. Stack effect could and would do the job by itself given half a chance; it needed only to raise the warmed air a metre or so above the occupants at a very modest velocity of about 10 cm per second. The final point was that after midnight this massive ventilation needed to be restricted by a factor of 5 or so, or occupants would be too cold.

8. The CHAIRMAN thanked Mr Webb. He found it encouraging that everytime anyone spoke knowledgeably in the field of comfort it emerged that the traditional construction was best in 99% of cases. Was there any way of restricting ventilation at night in the traditional Malayan house? Mr WEBB felt this would happen by the spreading of sleeping mats on the floor.

9. Dr S.M. ROMAYA asked whether people should accept 100% relative humidity and just concentrate on ventilation, or would a marginal drop in relative humidity help the degree of comfort considerably.
Mr WEBB said ventilation would reduce relative humidity as well as temperature but the trouble was that ventilation was being done with rather moist air. Dr ROMAYA wondered whether a drop in humidity would change the whole situation by making the temperature comfortable. Some sort of de-humidifier system or preferably air-conditioning was required. Mr WEBB said there would then be no problem - except paying the bill!

10. Mr P.A. OLUWANDE said that in houses in tropical regions it was desirable to keep the air in motion and therefore it was better to have the houses only one room deep with windows opposite each other.
Mr WEBB said wind was a help in a small building, but in equatorial areas there were a lot of calms especially at night. In a

large multi-storey building a moderate wind might hamper the stack effect, and at best would only give a transient benefit on the windward side. Possibly people had concentrated too much on wind in the past and it was no use making a place suitable for wind ventilation if there was no wind. In Malaya there was little wind most of the time, and then occasional sudden brief squalls when there was far too much wind. The CHAIRMAN felt perhaps a thorough study should be made of the strength and frequency of wind before deciding whether it could be of benefit.

11. Mr I.R. BENTON said cross ventilation was sometimes difficult to achieve in high density housing. What type and location of openings in buildings would maximise the benefits of stack effect? Mr WEBB said that preferably the openings should be in the floor and in the roof but although this was not impossible in a multi-storey block it was not easy. Openings should be half at low level and half at high level, and well separated. Unfortunately, the stack effect in the equatorial climate did not work downwards. In desert environments it would work downwards so that it could be boosted by a little air-conditioning to keep it going.

12. Mr F.W. CROWLEY suggested that apart from Singapore, Kuala Lumpur and other larger cities, there were many areas in Malaysia where air conditioning could be nothing but a nuisance because of the failure of the power supply. In those conditions Mr CROWLEY thought it would be much more sensible to design more closely towards the old traditional methods of higher ceilings and where possible a central fan. The type of comfort should relate to the reliability and maintenance of power supply. Mr WEBB said he had been in early colonial buildings where some of the ceilings were 25 feet high.

13. Dr ROMAYA said Mr Webb had mentioned 100% relative humidity and yet at the same time said "sweating copiously". He believed that discomfort with high relative humidity was partly because the body could not sweat copiously and therefore could not discharge some of the excess heat. Mr WEBB said it was easy to perspire but it was difficult to get evaporation of the perspiration.

14. Mr BENTON said studies had indicated that any ceiling height above about nine feet did not give extra benefit. Mr WEBB said the simple calculation for stack effect involved the square root of the height of the room between entry point of the air and the exit point. In fact all the air was not warmed at the entry point nor did it get warmed continuously as it passed through, but it got warm as it passed over people. Thus the effective height of the room was probably the height from about waist or chest level of the occupants to the middle of the upper opening where the air was leaving. He thought there was a strong tendency to reduce ceiling heights in the post-war period and sometimes slightly suspicious arguments were used in this direction. The CHAIRMAN said these studies had been done in Israel.

15. Mr H. MANN said he noticed that in Mr Webb's calculations the effects of insulation had not been taken into account. Mr WEBB said insulation was important when it kept out wild heat. Mr MANN said many tropical houses were made with extremely thick earth walls, and referred specifically to houses in Uganda. Mr WEBB pointed out that thin walls were common in a damp climate. Mr OLUWANDE said in northern Nigeria very thick walls were often found because it was hot and dry. However, in the south where it was warm and humid the practice was to make the walls thin.

16. Mr B.M.U. BENNELL said blocks of flats were sometimes constructed in a square with a central void and he wondered if this helped the stack effect. Mr WEBB said sometimes there was pronounced stack effect in the central court of a multi-storey building. An outstanding case of this was the Cathay Building in Singapore. At the entrance to the court it was necessary to hold one's hat on.

17. The CHAIRMAN mentioned noise pollution. This was one of the problems in the type of climate discussed. Through ventilation was needed but where there was through ventilation, noise went. Mr WEBB felt it was a pity that people concentrated so much on through ventilation and neglected the stack effect. The use of a wind tunnel was misleading.

18. Mr D.M. TURNBULL had noticed that some of the older houses in South America were never comfortable in spite of the ceiling heights, because they had almost no openings on the outside of the building.

19. He said that building services in a fully air-conditioned building in the U.K. were something like 35% of the total building cost. The argument for keeping the ceiling heights low to reduce costs would disappear if an extra couple of feet in ceiling height produced a stack effect.

20. Mr TURNBULL had seen an article

recently describing a proposal to put a little blower in the ceiling of a two-storey house to get a stack effect by pulling the air in horizontally through air bricks in the side and wondered whether this would work. Mr WEBB said this would not give air movement on the same scale as the stack effect; it would move a little air much too fast instead of moving a whole mass of air slowly. Openings should be quite large, of the order of about a square metre per person - for a lot of people this added up to a lot of openings.

21. As comfort (and research in the field of comfort) was really the basis upon which most service engineers designed air-conditioning systems, the CHAIRMAN wondered whether more field studies on comfort should be carried out in different parts of the tropical world. Dr ROMAYA asked for an indication of the range within which the human body could adapt to a degree of comfort. Mr WEBB said there was a graph by Humphreys which indicated that the monthly average of the sensation of warmth was independent of the average temperature from 18-39°C which meant that once acclimatized, people felt no warmer at 39°C than at 18°C.

22. In some American experiments people spent several nights on the ground with snow all round and only one blanket. The first night they could not sleep for shivering. After about three nights they still shivered a lot, but they did sleep. Eventually they learnt to sleep and stay warm with just one blanket. At the other end of the scale in experiments at St Tomas' Hospital in the 18th century a room was warmed up to a point at which brine was slowly bubbling away (about 120 or 130°C) and people sat there quite reasonably comfortably. They found they could put a steak or egg on the table and it would slowly cook itself: if they fanned it it cooked quicker.

23. Mr M. LANSDELL felt that air-conditioning systems were often very much over-done: sometimes at airports it was really cold. Mr WEBB said airport lounges presented difficulties because people arrived from different directions completely unacclimatized and nothing could suit them all.

24. Mr MANN said over-conditioning often happened in public buildings in tropical places where everyone using the place was from the same area. Mr WEBB felt there had been some confusion about what to design to. The lower the temperature the more profit there was to the air-conditioning engineer!

25. Mr OLUWANDE said at present in Nigeria it was the practice to air-condition everything, including cars and offices (if one could afford it). However, he wondered whether this was always a good thing because people had to walk in the streets and these could not be air conditioned.

26. Mr WEBB said some years ago a town in the Gulf of Iran had district air-conditioning which was free: a knob in the homes just had to be turned. The family indoors during the day rapidly acclimatized to air-conditioning and turned the temperature down until eventually the knob was turned as far as it would go. Meanwhile father had been drilling an oil well in the sun and returned in the evening to the very cold house and got pneumonia.

27. The CHAIRMAN on behalf of everyone thanked Mr Webb for his expert and entertaining exposition on the subject of thermal comfort and ventilation.

P.N. PAUL & J.F. BATES

a discussion: British consulting engineers in Arab States

CHAIRMAN: W.H. MEREDITH, BSc, FICE, FIPHE, MIWPC
Partner, Howard Humphreys & Sons

The CHAIRMAN suggested that the discussion should be confined to the water cycle. The introductory speakers, Mr Paul and Mr Bates, were partners in firms very actively engaged in Saudi Arabia, the Gulf and North Africa.

2. Mr P.N. PAUL said the Conference discussions had so far been orientated towards water, waste and health in the poorer countries of the world. During this session they would be turning towards countries which had just about the highest gross national products in the world. With the enormous increase in spending power, the oil-rich Arab States had now embarked on a crash programme of construction aimed at transforming their countries into the industrialised nations of tomorrow. The vast oil revenue had encouraged the establishment of welfare states with heavy expenditure on water and sewerage, and other facilities necessary to develop their infra-structures. British consulting engineers had not been slow to take advantage of this market, and had been given a major part of the public health engineering schemes emanating from the Arab States during the past five to ten years.

3. It was difficult to generalise on methods of obtaining new work because of the great variation from one country to another. Procedures had certainly changed from ten to twenty years ago when firms were normally selected on the basis of their reputation alone and not on the basis of cost. Then there was little effort made by consultants to obtain work in the Arab States; firms would receive a letter saying they had been appointed and would they please go and sign the agreement. Nowadays it was the practice either for clients to approach a number of pre-selected firms, or more commonly to advertise locally asking for consulting engineers who wished to tender for services. Consulting engineers now had to chase prospective clients. This could be a long and expensive process, particularly if a firm had not operated in a country before, and therefore did not have the necessary contacts to gain access to the people who really mattered. Often two or three years were spent chasing a particular job. Thus a considerable capital expenditure and investment should be anticipated in order to obtain a job. Competition was keen: over eighty firms of consultants specialising in public health engineering were registered in Saudi Arabia but less than ten were currently working on active schemes.

4. Consultants had first to put in submissions stating how they proposed to undertake the work, any aspects which would require special study, details of the personnel they proposed to use and the fees that would be charged. In some instances the brief given was very detailed with a good description of the physical extent and purpose of the scheme, and the terms of

payment clearly defined. In other instances there was no basic information at all, or else one was asked to put in a submission on the basis of a 5-minute chat with the local Sheik. No idea was ever given of the time scale of the scheme, but usually it should be assumed that it should be completed yesterday.

5. The scale of fees suggested by the Association of Consulting Engineers was not applicable. The fee stated in the submission was based on how much it would cost to do the work, how keen one was to obtain it and what price competitors were likely to quote. Mr PAUL knew of cases in recent years where the lowest price always got the job. Some Arab States insisted on deducting up to 10% of all consultants' fees as retention money until the engineering duties were complete. On a very large scheme the duties could go on for a very long time beyond the maintenance period. There was also the possibility of further negotiation of the fee after selection, which might make a substantial difference to profit margins.

6. However, there was some evidence now to suggest that the lowest price was not always selected. Selection was based on price, technical capability and the quality of service likely to be provided by the consultant. In the past some Arab countries had employed what might be called "hack consultants" from other parts of the world who provided poor technical work, no service to their clients and demanded throughout the job additional fees.

7. Mr PAUL suggested that for some countries it was not wise to refuse to put in a submission when requested to do so. If they refused firms might never be asked to put in a submission again.

8. It was necessary to consider from the outset whether to establish a joint venture with a local firm and put in an offer together. In Iraq it was now compulsory to tie up with a local firm and in most other Arab countries it was preferred, and Mr PAUL thought this was likely to become the rule.

9. Consultants should appreciate the speed with which the Arab States wished to turn their schemes into reality. There was a sense of urgency attached to projects which was often sadly lacking in the U.K., and a British consultant given his first job in an Arab State would find it difficult to adapt to these needs. In order to provide an efficient service and necessary liaison with a client it was essential to have one or more engineers on the ground from the start. Clients preferred to deal with engineers from a local office rather than to suffer the delays of engineers having to fly out from the U.K. Often there were communication problems, postal delays and difficulties with getting Telex facilities, and it was therefore necessary to ensure that the quality of engineer working overseas was good, and that he had a fair measure of autonomy so that he could make decisions without continual reference to head office. This in turn necessitated that the senior man overseas had a high level of competence and that head office had confidence in him.

10. Most public health schemes were wanted by yesterday and a client was always looking for results and not excuses. It was therefore advisable to warn clients of problems envisaged before they occurred rather than after. Above all the consultant must appreciate that the Arab States wanted service and if they did not get it from one consultant they would go to another - they were not afraid of sacking consultants.

11. Staff should be prepared to attend meetings at short notice, and spend considerable periods of the day during which they felt that little constructive work had been done.

12. Working conditions and hours of work could be rough. Very often it was a twelve-hour day, six or seven day week, with temperatures up to about 120°F with humidity in the 90's. For an engineer who had spent all his life in the U.K. the climatic conditions in most Arab States took a lot of getting used to.

13. In most cases a consultant could expect to be given additional work outside the original scope of works, so even if a consultant carried out the major design work in his head office, he should allow for having some design engineers in the local office, who could undertake the smaller jobs. Trying to plan the number of design engineers required was difficult as the situation could change dramatically from one month to another. Work permits, residents' permits and driving licences all took time to obtain and it was highly desirable in the local office to have an office manager to be responsible for getting these and for dealing with government departments on general office matters. This should preferably be a local man who knew the relevant procedures, who could speak the language and who knew all the short cuts. This could take a big work load off the engineering staff. Mr PAUL said there were a multitude of other points that could be mentioned and he hoped some of these would

be raised during the discussion. Essentially the problems revolved around a need to provide a quick and efficient service and at the same time trying to balance this with delays that could be experienced in trying to obtain information from government departments. The high level of bureaucracy necessitated multiple form-filling and multiple signatures.

14. Mr PAUL said there were problems that British consulting engineers would find in operating in Arab countries but a number of these problems were no different from those that one might expect to find in other parts of the world or in the U.K. When the incredible changes that had occurred in Arab countries were considered, the speed with which they had completed capital works programmes was amazing.

15. Mr PAUL concluded by posing some questions: were British consultants in general offering a good service to the Arab countries; were there ways in which this could be improved; and was sufficient account taken of local needs both in terms of design procedures and the type of works recommended to the Arab States? One area worth discussing was what might be termed "after-sales service".

16. Mr J.F. BATES said a few years ago Arab States used to like being given reports, and they had thousands of reports in some offices in Arab States. Nowadays if one did get a commission to work, the biggest problem was to establish the basic parameters. One needed a crystal ball in most Arab States at the moment because development was so fast.

17. In Saudi Arabia, Dubai and Bahrain planning was not a very developed science. So the public health engineer needed to do a lot of his own planning by deciding what was likely to happen in the way of development, such as where centres of population were going to grow, the type of population, the amount of industry, and the likely water consumption. These had to be established right at the beginning to produce designs that would be acceptable by the time they were completed. It was possible to complete a scheme which was overloaded from the start. It was often found after completing a design that the client suddenly decided to build a palace here or an industry there and thus the design had to be sufficiently flexible to absorb these new ideas.

18. It was important to produce a design which was simple to construct, operate and maintain. Sophistication would be wanted later, but for a new scheme simplicity must be uppermost in the designer's mind. In the early days more sophisticated contractors were available in the Gulf for water supply and sewage treatment schemes. Nowadays the work was being carried out on lower prices by local contractors who had limited know-how, so the form of construction should not be difficult to implement. Specifications must suit local conditions; it was no good using specifications that were appropriate to work in the U.K. Most of the materials and plant had to be imported and a lot of countries had had a great deal of difficulty with concrete.

19. Cement was generally imported although there were some cement works now in production. There were always difficulties with anything that had to be imported. Sometimes there were panics and all the agents thought it would be a good idea to buy cement, so the country became flooded with cement. Mr BATES had seen great piles of cement, because there had been a shortage and there was now a surplus. It was important to ensure that one did not use the cement that had been in store for months. Sources of aggregates were very difficult in this part of the world and a great deal of care had to be taken in selection. Reinforcement had to be imported; it was no use changing designs at the last minute because it was impossible to go to the stockist and get the different types of bars wanted. A great deal of care had to be taken in the type of water used because of the chloride content.

20. Ground conditions varied along the Gulf. Most development was along the shoreline around creeks where groundwater was very high. A good soil investigation programme was essential. In some countries groundwater was only a metre below the surface so hardly anyone had gone below two or three metres. For sewage systems problems of groundwater arose that had not been considered before.

21. Supervision had to be of a very high level. More use was being made of local contractors who might be associated with international firms, but a lot of local inexperienced labour was used. Thus generally the resident engineer had a great role to play. Sophisticated form-work and materials available in Britain were expensive to obtain in the Gulf States. On a large scheme with a lot of standard work it was worthwhile to import steel forms as local carpenters used very thin wood and had to be watched carefully. Safety in construction was not given much thought in the Arab world as there was little regard to life. It was

common to find a man at the bottom of a deep trench with no support.

22. Finally Mr BATES said it was fascinating to see the amount of improvisation that was done in construction in that part of the world. If a pipe needed plugging a small garage or contractor would use a vehicle tyre to make a plug.

23. Mr G.B. RALPH asked for comments on the ethical constraints imposed by the code of conduct which British consultants were expected to observe opposed to the unbridled approach adopted by some consultants from other countries. After-sales service had been touched upon in earlier discussion during the Conference, and from the depth of feeling as to its desirability from engineers and administrators present, Mr RALPH suggested that consideration should be given to incorporating supplementary offers into submissions, quoting an additional price for a further commitment for say two or three years beyond the normal maintenance period.

24. Mr PAUL replied that as regarded ethics it was up to the individual firms to sort out their own policies on this matter. He was not in favour of bribes and did not think that in the long term it paid to give them. The CHAIRMAN felt it was known that British consultants "played it straight" for the past fifty years and more.

25. Most consultants working in these areas were very conscious of after-sales service and did alert the client to the need he had to operate a plant or system. Initially the client probably needed 100% assistance. He would probably take on a two-year operation and maintenance contract when the maintenance period started in the hope that in those two years they could train sufficient operatives to take on the plant. This was costly. The CHAIRMAN's firm were presently doing a scheme in Benghazi where a two-year operation and maintenance contract for a conventional 6 mgd treatment plant, where the contractor had taken on the total cost of operating and training, was of the order of £1½ million. This was the sort of cost that these exercises demanded, but no half measures could really succeed.

26. Mr B.M.U. BENNELL asked whether it was felt that adequate support was given by the British research institutions. He thought perhaps more could be done to help with problems such as using highly polluted water for concrete. The CHAIRMAN felt their support was recognized and used. The difficulty was possibly getting an answer a thousand miles away from the actual laboratory. At times staff from the WRC/ Stevenage were seconded to do a particular job. Mr BATES suggested that more help was available for water supply than for sewerage and sewage treatment.

27. Mr M.I. ALDRED asked about the differences between the basic design and the actual construction. Mr BATES said guesses made seven or eight years before on loadings on biological filters had come out very well. The strength of sewage varied enormously, depending on whether the state gave its water away or charged for it. Changes in basic concepts in design were required less than design for flexibility.

28. Dr S.M. ROMAYA wondered to what extent local engineers were brought into the design stages. Mr PAUL replied that this was very variable. If there was a joint venture a fair measure of the design work would probably be done in the local firm's offices; obviously local engineers would be used, supplemented by one or two people from the U.K. On other schemes all the design work was done in the U.K. Mr BATES said that his firm welcomed working with local firms and local engineers, but there was a lack of know-how and a lot of training was necessary, especially of technicians.

29. Professor S.V. PATWARDHAN asked what other countries were in competition with British consultants and had consultants tried collaborating with other developing countries, like India? Also, what testing and investigatory facilities were available in the local countries, and could equipment and suitable sand be obtained easily? Mr PAUL said consultants came from all over the world but the Americans did not seem to have moved into the Gulf area in a very big way in water and sewerage. In the Gulf it was possible to obtain quite experienced engineers from India and Pakistan. Mr BATES said testing and investigation had developed considerably in the last five years. However, very few local firms could do detailed soil testing in Saudi Arabia. Water was often tested in the U.K. The availability of small equipment such as pumps was improving all the time. It was often a problem to find sources of good concreting sand.

30. Mr P.A. OLUWANDE asked whether Mr Bates would favour oxidation ponds as he had mentioned simplicity of design. Mr BATES said oxidation ponds were simple to construct and were ideal in circumstances where there was a lot of sunlight, but he contended that they could be difficult to operate on a large scale. It was necessary to have experienced people and sophisticated control

for a population of 100 000 for instance. Perhaps biological filtration was better because it was relatively easy to operate and could take shock loads. In New Zealand ponds had become septic despite sophisticated operators with a sophisticated laboratory. In the Arab world smells were something to be very much avoided, and he had been told "no ponds" by some people.

31. The CHAIRMAN felt that in any system a level of competence was needed. Ponds required good laboratory technicians. By and large the biological filter was the simplest treatment Arab States would look to. Another aspect was that ponds were usually built some distance from houses, but before long the town had developed to surround them.

32. Mr OLUWANDE asked about re-use of sewage effluent. Mr BATES said effluent was needed for irrigation. Pathogen removal in ponds could be effective, but algae growths sometimes limited the use of the water.

33. Mr R.P. WHITING had heard that a number of consultants in European countries received help from their governments in one way or another, and that British consulting engineers were at a disadvantage because they did not get this help. The CHAIRMAN said British consultants complained about this from time to time but got no response from the Government. Some European and other overseas consultants received special tax concessions and there were specific instances of a European government giving specific aid towards a project. Mr BATES said there were government controlled consultancies in some European countries. The CHAIRMAN said this was probably a more serious problem to British consultants because it was very difficult for partnerships to compete against government agencies.

34. Mr ALDRED asked what difficulty had been experienced from clients pressing for a greater degree of sophistication in design than was considered desirable on a particular scheme. Mr BATES had not had a client who had pressed for more sophistication. Over the years British consultants had created quite a reputation and usually their advice was relied upon.

35. Mr J.C. HOWARD had the feeling that British consultants were all lone operators competing with each other. It might be useful to have someone to look down on them and give advice on where they might operate jointly with shared facilities and communication. The CHAIRMAN felt there was probably an unnecessary expenditure of effort in the securing of work by British consultants due to their individualistic outlooks and attitudes. Mr HOWARD said management study was a salutory thing, and sometimes a fresh eye might come up with a good idea. The CHAIRMAN said consultants had employed management consultants and done some of the things they advised, but ignored 90% of some advice.

36. Professor M. DANBY asked to what extent consultants used university facilities in the U.K. and locally. The CHAIRMAN replied that on the water side his firm had used them from time to time overseas. On the sewerage side they had not used much university facility, but tended to go to Stevenage.

37. Professor DANBY had worked at a local university in an Arab State and often British consultants went to that country and seemed totally unaware of the University. There was a fair amount of research work done at that University which could have been extremely useful to them. He wondered if the laboratory facilities of the engineering college at Riyadh had been used. This could be useful to the consultants and the consultants themselves would help the educational process locally if they were involved in an interesting project, by talking to the students. There had been lack of fruitful contact in countries he had been concerned with.

38. The CHAIRMAN thought there was a lack of local technical use by consultants in some overseas projects. Generally consultants were so busy getting the project brought into operation that they did not have the time or facilities to be dabbling in the educational aspects that arose from the project. Dr ROMAYA felt that a little effort and expense could generate a lot of goodwill.

39. Mr M. LANSDELL said recently he had visited an American-designed sewage works in Trinidad where the annual temperature ranged between about 28 and 32°. He was surprised to find at these works two heated digestors, with walls about two feet thick, gas collection and the remains of a boiler. All this had been abandoned and comminuters had been replaced by a man with a screen and a rake. Mr LANSDELL wondered to what extent our consultants were guilty of fetching out drawings from the U.K. and using them without considering the local capabilities of the staff who had to maintain these works. The CHAIRMAN felt British consultants were capable of treating each job as an individual job and giving full forethought to the design study required. British consultants in the main were not in and out of an area: they

remained for ten to fifteen years, and had an on-going concern which meant that once they finished a job they had to make sure that it worked.

40. Mr BENNELL asked whether consultants felt they were under any threat from the manufacturers offering package deals for the installation of sewage and water treatment plants. He suspected the instance quoted by Mr Lansdell may have been put in by an enthusiastic manufacturer from the States without a consultant's advice. The CHAIRMAN did not feel there was any threat. If the client wanted to try the package plant, the consultant would give advice as to how he should draw up his terms of reference and the tendering procedure for the package plant. An alternative was for consultants to make their design expertise available to the manufacturer to give him a full awareness of what was required.

41. Mr BENNELL said the situation he envisaged was a plant manufacturer offering the package to the Sheikh without any consultant being involved. The CHAIRMAN said nothing could be done about this, but he did not think there was an increase of this practice. Mr BATES thought a lot of Arabs had had their fingers burnt on this and were now more cautious.

42. Mr R.G. DEFRIEZ asked whether the 10% retention of consultants' fees was over and above the contractors' retention. Mr PAUL replied that it was.

43. Mr DEFRIEZ asked whether there was usually any difficulty in getting payments. The CHAIRMAN replied that it took anything from three months to three years. It was difficult to obtain prompt payment, but this generally was tied up with the client's heavy administrative load. In North Africa consultants had to provide something like a 5% bond which could be quite a large sum of money. Consultants were concerned that the British Government did not recognize this as needing a special arrangement of government aided insurance cover.

44. Mr PAUL showed some slides of construction works in Saudi Arabia and Baghdad. The CHAIRMAN thanked Mr Bates and Mr Paul for their introductions and for taking part in the discussion.

J. MARRIOTT

solid waste management and disposal – practical considerations

INTRODUCTION

"Hot countries" differ tremendously in character and range from arid desert to tropical rain forest; in consequence the nature, yield and composition of domestic solid wastes vary enormously, the most important differences being those of organic and moisture content. The percentage by weight of organic matter can range from 25% up to 85%, and there are often wide seasonal variations.

The only uniform factor throughout "hot countries" is the effect of high ambient temperature on the rate of decomposition of the wastes and consequently on rapid infestation with insect and other pests.

Appendix 1 outlines the life history of the fly and the control measures which this requires, and it illustrates the acceleration of breeding rate due to temperature effects.

The essential objective of solid waste management is the promotion of public health. Unsatisfactory methods of storage, collection and disposal of solid waste create ideal breeding facilities for flies and other pests, which are themselves the vectors of many endemic diseases. The fly population CAN be substantially reduced by proper methods.

The fundamental practical approach to sound solid waste management in hot countries (however poor the community) is the application of systems which will ensure the elimination of conditions which are conducive to the propogation of insect and other pests.

BASIC PRINCIPLES

1. Waste must NOT be deposited on the ground surface, or in open dumps, in order to prevent the infestation of the waste and also the subsoil. Waste should ALWAYS be deposited into metal or plastic receptacles (and ideally these should have tight fitting lids). They should be emptied regularly (preferably daily) and be kept clean at all times.

2. Conveyance of waste from the storage receptacle to the collection vehicle should be either direct, or by the use of carry containers or sheets of impervious material, designed to ensure the waste is completely covered during transit, and capable of easy cleansing.

3. Transport of waste to disposal site should be in covered vehicles (or in closed containers carried by open vehicles).

4. Disposal, which is usually to land, should be in accordance with sound methods of sanitary landfill. This requires the IMMEDIATE covering of deposited and consolidated waste with an adequate thickness of sealing material. The open burning of waste is insanitary as combustion is ineffective, and results in a smouldering mass of decomposing waste, which forms an ideal media for fly infestation.

The foregoing principles can be applied in many different ways according to local circumstances and the facilities available.

STORAGE AND COLLECTION

Large towns and cities usually consist of mixtures of old and new development, with extensive areas where facilities for on-site storage are very limited. This often results in open dumps on vacant land (and even deposit of waste in streets and lanes). Individual bins for each property are a rare occurrence. Street cleansing therefore becomes an important task, but this is often carried out in a primitive manner. Access to older premises (especially in hilly areas) is often by steep stairways and narrow streets and passages, which are inaccessible to vehicles. The waste has therefore to be manually carried for long distances to vehicle collection points, where it is often deposited in another dump to await collection. In small villages there are usually communal dumps which may be removed at infrequent intervals.

Even in the poorest community it is desirable that WHEREVER POSSIBLE

1. Individual storage receptacles be available to each property OR

2. Proper covered metal storage containers of appropriate capacity be provided to replace open dumps (including those at vehicle collection points). Where possible these containers should be mechanically emptied into proper collection vehicles, or with large capacity containers, be lifted and transported by special handling vehicles.

3. In small and poor village communities pit trenches (suitably located to avoid contamination of water) should be used in a similar manner to trench latrines. Great care should be taken to secure the covering of the waste with excavated soil after it is deposited.

The proper use of the modern container systems can save considerable time, labour and cost by the elimination of double and treble handling of waste. Containers vary in size from ½ - 4½ cubic metre capacity when used for mechanically emptying into standard collection vehicles, and up to 12 cubic metres capacity when a special handling vehicle is used. The large containers are in effect demountable vehicle bodies, and they are used on an exchange basis (empty for full).

DISPOSAL

Disposal to land is the common method and will remain so, although in some cases it may be pre-treated.

Cost considerations in many places restrict disposal of waste to simple methods of land disposal, BUT THE ONLY ACCEPTABLE SANITARY SYSTEM is controlled landfill. This requires the deposit of waste in shallow layers which are consolidated as firmly as possible, and then covered with at least 15 cm of soil or other inert material IMMEDIATELY after the wastes have been deposited and consolidated.

Where the land can be readily excavated, and there is an adequate area available, the CUT and FILL method is appropriate. Great care is necessary to avoid water contamination by careful siting. In wet tropical areas with a high subsoil water table, surface deposit in the form of windrows is advisable; this method can also be applied where there is a rocky subsoil and there are no natural or man-made excavations to fill. Suitably formed and COVERED windrows will quickly ferment and in a period of a few months will convert the wastes into a composted material. Where cover material is scarce, this composted material will provide ideal covering material for new wastes.

Where money is available, there is great advantage to be derived from the pre-treatment of waste by mechanically shredding or pulverising. Properly done in a suitable plant, the waste is converted into a material of a homogeneous nature, free from voids. The milled material is largely free from pest infestation, as the eggs and larvae are destroyed in the milling process, whilst food and organic material is thoroughly broken up, contaminated and coated with dust so as to render it non-attractive for reinfestation or as an animal food. Shredded waste can be readily ploughed into agricultural land, it can be converted to good compost by windrow methods, or it can be disposed of more easily by sanitary landfill methods. New processes are in development which can enable it to be converted into useful fuel briquettes.

The handling of wastes at large disposal sites requires proper and suitable equipment. The most useful machine is a suitable loading shovel, mounted on four-wheeled drive pneumatic tyred tractor and fitted with a scoop bucket to which is attached a clam shell crab lid. The versatility of such a machine excels the output of the normal crawler machine. It must, however, be of a make and type designed especially for solid waste handling.

APPENDIX 1

THE IMPORTANCE OF FLY CONTROL

1.1 The fly is one of the most prolific pests of man. It can carry disease organisms causing typhoid, cholera, gastro-enteritis, diarrhoea, dysentry, eye disease, hepatitis and tuberculosis, as well as intestinal worms.

1.2 The fly can only swallow liquid food, and in order to use solid foodstuff, it uses saliva and regurgitated fluid from already digested food to dissolve the solid into a kind of broth which it sucks up through its proboscis.

1.3 During breeding it goes through four stages: egg - larvae - pupa - adult fly.

1.4 It requires certain conditions for the deposit of its eggs such as moist fermenting or decomposing vegetable or organic matter. The female seeks a suitable breeding site by sense of smell, and deposits her eggs into the mass of breeding material in order to prevent them being destroyed by the sun, and by being dried out in other ways. The batches of eggs number up to 150, and an adult fly will lay several batches during her short life.

1.5 The full cycle - egg to adult - depends on weather and temperature. Under ideal conditions it can be less than seven days. In hot countries the fly lives about one month.

1.6 The eggs quickly incubate, and produce a small maggot or larvae which burrows into the food to avoid light and to feed on the material. During this larval stage it remains below the surface, but it will eventually move to just below the surface and it may migrate some distance horizontally. In this position a pupa is formed (a small bean-shaped object up to 7 mm long). Excavation of infested soil around a refuse dump will reveal at about a depth of 5 cm considerable numbers of larvae and pupae. These can total over ten thousand per square metre.

1.7 In due course the adult fly emerges from the pupa and makes its way to the surface. Here it walks about on the surface for some time until its wings fully expand and its air sacs are filled, when it commences to fly. The adult fly can travel many kilometres from its breeding site.

1.8 When already inoculated material is buried and covered with clean material the larvae which hatch out eventually move upwards and outwards to pupate just below the ground suraace, and in due course the adult fly emerges at the surface.

1.9 If larvae are already present in the material which is buried, pupation takes place in that material, but the live fly can penetrate upwards through very thick compacted layers of clean material. It has been found that this emergence can occur through 45 cm of hard packed soil.

1.10 It is clear that the usual covering of clean material as used in sanitary landfill can do little to prevent the emergence of flies from waste which has been previously infested with eggs or larvae. The heat of fermentation of the waste will, however, destroy considerable numbers, but nevertheless many adult flies will escape.

The drier the ground conditions and the slower the rate of temperature built up from fermentation, the greater will be the number of flies that will emerge.

1.11 The fact that the newly emerged fly must remain on the surface for some time after it emerges indicates that for control purposes treatment of the surface with an insecticide which has residual toxicity is necessary.

1.12 The most effective means of control is to prevent eggs being laid in waste before it is collected. This clearly indicates the need for impervious covered storage containers. Open dumps cause infestation of the ground. It is extremely important to keep waste off the ground to avoid infestation, and as it is always difficult to completely cleanse the surface after removal of waste, there is usually sufficient organic matter left behind in which flies can lay more eggs. Residuals of waste in bins, containers and collection vehicles also encourage the deposit of eggs and later infestation of other waste placed in the receptacle. For this reason thorough and regular cleansing of the receptacles is important.

1.13 Where sanitary landfill is practised, it is important that incoming waste is placed into position, levelled off, and covered with the greatest speed, to prevent further laying of eggs in the mass, and also to create fermenting conditions as rapidly as possible.

discussion

CHAIRMAN: W.H. MEREDITH

The CHAIRMAN introduced Mr Marriott as a recognized authority in the field of solid waste management and disposal. He had spent a long part of his life in municipal engineering and was responsible for the local refuse and compost installation at Wetherby. Since 1974 he had been acting as consultant in this field to WHO and to the Chairman's firm also and was an active member of the Government Working Parties on waste.

2. Mr J. MARRIOTT said Americans referred to solid waste as "garbage" and in the U.K. it was "refuse". Hot countries differed tremendously from arid desert conditions to tropical rain forests and consequently the type of waste produced differed quite considerably. The most important element was organic matter, that is the matter easily and readily putrescible. Up to 80% of the solid waste from hot countries was organic matter. In hot countries there were large cities such as Singapore where the waste was similar to that found in cities in Europe i.e. an increasing amount of packaging material and declining organic matter because of change from natural foods to package foods.
Mr MARRIOTT gave Jedda in Saudi Arabia as a typical example. Analyses over a five-year period showed a changeover from a high organic content to an organic content as low as 20% - similar to that in some European cities. This was an important aspect in relation to what should be done about waste.

3. Throughout hot countries there were really two factors that had an important bearing on solid waste management. One was the high temperatures and the rapid decomposition of organic matter which made it an ideal media for the production and breeding of insects - flies in particular - and other pests. This was the most important reason for managing solid waste properly. The fly was the main vector in the transmission of many endemic diseases in hot countries. If wastes could be properly controlled from the point of actual production to that of final disposal by the elimination of fly-breeding as far as possible, a lot would be achieved towards eliminating disease in hot countries. The second factor was a lack of solid waste management skill.

4. Sophisticated disposal systems should not be set up unless the waste was properly stored, properly collected and properly transported to the disposal point. The problem was to ensure that waste was kept off the ground whilst awaiting removal. In many areas it was either put onto dumps, discharged into streams or accumulated on waste ground. It might be collected regularly, but the method of placing it on the ground caused heavy impregnation of the sub-soil with fly and other insect larvae and thus perpetuated the fly-breeding cycle. In two countries Mr MARRIOTT had worked in it was remarked that if this dumping was stopped there would be a lot of hungry goats in the community! Human and animal scavenging was an almost universal practice and once an attempt was made to effectively control the storage and transportation of waste in an effort to reduce the vectors of disease transmission then there would be agitation from many people who would thus lose their normal means of keeping goats and other animals. However, this was a problem that had to be faced if progress was to be made.

5. There were many areas in hot countries where money was not available to introduce sophisticated methods of waste disposal. There were communities so poor that any form of mechanical equipment was out of the

question. However, progress was still possible by applying sanitary landfill methods according to the local circumstances. The only acceptable method was to cover the waste as quickly as possible after collection. The most satisfactory method was by cut and fill trench excavation where one would excavate an area, fill in the waste and cover with the excavated material. This was costly because it needed proper earth moving equipment to do it, and there were areas, for example in the desert areas of Jordan, where the rocky sub-soil made it impossible to excavate. There were other areas (for example in parts of Nigeria and Malaysia) with a high water table where excavation was impossible as waste would be deposited in water. In these conditions waste could be deposited in windrows, but this needed a loading shovel with a grab bucket. The windrows should be covered. The waste in the windrows was quickly converted into a form of compost. This compost or stabilized waste could make a good covering material for other waste. Initially it might be necessary to import material but after two or three months the earlier heaps would have decomposed to an inert material which would form the covering for future heaps. The essential thing was to cover the material on all exposed faces as quickly as possible after placing it in position to prevent scavenging by birds add animals and infestation by insects and other pests.

6. Where money was available landfill could be improved by using some form of mechanical shredder. This needed a power supply and mechanical systems for feed and discharge. However, the plant itself was fairly simple and reliable. The process of shredding had several advantages, because the waste was broken down to more homogeneous material with maximum particle size of about five or six inches which ensured that the material would go into sanitary landfill easily. In the process of milling 99.9% of fly infestation already in the material would be destroyed by heat and friction. Most waste was already innoculated with fly eggs and fly larvae and pupae had already started to form by the time it reached the disposal point. The intimate mixing of the materials as the result of shredding made the waste less attractive to animals. Shredded waste if put into windrows would quickly ferment into a compost material. In many cases shredded refuse could be taken direct from the milling plant and ploughed into agricultural areas. In hot countries it added humus quite quickly to the soil.

7. There were rare cases where incineration might have benefits. In several countries there was a need for a fairly cheap solid fuel for domestic use and a system was now being developed in the U.K. (which Mr MARRIOTT hoped by the end of the year would be commercially available) where milled refuse could be mixed with a bonding material to produce fuel pellets.

8. Mr W.C. CARNEY was pleased that the emphasis had been placed on the necessity for good management practice, particularly of landfill areas. The effect of landfill on surface water drainage was often overlooked with disastrous effects on surface drainage and the landfill site itself. Mr CARNEY asked Mr Marriott to comment on the choice of landfill sites.

9. Mr MARRIOTT replied that selection of the site was the major problem, and in many cases there was not much choice. It was necessary either to transport waste very long distances to acceptable sites or to adapt the site to the material to be put on it. There was always a risk of contamination of groundwater by leachate from the tip material, although when tipping in a desert area the leachate did not penetrate more than a few metres. Sites should be remote from water supply aquifers and the underlying strata should be free from fissures. Tips should be shaped so that rainwater did not pass through the tipped material. The Report on Disposal of Toxic Waste (the Key Committee, 1971) suggested that by shaping and shedding rainwater toxic waste could quite safely be placed in tips. For any large community the hydrogeology of the area should be carefully considered in relation to the meteorology and climatic conditions.

10. Professor S.V. PATWARDHAN said that with composting waste varied so much that sorting and sifting became necessary; stones, glass etc should be removed. Two methods which had been suggested were filling in trenches, where composting took 2-6 months, and using stacks. The second case was aerobic composting and the temperature rose to 70°C; most of the fly eggs and larvae were burnt out. It took only 15-21 days, so economy could be achieved. To control flies, a permanent compost pit could be made of bricks and covered with a fly net. It would be found after 15 days that there was a good compost.

11. Mr MARRIOTT said the system of composting needed to be carefully looked at. In a number of countries, because of the high organic content of refuse, the production of compost by simple non-mechanical methods had a great deal to be said in its favour.

On the other hand, in the cities of Saudi Arabia there was a big move towards packaged foods and consequently the organic matter had dropped quite dramatically and packaging and paper formed a large proportion of the waste. In a situation like this composting had nothing to commend it. On the question of recycling, many areas in hot countries needed compost as a land conditioning material, which would retain moisture and add humus to the soil. Professor Patwardhan had said that to make compost it was necessary to sort it, but if the waste could be put through a pulverization plant, timber, wood, bricks or stones would be ground up. The process of milling was shredding and impact breaking so that brittle material was broken down to a very fine powdered material and with sound mills there were no detectable glass particles. Mr MARRIOTT said his own plant at Wetherby had this system and in spite of the high proportion of glass in waste in Britain it never produced any compost where it was possible to detect any glass particles by observation.

12. Fly-breeding in a normal compost heap or a sanitary landfill above ground was due to the prior innoculation of the waste at the point of production and during collection and transportation. The whole life cycle - egg to fly - took around four days with the right temperature and moisture conditions. When a fly emerged from a mass (and it could burrow up a long way) it needed to do two things before it could fly: harden its wings and fill its air sacs and this could take an hour or more. If the flies could be trapped during that time or destroyed by using an insecticide, much would be achieved.

13. Professor N. MAJUMDER said many villages still composted night soil with garbage. Mr MARRIOTT felt that provided it was properly fermented with waste, the ultimate material should be quite clear of pathogenic organisms. One problem was parasitic eggs, and the difficulty was getting the composting temperatures high enough to destroy the parasitic eggs. Professor MAJUMDER said the reason for mixing night soil with garbage was also to maintain a proper proportion of carbon to nitrogen.

14. Mr W.E. WOOD asked about the effect of milling on metals and the effect of the modern practice of bagging refuse, particularly in plastic bags, on heat production and general decomposition in landfill. Mr MARRIOTT said once the material had been put through a mill it was much easier to magnetically extract the ferrous metals. A number of communities had small foundries with small electric arc furnaces where tins and other metals were smelted to make low grade castings. In reply to a further question from Mr Wood, Mr MARRIOTT said metals should not be removed before pulverization. In composting tins formed a useful catalyst by providing pockets of air in the mass. In landfill ferrous metals were quickly corroded by the acids which were formed in the mass.

15. Wetherby had pioneered the introduction of the bag system of refuse storage and collection. They started with paper bags but Mr MARRIOTT found great advantages with the plastic bag and there was no problem with the milling of bagged waste. The mill shredded the bag to a size of 3-5 inches but in the subsequent process either of landfill or windrow composting this material tended to roll together into a tight little ball. Where there was no pulverization a lot depended on the system of collection, but most modern collection vehicles in cities and towns had compression loading to produce effective pay-loads. The compression devices usually punctured or tore the bags. If the refuse was being taken by open donkey cart, then the bags remained reasonably intact, but in landfill or tip there was an inherent passage of moisture into the bag and the decomposition started inside.

16. Mr P.A. OLUWANDE asked about pre-treatment of refuse before pulverization. He had seen a plant which had been put out of operation simply because of big concrete blocks in the refuse. Mr MARRIOTT said modern mills tended to take more of these "tramp" materials. The method of feed to the mill was important. The money spent on bunkers would be better spent on providing a proper reception place where vehicles could discharge their load completely under cover to entrap any flies that emerged from the load. Material deposited on the floor was discharged to the mill feed elevator by a simple form of loading shovel. The operator could be very selective in what went in.

17. Mr OLUWANDE asked about smell from such a plant. The industries around the plant he had mentioned actually went to court to prevent the plant operating. Mr MARRIOTT said there should not be too much odour in the actual milling process. In fact some types of mill in which the conveyors were totally enclosed gave off no detectable smell at all. The problem was at discharge. If refuse was windrowed at the same point at which it was milled and it was near other properties, then there could be problems when the composting material was turned over.

There could be nuisance from noise at a pulverization plant. There was a danger of explosion because all sorts of things got into plants, including calor gas containers, sometimes partly filled with gas. With proper design and explosion proofing there was little risk to personnel operating the plant and no harm to the plant itself.

18. The CHAIRMAN said one further aspect was the management, which must start at source rather than at plant. Just as it was important to have an effective sewerage ordnance, it was necessary to have an effective waste ordnance, and some authorities were lax in appreciating this. It was no use expecting to deal with all these hazards in design.

19. Mr E.L.P: HESSING felt an important problem in waste management was the collection and transportation of the waste. Could Mr Marriott enlarge on that aspect and perhaps give examples of appropriate collection and transportation techniques particularly in shanty towns of big cities. Mr MARRIOTT had recently carried out a study in Amman for the World Health Organization. In Amman there were nearly 300 000 refugees in a city of 600 000 population. Amman was on seven hills so there were very steep gradients. Roads were several kilometres away from the lowest houses and the only access was by tortuous stairways or passages, too steep for animals or vehicles, so that waste had to be carried from the point of production to a place where it could be picked up by a refuse vehicle. In Amman hesian sacks were used to carry refuse. The collectors liked them because any liquid in the waste ran out. Rubberized sheets about two metres square were now being used; at the end of the day they could be hosed down.

20. At the collection point the same piece of land was always used to dump the refuse. Excavations about 25 mm below the surface showed a heaving mass of fly larvae. It was clearly desirable that some form of impervious container should be used to replace the dump. The carrying sheets could be emptied into the containers, which in turn could be mechanically lifted to discharge their contents into the collection vehicle. In Saudi Arabia there were uncovered concrete communal dumps which probably received anything up to 6 or 10 tonnes of waste each day. These should be replaced by large covered containers which needed a special handling vehicle working on a replacement basis, the empty containers being put into position before the full container was taken away. In Jedda there had been a television campaign with the theme "keep waste off the ground".

21. Mr M. LANSDELL said that Caracas in South America had a population of two million of whom 600 000 lived in ranchos on the hillsides. There was a mechanised refuse disposal service twice a week in the town in the valley, but until recently there was no refuse collection for the ranchos on the hillsides. The rubbish went into streams that descended the hillside and caused terrible problems of flooding in the surface water drainage system in the city itself. Twelve months ago the municipality introduced a system of three different coloured sacks; one for tins and bottles, another for putrescible material and the third for paper. The municipality paid for full sacks. This system had also been instituted in the city centre itself and had eased the sorting of bottles and reclamation of iron and steel and paper. Mr MARRIOTT had not mentioned sack systems because on cost grounds it did not appear to be a practical solution in hot developing countries except for the wealthier oil countries. The cost of plastic bags was geared to the cost of oil: plastic was an oil derivative and in two years the price had trebled. The sack was a disposable receptacle which could only be used once because it was impossible to clean it at an economic cost.

22. Mr D.M. TURNBULL said that milling was unlikely to be a universal practice in most countries for a long time and there was a terrific increase in the use of plastic containers in one form or another. Would Mr Marriott prefer to see a biodegradable plastic as the first priority? Mr MARRIOTT felt this must eventually come. In 1965/66 the DOE had discussions with the Biological Research Laboratory to see whether some means could be found of biodegrading plastic. Recently a new system had been developed which involved incorporating starch granules into the plastic.

23. Mr J.C. HOWARD asked for comments on rat control, and Mr MARRIOTT said rodents were not troublesome at all in some areas, particularly in dry desert, whereas in other areas with a copious water supply they were a serious problem. Rodents could not live long without access to water: they could go without food for much longer than they could go without water. The control measures advocated for flies and insects if carried out thoroughly would effectively control and minimise rodent infestation. When refuse had passed through a pulverizer it was not attractive as a food or habitation for rodents. The food in the waste was intimately mixed with dust, grit and

glass thus making it unattractive as a food supply, and there were no natural cavities in tipped milled waste where the rodent could make its burrow.

24. Mr R.A.J. SIMKINS was interested that with increase of packaging the amount of putrescible material seemed to decrease. Some people thought nowadays that the amount of packaging was excessive and possibly should be reduced for various reasons. Did Mr Marriott favour a reduction in all the sophisticated packaging of various kinds? Mr MARRIOTT said there was a British Government Advisory Committee looking at this. With modern methods of distribution and retailing, the maintenance of good hygiene prevented any major reduction in packaging of food. Oil-rich nations were importing more packaged foodstuffs to replace indigenous food. In the present economic world recession a great deal more thought should be given to the cost of packaging. In 1969 it was estimated that the average housewife in Britain paid £1.50 per week for packaging of the goods she bought. Mr MARRIOTT did not think there would be such a major reduction of packaging material as to seriously affect the problems of waste disposal.

25. Mr HOWARD asked for information about the cost of pulverization. Mr MARRIOTT said the capital cost of the plant depended on how sophisticated it was. The operational costs were in respect of taxes, maintenance, electricity and labour. In general if the cost per tonne of crude tipping was taken as an index of one, sanitary landfill cost had an index of two, pulverization an index of three, composting by natural methods an index of four, and incineration an index of eight to ten. However, there were big variations depending on various factors, particularly the cost of electricity.

26. The CHAIRMAN thanked Mr Marriott for introducing the paper and he also thanked the participants for a very interesting response to the introductory remarks.