ENGINEERING, SCIENCE AND ... [illegible]

THE PREVENTION OF TROPICAL WATER-RELATED DISEASE

PROGRAMME

MONDAY
11
DECEMBER

Registration, Official Opening and Welcoming Addresses (10.00-1200)

1. Introductory Paper by D.J. Bradley – Engineering, health and policy in developing countries – some strategic issues (12.00-12.30) (p. 1)

SESSION 1 (1400-1530)

2. Some ecological problems concerning engineering and tropical diseases: E.B. Worthington. (p.5)
3. Domestic water supply in the Third World: G.F. White (p. 13)
4. The incorporation of health parameters into engineering design: P.L. Rosenfeld and B. Bower (preprint not included)

SESSION 2 (1600-1730)

5. Rural water development in arid regions: P.H. Stern (p. 21)
6. Evaluation of rural water supplied in Eastern and Southern Africa: L. Rosenhall and L. Hansen (p. 25)
7. Potable water and village health – is primary prevention affordable? E. Pournadeali and M. Tayback (p. 31)

TUESDAY
12
DECEMBER

SESSION 3 (0900-1030)

8. Of typhoid fever and telephone poles: deceptive data on the effect of water supply and privies on health in tropical countries: K. Kawata (p. 37)
9. Environmental health among the Masai of Southern Kenya: *the effect of water supply changes*: R. Shaffer (p. 45)
10. Child health, diarrhoeal disease and use of water in an African city: L. Freij, G. Sterky, T. Waldstrom and S. Wall (p. 49)
11. Polluted water and childhood diarrhoea in Jakarta Indonesia: M. Gracey (p. 57)

SESSION 4 (1100-1230)

12. Strategies for the control of shigellosis at Teknaf: M. Rahaman (preprint not included)
13. Assessment and control of water quality in a town distribution system with reference to the incidence of gastro-intestinal diseases: V. Raman, N.M. Parhad, A.W. Deshpande and S.K. Pathak (p. 65)
14. The survival of viral pathogens in water and waste in the tropics: E. Lund (p. 73)

SESSION 5 (1400-1530)

15. Sanitation versus immunization in the control of enteric and diarrhoeal diseases: B. Cvjetanovic (p. 81)
16. The epidemiology and control of Cholera: a review: W.H. Mosley (preprint not included)
17. The survival and transmission of *Vibrio cholerae* in an artifical tropical environment: M. Isaäcson (p. 89)

SESSION 6 (1600-1730)

18. The need for integrated planning in *rural* health services: E.S. Degoma, E.A.R. Ouano and C. Polprasert (p. 97)
19. A community organisation approach to clean water and waste disposal in Cameroonian villages: R.B.Isely (p. 109)
20. Nitrate levels in groundwater from the fleuve, Senegal: M. Berwick (p. 117)
21. The health hazards of open drains in developing countries: P.A. Oluwande, M.K.C. Sridhar and O. Okubadejo (p. 121)

ENGINEERING, SCIENCE AND MEDICINE IN THE PREVENTION OF TROPICAL WATER-RELATED DISEASE

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ENGINEERING, HEALTH AND POLICY IN DEVELOPING COUNTRIES — SOME STRATEGIC ISSUES

Heavily malaria - orientated

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Our view of the key issues in the relation of engineering to tropical diseases has changed drastically several times this century. At present, emphases are changing every few years. By looking at this process it is possible to suggest the likely future strategic issues and also to point to at least one major re-orientation that will be needed. Prediction is a risky pursuit, and scarcely science, but is needed if we are to utilise the lessons of recent years, and still more if several separate lines of thinking, now converging, are to be successfully integrated.

A. THE FIRST HALF-CENTURY

In work prior to the second world war there were four main phases to the areas where engineering and medicine intersect. The phases overlapped, and once each had begun it continued at some level throughout the period.

(i) The public health tradition of temperate countries

The history of water supply and water-borne excreta disposal in temperate countries, cholera epidemiology and John Snow, and the action taken on a municipal rather than national basis to improve water supplies, is well known for the western world. This approach became firmly embedded in the training not only of public health engineers, but also of doctors specialising in public health. The statutorily required D.P.H. qualification in Britain, for example, brought in some uniformity of approach. With the growth of colonial administrations this view of the key issues of water supply and sanitation, which we have elsewhere termed the 'temperate municipal' approach, was carried to the tropics by government doctors and engineers. When indigenous physicians and engineers emerged, they too accepted this view of the key issues because postgraduate training until recently was confined to the metropolitan countries. These views, where successfully implemented in the smaller cities and towns of the tropics, were highly effective in reducing the level of water-borne disease. They were less successful in huge, poor cities where the problems were on a vastly greater scale than there were funds available to combat them and the problems of villages and rural dispersed populations were simply not tackled. For these a series of ad hoc solutions were developed over the years but, except for bore-holes, these tended to fall in the uncertain area between the domains of engineer and physician, being gradually abandoned by both to community development workers.

(ii) The transmission of parasites

In the fifty years following Manson's demonstration of the role of mosquitoes in filariasis transmission in the 1870's, numerous parasitic infections of importance in the tropics were shown to have invertebrate hosts whose life histories depended upon surface water. Most important, the anopheline vectors of malaria, in their larval stages, and the snail hosts of schistosomes are aquatic. It followed that the importance of water in disease transmission, already appreciated in relation to typhoid and cholera in temperate countries, assumed greater proportions in the tropics.

(iii) Malaria control by species sanitation

The logical consequence of showing that mosquitoes carried malaria was that mosquito control might reduce transmission of the disease. Such logic was not easily accepted by the public health experts of that time, but Ross pressed the matter both by practical demonstration of its efficacy in the Middle East and by mathematical models showing that the requirements for effective malaria control by mosquito reduction were not impossibly stringent. The key early work by Watson in Malaysia showed not only that drainage would rid some towns of malaria, but also that choosing the correct sites to drain required detailed understanding of mosquito larval ecology, since the vector in one place might breed in quite different habitats from the vector in another. Thus the concept of 'species sanitation' grew up. First practised by physicians, but requiring a combination of entomological and engineering knowledge, the environmental engineering control of malaria was undertaken by many workers, particularly in India.

The Tennessee Valley Authority then became perhaps the key organization in bringing malaria control into the activities of engineers and their extensive American work on malaria control in impounded waters was both effective and well known. Not all the methods are applicable in other countries and, in particular, methods appropriate to small reservoirs in the USA would be both impracticable in large African lakes and without effect on malaria even if carried out.

But in all sites the engineer was central to effective malaria control - by drainage, by level of water fluctuation, or by irrigation management or oiling - just prior to the second world war.

(iv) Geohelminths and the Rockefeller Foundation
The fourth major issue prior to 1940 was geohelminth control. The Rockefeller Foundation mounted a prolonged and thorough campaign against hookworm transmission, chiefly in the southern USA, in the 1920's and 1930's and this drew attention to problems of rural excreta management. The detail of these studies both set a standard of careful investigation and spread into work on other excreted helminths. As with malaria, the boundary between engineering and epidemiology was obscured and real advances were made, though the conclusions were not as fully incorporated into the education of either profession as was desirable.

B. THE NEXT QUARTER-CENTURY

The second world war sharply demarcates the end of the first period, because by the end of it sulphonamides, DDT and penicillin were in large-scale use and several synthetic anti-malarials had been developed. Consequently, effective treatment was available for many of the major water- and excreta-related diseases and an almost miraculously effective persistent insecticide could be used. The latter, and its development into the key weapon in the global malaria eradication campaign, killed interest in the engineering control of malaria, while the health aspects of domestic water supply and excreta disposal became neglected. It was widely felt that everything of importance was already known, and the subject could be left to other professions, especially engineers, for implementation. This thinking had several defects so far as developing countries were concerned. First, it assumed there were public health engineers available and able to work in the rural as well as urban areas. In fact they are usually even scarcer than doctors! Second, it assumed that temperate country epidemiological findings could be carried over to the tropics unmodified and this is certainly untrue in detail. It may also be inaccurate on major issues of epidemic disease transmission that affect the most cost-effective improvements when funds are severely limited. The third consequence of the loss of research interest in tropical water and sanitation was its general neglect. If men of influence were not specially interested in the problems, priority of implementation fell and the professions related to the problems were considered less attractive. Interest in the general environmental aspects of health reached a very low level by 1960. Since then there have been three successive waves of renewed interest: first in water, then sanitation and thirdly in environmental means of malaria control.

In parallel with these engineering aspects of health improvement there has been a growing concern for the adverse health consequences of engineering activity, particularly focussed on the spread of schistosomiasis as a consequence of water developments. Institutionally, this has developed in a quite different way from the other three topics, but it is clear the issues each raises are now converging.

What were the key issues in the revival of interest in rural domestic water supply in the tropics? The causes were various and included needs of aid organisations as well as scientific issues and concern for how decisions are made in small communities. The main issues were first, that water-related disease was a rural as well as an urban problem; second, that improvement of water supplies was not an all-or-none phenomenon but could be viewed better as an incremental process, and third that the inter-relation of health and improvements could be analysed in operational terms, rather than in purely medical categories, in ways that were relevant to increasing the cost-effectiveness of expenditure on water.

Since then, emphasis has moved on to the multidisciplinary evaluation of water supply programmes, and the key importance of operation and maintenance in keeping the maximum number of people adequately supplied. However, the implications of this have not been accepted as yet. Organizations are oriented towards construction rather than maintenance, and aid, whether bilateral or as a loan from an international bank or other agency, is usually for capital rather than recurrent expenditure. Thus all the pressures are towards building, and away from maintenance, quite apart from the innate attractions of the former to able engineers.

Ever since the charter of Punta del Este, in which the proportion of the population to be provided with water exceeded by 20% those to have sanitary waste disposal, the picture of water arriving but waste not being removed has been illustrated! The immense costs of conventional sewerage, even in densely populated tropical cities, have led to a revival of interest, led by the World Bank, in alternative approaches to excreta disposal, and health issues have been raised by the alternative technologies. The same key issues were raised as with water supply, but in addition the cultural and behavioural problems surrounding the use of facilities have loomed very large.

Both water and sanitation in urban situations have been centrally administered and rural supplies have raised many organizational problems. The conventional wisdom has been to instal through a government organization and rely on the local community to maintain the facilities. It is now clear that the reverse may be more realistic: to involve local groups in self-help construction which is the sort of short-term project that village enthusiasm can aid, while relying on a government bureaucracy for operation and maintenance. This requires the latter to be well organised and reliable.

With the collapse of the malaria eradication programme in many tropical countries, and a return to control, many of the tools of eradication may be of little use due to resistance to chemical control agents and the high price of newer insecticides and drugs. The older generation of malaria control engineers have effectively gone and no-one has been trained to replace them.

Among the vector-borne diseases, two clear trends are likely. As malaria parasites become resistant to chloroquine and their vector mosquitoes to insecticides, the engineering control of malaria will be revived greatly over the next 5-10 years. Only a highly successful vaccine or depot chemotherapy preparation would end its importance and the latter is unlikely, even though optimism about a vaccine is great. Conversely, schistosomiasis control is likely to move away from molluscicides and towards chemotherapy for up to a decade, but the importance of engineering interventions will also increase, especially when they can utilise our growing understanding of human water contact patterns to limit the extent of environmental alterations needed to reduce schistosome transmission.

The other tradition involving schistosomes has been that of water resource development for irrigation and power. Here the physician began as merely a nuisance to the engineer pointing out health hazards it would have been convenient to overlook. It was easier to prevent than cure such hazards and the key message was to involve the epidemiologist at the planning stage. This is now accepted by the more enlightened planners and funding agencies though often neglected in smaller projects. Consequently, some blunders have been avoided. However, to prevent other problems has often proved too expensive. The change of philosophy from big projects to more integrated rural development has made a more rational basis for health inputs however, which can be planned over a longer time scale and fitted into the general development pattern. This also provides a better basis for continued public health engineering effort. The problem which remains is that integrated rural development is difficult and complex, and the feasibility of what is aimed at is often far from clear.

EDUCATIONAL IMPLICATIONS

Where then do we stand now? It is clear that water supply has moved back into the mainstream of development and environmental health as well as engineering. It looks as if excreta disposal will become of comparable concern, though both social and technical problems are greater and offer constraints as well as challenges. Both water supply and excreta disposal are the chief concerns of a professional, the public health engineer. Progress in the broadest terms within these subjects is likely to be concerned with the organization of adequate maintenance and operating institutions, and with the relation of these topics to integrated rural development. Consequently, the education of P.H. engineers will need broadening. If one believes, as I do, that successful integrated rural development will come from more widely educated engineers and others, rather than from vague generalists, this addition to training needs high priority.

But what of the other intersections between engineering and health? There is a greater risk here. Drainage against malaria, or irrigation design to minimise schistosomiasis, do not tidily provide a profession. Rather they are extra activities -or better, a way of performing other activities - that make the main occupation of the agricultural, irrigation or dam-building engineer to improve rather than worsen the public health. Many of these activities fall at the professional intersection of the engineer, planner and community health expert, so again this is an educational issue: to ensure that the relevant people know enough outside their main subjects to cope with these problems.

The key conceptual issue of a few years ago in water was to persuade people to think in terms of incremental improvements rather than all-or-none terms; to show that there were many steps between fetching water from a filthy pond and having multiple taps delivering chlorinated safe water. Still many people have not really accepted the need for this change of attitude. The pattern of responsibility, whereby an engineer is responsible for a project rather than for a defined population, makes the change harder.

The main current conceptual issues are those of equitable distribution of water and sanitation benefits and of how to integrate water supply and excreta disposal into an overall rural development programme. The complexity of the task will give others besides engineers a headache.

What of the future? First someone must take responsibility for sorting out the other environmental health problems as well as water and excreta disposal. This is best the engineer, preferably in league with the medical man, but requires very much a concern for the health of the community rather than for the building of structures as ends in themselves. Second, if emphasis is to be on operation and maintenance, not only will salary patterns need adjustment but also educational ones. There will need to be regular short refresher courses, rather than rare longer courses for the few.

CONCLUSIONS

We have seen therefore a revival of interest in the health aspects of water supply, in large part stimulated by geographers and economists, though involving medical men and subsequently engineers. The similar revival of concern for sanitation, just under way, has similar economic origins - overt, in that the greatest efforts have come from a bank - but with engineers having moved into the position of prime movers. The issues raised in an amateur way in the publications on water have begun to be tackled by various relevant specialists in the study of sanitation. Third, the revival of concern for environmental means of control for vector-borne diseases, which is just beginning to gather momentum, arises from technical rather than economic issues: the spread of malaria, insecticide resistance and demands of environmental legislation in relation to water developments.

Except for the last-mentioned topic, these engineering and health matters affect everyone: all people need water supplies, sanitary disposal of excreta, and a low level of disease vectors. They are community needs. The health aspects of socio-economic development, and especially water developments, arise rather differently, in relation to projects and changes involving a limited number of people. However, all four are mainly tackled on a project basis at present.

To conclude therefore; if the central problem of water supplies be operation and maintenance; if the chief difficulty in overcoming the health problems of water and other engineering developments be behaviour changes in people; if the aim of development be concerned with distribution as well as growth; if the defect of village primary health care projects be that they cannot be widely replicated; and if the same hazard afflicts rural development projects, then an important conclusion emerges. The short-term project is not the unit of sustained progress. Rather it is a long-term institutional and sectoral development and strengthening so as to maintain a better state of water supply, sanitation, and environmental control of disease transmission. To strengthen recurrent as against capital expenditure and to develop effective long-lived local organizations is difficult and must be primarily an indigenous exercise. It is more difficult than building structures but follows from the preceding discussion. How best to undertake it is not clear to me, but I feel sure it is a key issue for the future. No doubt there are many others.

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SOME ECOLOGICAL PROBLEMS CONCERNING ENGINEERING AND TROPICAL DISEASES

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Summary
In the tropics health is controlled by three main factors - prevention of disease, good habitat, adequate and balanced nutrition. Engineering is involved in all three. The organisms which cause water-related diseases include viruses, bacteria, protozoa and worms. Some get into the human in drinking water, others via vectors. Prevention is possible by separation of clean water from waste water or breaking the contact between the vector and human host. Most vectors are very choosy about their environment so relatively slight alteration can often make life intolerable for them. This opens the door to their control by physical, chemical and biological methods, or several of these combined into "integrated control". Chemical control has become dominant and is of great value, but the development of resistance is raising many difficulties; it should be regarded as a temporary expedient rather than permanent prevention.

Ecological problems are illustrated with reference to Schistosomiasis (Bilharziasis), Onchocerciasis (River-blindness), malaria and noxious insects. The effects of major works, such as man-made lakes and irrigation schemes are discussed. The overriding problem is to work with rather than against nature, including human nature.

INTRODUCTION

In the tropics health is secured by three main factors - good habitat including pure water, adequate and balanced nutrition, and the prevention of disease. Engineering is involved in all three and, though we are concerned here primarily with the last, measures taken concerning the other two are often crucial in achieving success.

A few diseases of warm climates result from dietary deficiency or excess, but nearly all are caused by living organisms of which a high proportion are water-related. The organisms include viruses, bacteria, protozoa and worms. Some of these organisms get into the human body in drinking water, but most of them do so via vectors which are blood-sucking insects with aquatic larvae or water snails. Occasionally the vector acts merely as mechanical carrier, but in most cases the vector is an intermediate host, necessary for the disease organism to achieve its life cycle and prepare itself for parasitic existence in the human body.

Some tropical diseases can be controlled by prophylaxis and some are curable by chemotherapy. But such methods, even when fully effective, are very expensive when applied to large populations. Moreover, they mostly need close medical supervision if undesirable side-effects are to be avoided. Prevention rather than cure must be the aim, and prevention is most often possible by breaking the contact between the vector and the human host.

Most vectors are very choosy about their environment. The larvae of each species of mosquito (*Anopheles, Culex, Aedes*) and blackfly (*Simulium*) tolerate only a narrow range of aquatic conditions (temperature, pH, salts in solution, suspended matter, rate of water movement) and the changes which these undergo diurnally and seasonally. Moreover the larvae need the right food available at the right time, and a measure of defence from enemies and competitors. A relatively slight alteration to the environmental factors can make life intolerable for them and this opens the door to their control by physical, chemical or biological methods, or more than one of these combined into "integrated control".

Since the discovery of DDT during the war and later of other more sensitive and specific pesticides, chemical control has become dominant. The ease with which pesticides can be applied, from the handpack to the helicopter, has tended to draw attention away from physical and biological methods, and much engineering skill has contributed to the success of chemical control of vectors. But the genetic development of resistance throughout the range of target organisms is raising many difficulties, and the realisation that the side effects of toxic applications can be extremely damaging to other organisms and to the environment in general, has grown almost world wide since the publication of "Silent Spring" in 1962 (1). It is therefore surprising that in a very recent booklet on the engineering aspects of vector control issued by WHO (2), 38 out of 40 pages are devoted to the application of toxic chemicals, with all other aspects of engineering methods dismissed in the remaining two. This booklet concedes, however, that more attention should be given to other methods.

Some ecologists decry the use of toxic chemicals in almost any circumstances. I am not one of them, for I am sure that toxic chemicals will always have a place in managing the environment. There is a big problem however for the chemist, in cooperation with the biologist, to produce chemicals which are ever more specific in their action, and to deliver them to the target organisms in a manner which is much more discriminating. Meanwhile, taking the long view, experience with the chemical control of tropical diseases, especially those which are vector borne, often shows that treatments will have to continue perhaps forever. By contrast it has been shown in some cases that civil engineering works - the creation of a reservoir or the careful design and construction of an irrigation scheme with appropriate amenities and safeguards for the farmers - can, by a once-for-all action, provide built-in defence against disease. I hasten to add however that this does not imply indiscriminate use of concrete, which can be every bit as damaging to the environment as indiscriminate use of pesticides. For the prevention of most diseases the basic need is the provision of pure water for domestic use and the separation of the people, in work and in play, from waste water; but this is no simple problem as indicated by a number of contributors to a recent book on water, wastes and health (3).

Ensuring the purity of drinking water is no new problem either, as we are reminded by the Royal Society of Arts (4) in an exchange of correspondence 100 years ago between the then Prince of Wales and President of the Society, on the water supply to towns like Manchester, Liverpool and Birmingham, not forgetting the "smaller towns and villages which are dependent on accidental sources of supply, and in many instances these are wholly inadequate for health and comfort". Although the ecological relationship between water and health has been recognised ever since the time of Hypocrates, who pointed to the association of marshes with fevers, it was not until 1855 that cholera became the first disease proved by scientific evidence to be carried directly by water. The first disease to be definitely associated with a water vector was filariasis in 1877.

Many of the problems we have to consider are dependent more on human ecology than plant or animal ecology, as well presented and illustrated in a recent book by White, Bradley and White (5) on the domestic use of water in East Africa. There the infective diseases related to water are divided into four groups:

1. Water-borne: including typhoid, cholera and infective hepatitis.

2. Water-washed (associated with lack of water for personal hygiene): scabies, tracoma, bascilliary dysentery.

3. Water-based (worms of which young stages enter the human body directly): schistosomiasis, guinea-worm.

4. Dependent on water-related insect vectors: yellow fever, malaria,

onchocerciasis, arboviruses, and also sleeping sickness transmitted by those tsetse flies which bite only near water.

In addition to impure water supply, defective sanitation is involved in all four categories. In this connection it is worth noting the substantial economic advantages of recycling excreta, usually as manure. In some countries which have a highly developed fish pond industry, such as Taiwan, even un-processed night-soil is a marketable commodity. It is sold and sometimes stolen from privies, thereby solving one of the more difficult problems of waste disposal!

Some vector-borne diseases will illustrate ecological problems, and how greater use of engineering skills might lead to long term solutions.

SCHISTOSOMIASIS (BILHARZIASIS)

Three related diseases, each caused by a different species of parasitic worm are included here. The adult worms live in human blood vessesl and water snails serve as intermediate hosts. The eggs, voided in human urine or faeces, on reaching water produce first stage microscopic larvae which multiply in particular species of water snail, and after release into the water enter the human host by boring through the skin.

Schistosomiasis is today very widespread; the infection rate sometimes reaches practically 100% and its prevention, control and cure have proved highly intractable. This disease does not kill, except in association with other conditions, but it causes an incalculable amount of debility. It is an ancient disease, identified in mummies of the early dynasties of Egypt, and in the irrigated strip of Egypt by the Nile it has presumably been prevalent ever since. Schistosomiasis appears to have greatly extended its range and frequency during the last half century and as a problem it has increased steadily with the expansion of irrigated lands which provide ecological situations particularly favourable for its transmission. Moreover people have taken to travel and carry the disease with them. There are still countries where the disease is unknown - Guyana is one, Indonesia another - but who can say how long they will remain so? If the administrative and technological skills of mankind have caused this disease to become so important, it is up to mankind, by applying similar skills, to prevent it. This provides great opportunities for engineers working in association with aquatic ecologists and those skilled in medicine and the social sciences.

The literature on schistosomiasis is already very extensive. It has been brought together in long lists prepared by WHO and by K.S. Warren and there is another useful list with a more limited objective shortly to be published by CHEC (Commonwealth Human Ecology Council). These lists reflect the development since discovery of the life cycle of _Schistosoma_ in Egypt during the first world war; they reflect also the difficulties of curative medicine and prophylaxis, the growing understanding of the ecology of those water-snails which provide intermediate hosts, and also the very extensive work on molluscicides. Rather few publications are concerned with the possibilities which now exist for applying all such knowledge, including engineering and the social sciences, to preventing the disease. Each case has special features and the technologies need selection as appropriate to the local ecology and social conditions. One of the recent authors who has developed these lines is A. Coumbaras, a French medical scientist who has conducted many studies for WHO (see papers in (6)). Coumbaras has also prepared a paper (7) which focusses attention on the needs for engineering design. While not neglecting the chemical and biological control of the vectors, and theraputics, he focusses specially on aspects of the human environment which fall mainly within the province of engineers, namely latrines, domestic water supply, washing water, and bathing, coupled of course with the public education which is needed to use such facilities in a sensible way.

Environmental sanitation measures for schistosomiasis control are more varied, and therefore more complex in execution, than measures against the other diseases transmitted via human excreta. Transmission patterns vary between one area and another, and no single measure will suffice for control. Among the many factors are the distribution, density, occupations, and degree of mobility of the human population, the biological characteristics of particular species of snail, and the ecology and climatic features of the region. An important point is that a schistosomiasis control programme which involves strict discipline in water utilization contributes significantly to the control of other diseases as well, including malaria and enteric parasitic diseases and water-borne infections in general.

Personally I am impressed with the great attraction which water exerts on children in all countries and at all social levels, and it is the children who normally get infected with schistosomiasis for life. If a swimming pool were incorporated in the planning of every village in an irrigation scheme there is no doubt that the infection rate of this and other diseases would be much reduced.

ONCHOCERCIASIS (RIVER-BLINDNESS)

This disease is also caused by a parasitic worm. The adults live mainly in the human skin where they tend to form nodules in which pairs of worms are coiled. The female, which is much bigger than the male, produces millions of embryos during a life-span of up to 15 years. These embryos invade the skin where they may be ingested by a biting female blackfly (*Simulium*) (the males do not bite). In the fly the minute embryo passes through three larval stages in muscular tissue and then migrates to the proboscis whence it enters the next human victim when its host fly needs another meal of blood. Like schistosomiasis this disease does not kill, but it causes much disability and when the worms reach the eye blindness results.

Blackfly larvae are aquatic and feed on minute organisms and detritus which pass with the stream. By far the most important vector is *Simulium damnosum* which needs a rapid stream, preferably white water. Its limitation to this habitat provides the opportunity for localised control by insecticides. DDT added to the water above the breeding sites has achieved considerable success, for example in Tanzania and at Jinja in Uganda where *S. damnosum* was extremely abundant at the Nile's origin from Lake Victoria and was a threat to the construction of the Owen Falls Dam and hydroelectric installation. DDT kills so many other organisms however, that it upsets the ecological balance, so some other insecticide, less generally toxic and less persistent, was needed.

The area where onchocerciasis is most prevalent, reaching nearly 100% infection in some riverine populations, with up to 5% of almost total blindness, is in West Africa, in the extensive savanah areas, well watered with streams and with fairly dense human population. Seven countries - Dahomey, Ghana, Ivory Coast, Mali, Niger, Togo and Upper Volta - clubbed together under the guidance of the World Health Organisation to bring the disease under control. A preparatory mission worked in the area from 1971-73 and produced an overall plan of operations (8). It entailed treating every breeding site of *S. damnosum* in the entire project area with insecticide applied from the air, mainly by helicopters, and repetition of the treatments until the fly was eradicated. The operations, which started in 1975, were designed to continue for 20 years, that being the time estimated for the disease to die out in the human host. Meantime the people, who had been driven from the river valleys by the disease to the relatively poor soils of the adjacent uplands, were expected to resettle in the valleys. Much work was undertaken in the selection of an appropriate insecticide specific to *Simulium* larvae; Abate was chosen and so far has proved highly effective. The total cost of the whole project was estimated at around 200 million dollars which it was hoped would be subscribed by a number of donor countries.

Under WHO as the Executive Agency, elaborate steps were taken, not only for the operations themselves, but for monitoring their results in relation to the effects on the flies, on the incidence of the disease in the human populations, and on the ecology of the rivers. In addition to the executive side, three advisory bodies were established, one on scientific aspects of the disease and its vector, one on economic development of the areas freed of disease, and a small ecological panel as a kind of watchdog.

The original concept of this great scheme was complete eradication once and for all of the fly and so of the disease from the whole project area. But to ecologists with experience of vector control this objective could not be a serious one since there were many areas, including whole countries adjacent to the project area, where things were left to themselves, and from which reinvasion by blackflies was inevitable. Indeed this has already occurred and reinvasions have taken place on stretches of river from which eradication had been completed. The project has its critics, for it looks as though the extremely expensive operation of aerial spraying, probably with new insecticides as the fly develops an immunity to Abate, will have to go on, perhaps for ever.

My purpose in recounting this story is to express the view, in which I am not alone, that the very extensive use of aquatic insecticide on which the project is based should be regarded as a short-term measure to bring the disease under some form of control. It should soon be replaced by more permanent measures based on ecological knowledge of the vector, hydrological knowledge of the rivers, the skills of engineering and of irrigated agriculture, and social understanding of the needs and desires of the people who will repopulate the vacated areas. The key to this concept may be the disappearance of blackfly and of river-blindness from areas where waters are impounded, coupled with the future needs of the resettlers for stream control and small impoundments in the interests of their future agriculture and fisheries. As a result of impoundments the flies' breeding sites, which are at present strung along many hundreds of miles of streams in inaccessible country, where rapids occur at frequent intervals, would be limited to relatively few at weirs, which are easy to treat with insecticide from the ground. In irrigation canals with rapid flow the flies' breeding could be prevented by shutting off the water periodically.

The hydrology of these many streams is reasonably well known, but they have not been studied thoroughly in order to identify possible sites for small impoundments to command riverine areas of good soil and at the same time to obliterate the maximum number of blackfly breeding sites. Such an engineering survey has been strongly advocated in the Ecological Panel of the project. Its cost, and even some of the construction to follow, would be small compared with keeping a fleet of helicopters and fixed-wing aircraft in constant use for toxic spraying. The infrastructure for future rural prosperity could be established at the same time as eradicating the disease and reducing the environmental risks of toxic chemicals. It has been argued that impoundments, while eradicating blackfly will encourage snails, so that the result would be merely a swap of oncho. for schisto. ; but this is a philosophy of despair!

MALARIA

Professor S. Cohen, in a review lecture on immunity to malaria to the Royal Society on 20th April 1978, pointed out that malaria in its many forms remains a major cause of mortality and morbidity throughout a very large part of the tropics and subtropics, that eradication measures based upon vector control and prophylactic therapy have proved inadequate, and that in many parts of the developing world the incidence of malaria is increasing.

In a sense this was perhaps inevitable owing to the rapid increase of population which provides many new potential sufferers every year. The achievements of science and technology in the fight against malaria have been outstanding, and statistics in no way belittle them. However, it was not insecticides or chemotherapy which eradicated malaria from the fenlands and the Pontine marshes, but drainage and land development for agriculture. As a conservationist I would not wish to see all swamps and marshes eliminated, for evolution has created in them some of the most interesting and beautiful ecosystems and organisms. But time will surely show that, in the final analysis, the engineer will have played a part equal to that of the doctor in the eradication of malaria, as well as of other tropical diseases.

NOXIOUS INSECTS

Anyone accustomed to the tropics will be familiar with blood-sucking insects which, while not necessarily transmitting disease, have a considerable effect on health, especially to people who suffer from alergies. The ecological requirements of many of these troublesome insects include water, or at least wet conditions, and their control offers interesting and sometimes intractable problems to the design engineer and architect. Such problems are pressing owing to the economic value of tourism and desire of many tourists to visit remote or wild places, but at the same time to live in comfort and safety.

Among such noxious insects are sandflies (especially Culicoides furens) which are pernicious in many coastal areas and other places where water, salt or fresh, grades into damp sandy soil, for it is in such conditions that the larvae of sandflies flourish in immense hordes. The female adults, so small that they can penetrate most forms of mosquito netting, have an irritating bite and in some places transmit a short-term fever. A reliable method of control is to separate land from water by moving earth and building walls, and this may be necessary in the immediate neighbourhood of hotels and other frequented buildings. But sandflies can travel several miles. To separate water from land on an extensive scale would alter the ecology drastically and often it is that ecology which is one of the tourist attractions. The wholesale destruction of sandflies with toxic chemicals likewise has devastating environmental effects where it has been tried. In the present state of knowledge it seems that the best way of reducing sandfly trouble to tolerable limits is by periodic emissions of insecticidal smoke, but this is really a confession of ignorance. I give this example as one of many cases where a well integrated method of control is needed, involving engineer, biologist and chemist.

MAN-MADE LAKES

Large engineering works, though localised in the area of construction, can have drastic effects on the ecology and hence on the pattern of diseases of vast areas. Outstanding examples are the great man-made lakes of which the implications for health and disease have been well documented recently, (see references (9) (10) (11)). Some lessons to be learned from their experience may be reviewed.

In constructing and managing major works of water control the Tennessee Valley Authority was among the first to consider fully the interests and health of the local populations. The Tennessee Valley was formerly well known for its prevalance of malaria, and the early dams of 1912 and 1927 altered the ecology to make it even more favourable for Anopheles and in consequence their construction was followed by violent epidemics of the disease. Engineers and biologists solved the problem by fluctuating the water levels and clearing marginal vegetation, thereby making the habitat intolerable for the mosquitoes.

The great man-made lakes of Africa present many similar problems as yet unsolved. The Volta Lake of Ghana, largest of them all, provides an outstanding example of change in the pattern of disease. Before impoundment the Volta river and its tributaries had many rapids providing favourable habitat for blackfly but not for snails: river-blindness was rife but schisto. was rare. After impoundment river-blindness disappeared from the area of the lake, although it continues in the unimpounded tributaries and at the spill-way and rapids of the lower Volta below the dam. Meantime, as the great lake filled, the high water productivity, consequent on drowning soil and vegetation, resulted in two ecological phenomena: one was an explosive growth of water weeds which provided excellent habitat for Bulinus, the main vector of schisto.. The other was an enormous increase in the numbers and availability of fish which induced most of the people to live in temporary villages around the shores in preference to the neat and hygienic resettlement villages pre-constructed well away from the water's edge. The conditions for schisto-transmission were perfect and infection rates mounted.

Lake Kainji in Nigeria is quite a different case in that the River Niger, being far larger than the Volta and subject to greater seasonal variations in flow, replaces the reservoir water annually and the reservoir level is subject to considerable draw-down. This makes for unfavourable snail habitat, so schisto. is not a major problem while, as in the case of Lake Volta, river-blindness has disappeared from the lake area except in the uncontrolled tributary streams. At the dam site the blackfly has been controlled with insecticide.

In the case of Lake Nasser in Egypt the health problems created by the high dam have been subject to much publicity and speculation. Certainly the large increase in the irrigated area of Egypt which was the primary purpose of the high dam has caused its problems. There have been epidemics of malaria and of schistosomiasis, especially among the resettled Nubians, who, living formerly in desert country, had not normally been exposed to these diseases. Certainly also there have been mistakes, and insufficient precautions taken against water-related disease in the new settlements.

However, it is wrong to think, as was widely publicised, that the many environmental effects of the high dam came as a surprise and to describe the high dam as an ecological disaster. With few exceptions the effects were predicted in advance and taken into account in reaching the decision to proceed with the project. Time, expertise and finance were insufficient to conduct all the pre-project study that was desirable; but that great authority on the Nile, H.E. Hurst, became satisfied that the high dam was right; and Egypt could hardly afford to look a gift horse in the mouth.

CONCLUSION

In this paper I have tried to focus attention on the delicate ecological balances which are concerned in the prevalance and prevention of some water-related diseases, and how engineering works, on a small scale as well as large scale, can tip that balance in a favourable and sometimes unfavourable direction.

All these problems of health and disease indicate the need for the integrated multidisciplinary approach, especially in the planning stage of projects. To achieve this proposals are made from time to time for establishing international institutes covering all the disciplines. Such was advocated for example in the case of man-made lakes, to help not only the relatively few very large projects but also the millions of small impoundment projects right down to the farm dam size.

Personally I am unconvinced that the centralised institute is the right approach, for problems are so diverse, whether of water, field, forest or town - physical, plant, animal or human - that workers on the project, rather than in an institute far away, should be best placed to find the solutions. As viewed from an ecological standpoint the overriding problem is to work in partnership with nature (including human nature) rather than against it. That can be achieved only with a knowledge of nature on the spot.

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DOMESTIC WATER SUPPLY IN THE THIRD WORLD

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how to integrate water supply & sanitation into development projects

The conventional and easy manner in which to outline the situation with respect to domestic water supply and disease in the Third World is to summarize and extend the statistics that are available on the proportion of population which is served by supplies with various reported degrees of adequacy from the standpoint of health. National estimates as to rural and urban populations served with what are regarded as "reasonable access to safe water" or "potable water supply" form the foundation of the statistics prepared by the World Health Organization. Such data customarily support the arguments for measures to improve the current state of affairs.

One will find them central to the arguments that were presented to the U.N. Conference on Human Settlements in 1976, and to the U.N. Water Conference in 1977, as well as in the mid-decade progress report prepared by the World Health Organization (Ref. 1) and in the papers reviewed by the Ad Hoc Working Group on Rural Potable Water Supply and Sanitation. Like most others interested in the field, I have in past used these statistics, with various extrapolations and modifications, to outline the prevailing situation (Ref. 2).

The more I do so and the more I look into the Third World's experience in coping with questions of water management as related to health the more I am convinced that primary reliance on this practice is misleading and that it may divert attention from what are more salient issues relating to the present situation. My reasons are two-fold. First, the statistics as now prepared and presented fail to provide an accurate picture of the actual situation in many places. Second, the statistics, even when accurate, would not tell us what we most need to know about the state of water supply in terms of the prospect for improvement in health and well being.

Before assessing the deficiencies in the current statistics and suggesting possible additional measures, it may help to review what the available national estimates show to be the situation in developing countries and how this relates to goals set at United Nations conferences.

ESTIMATES OF POPULATION WITH ACCESS TO SAFE WATER

The surveys made by the World Health Organization for a selection of 91 developing countries in 1970, updated for less countries in 1975, provide the only sets of data as to the proportion of population having reasonable access to safe water supply. Details are available in those publications (Refs. 1 and 3). The overall picture for 1975 may be summarized as shown in Table 1.

TABLE 1. Estimated percent of population having reasonable access to safe and adequate water - 1975.

Region	Rural	Urban
Americas	32	81
Eastern Mediterranean	16	80
Europe	63	81
South East Asia	19	70
Western Pacific	30	90

The overall estimate, excluding the Peoples Republic of China and a few other countries, suggests that about 12 percent of the rural population had "adequate" supplies in 1970, and the level had reached 20 percent five years later.

TARGETS AND MODES OF REACHING THEM

The Second U.N. Development Decade had set modest targets for improvement in community water supply, involving a doubling of the proportion served with adequate water. A more ambitious goal was recommended by the U.N. Conference on Human Settlements in 1976. It proposed that "safe water supply and hygienic waste disposal should receive priority with a view to achieving measurable qualitative and quantitative targets serving all the population by a certain date," and went on to urge countries to "adopt programmes with realistic standards for quality and quantity to provide water for urban and rural areas by 1990, if possible."

The U.N. Water Conference a year later reaffirmed the 1976 Habitat commitment, and recommended (Ref. 4):

(c) That with a view to achieving these ends, the nations which need to develop their systems for providing drinking water and sanitation should prepare for 1980 programmes and plans to provide coverage for populations and to expand and maintain existing systems; institutional development and human resources utilization; and identification of the resources which are found to be necessary;

(d) That the United Nations agencies should co-ordinate their work efforts to help Member States, when they so request, in the work of preparation referred to in subparagraph (c) above;

(e) That in 1980 the national programmes which have been implemented for that purpose, and the extent to which the countries concerned have succeeded in mobilizing local and national support should be reviewed by an appropriate mechanism to be determined by the Economic and Social Council and based on the use of existing machinery, with a view to attaining co-ordinated action toward agreed targets;

It then went on to outline a "Plan of Action" involving as priority areas: 1) cultivating awareness and public commitment, 2) remedying manpower shortage, institutional inadequacies, and lack of appropriate technology, 3) new approaches to generating financial support and speeding up the improvement work, and 4) providing community education, motivation and involvement in such improvements. The opportunities and problems in achieving these goals were reviewed succinctly by Burton on the eve of the Water Conference (Ref. 5), and then summed up by Stein at its conclusion (Ref. 6). Based upon the generally encouraging advances reported by WHO for the period 1970-75, the higher goals of Habitat were seen as more nearly attainable. The level of expenditure from national and international sources was believed to require major expansion. At the same time, the rhetoric of the Habitat and Water conference resolutions introduced perspectives that had not been prominent in discussions of domestic water needs during the 1960's. They placed much heavier reliance than had the preceding plans upon community participation, citizen involvement, simple technology appropriate to local conditions, village technicians, identifying segments of the population in greatest need, and institutional changes. They also recognized a need for closer collaboration and new approaches among international agencies and for viewing water supply and waste disposal as part of integrated development efforts in which public health is an important but not the sole objective.

Against this background, there is no doubt that the heightened sensitivity of the world community to the lack by great masses of people of safe water supply has been a prime force in the new stirrings. There also is recognition that reaching the ultimate goal of safe water for all is far more complex a matter than efficient engineering design and public investment levels. Accordingly, the indices of action need re-examination.

DEFICIENCIES IN STATISTICS ON DOMESTIC WATER SUPPLY

What is wrong with the statistics? At least three major deficiencies commonly are noted. One, the mode of compilation is to draw upon national reports prepared by national health or water supply organizations which often are not in touch with prevailing conditions at the local level. Second, although the reports may be accurate in terms of what the local people report, those reports may be misleading; they may indicate a water system is operating whereas it is out of repair or not operating at all. Third, the organizations commonly rely upon networks of reporters associated with their own programs so that if a community has made an improvement that is not a part of the national program it will go unreported, and so that if a rural group has managed through individual action to make certain improvements in the quality of its water supply they are not counted.

A fourth and underlying difficulty with present statistical practice is that it ignores significant factors influencing the degree to which the local community is concerned about and is active in improving and maintaining the quality of its supply. Essentially, if the community has genuine concern for its health and if it presses for action, there is likely soon or later to be some positive response. If it is apathetic about the situation or incompetent in organizing as a group to meet perceived needs the effectiveness of formal engineering or public health activity by national agencies is likely to be low.

In addition to whatever description of the prevailing situation may be gained from the reported statistics, it would be important to know what forces are making for change in the direction of either improvement or deterioration. Extrapolation of past trends in proportion of population having access to safe water may ignore these. Let us take two examples. If one had examined the domestic water supply situation in Egypt in the middle 1950's in relation to trends in improvement, one would have reached the conclusion that the prospects for major provision of potable water supply for the large rural population of the delta and valley of the Nile were dim indeed. There had been slow progress in providing piped supplies to the great population occupying the large rural villages throughout the delta. Then in the middle fifties as a part of the Nasser revolution came a massive program for provision of community supplies. In a matter of half a dozen years Egypt became one of the outstanding countries in the Third World in terms of proportion of rural population served by such facilities.

Reviewing the situation in Latin America in the late 1960's one might have been tempted to extrapolate past trends and to predict that there would be large and continued progress in provision of potable supplies in many Latin American countries on the basis of the performance in the 1950's and early 60's. These expectations were not realized. The reasons have begun to become clear: the more readily manageable types of improvements were completed, limits on capital investment from central sources were reached, and provisions for community management of completed supplies turned out to be relatively weak. In this case, as in the case of Egypt, one would have liked to know the answer to a basic question in assessing the present situation. What were the forces for community action linked with competent engineering and public health advice that were operating and promised to continue? Related to this are questions as to the political climate which promoted major changes in expenditure allocations, the administrative arrangements for community response and participation, and the consequences for design and maintenance.

ALTERNATIVE WAYS OF TAKING STOCK

To do this would require some alteration in the method of taking stock of water supply in developing countries. Ideally, one would like to know the rate of change in the degree of community involvement in water supply improvement, the extent to which national groups encourage and support such community involvement, and the extent to which there is continued monitoring. It would be helpful to record any variables bearing on public support for such activities which would avoid disillusionment and build a solid base for operation and maintenance. X

This is a statement of ideal attributes, and one recognizes at once that they are not readily specified within most nations in the Third World. What then would be a practical method of taking stock which reveals additional significant characteristics of the national situation and that may be compiled without setting up a new and elaborate data collection system? The answer to this question deserves careful appraisal by people who are familiar with water supply and the statistical reporting situation in the Third World. It may help to stimulate such critical review by suggesting a few supplemental measures which seem deserving of consideration. Four of them have to do with the nature of population served, and two have to do with the government stance with regard to improvements in domestic water supply. On the population side the four parameters that may merit further attention are:

1) spatial configurations of the population,
2) the proportion of population in urban squatter settlements involved in self-help projects,
3) the character of water supply in urban slums in relation to provision for water-borne waste, and
4) the proportion of rural population involved in some organized form of self-help community development.

On the government side it would be desirable to explore:

5) the extent to which there is involvement of users in choice of water supply service level, technology, and management policy,
6) the investment which the national government is prepared to make for improvements in water supply on a per capita basis.

Measuring each of these involves some plain and some more subtle difficulties, but they are sufficiently within the range of possible application to warrant asking a bit more as to what they might reveal and whether in practice they could be computed. To delineate such measures is to suggest, in effect, what seem to be the major issues related to the improvement of domestic water supply for health purposes and well being in developing countries.

In presenting them for discussion I am aware that some of them go counter to much of the conventional wisdom, and to the sanctified practice of inter-governmental and national agencies. They probe dimensions of water supply decisions that have not figured large in the WHO surveys. Their emphasis is more nearly in harmony with the initial approach taken by the Ad Hoc Working Group on Rural Potable Water Supply and Sanitation.

That venture took shape in 1974 and during the past year ground to a disappointing halt in bureaucratic discussions and negotiations. My curbstone observation is that it began in a fine burst of enthusiasm for stepping up provision of water supplies but that it frittered out in discussion of information and coordination programs at the very time that high-sounding appeals were being made at the Habitat and Water conferences for reaching goals of complete supply by short target dates. The failure seems to have rested in part on the definition of the problem and thereby in the limitation of the types of solutions which were explored and later undertaken, and in part on the resistance of major inter-governmental agencies to proposals calling for joint action of all agencies concerned with technical cooperation in developing countries. Its task force report (Ref. 7) which was rejected in early 1978 called for coordinated operations at the country level. From a statistical standpoint it tended to emphasize gains in reported water service rather than strengthening the community process by which gains are made.

Spatial configurations

The ordinary classification of population by "rural" and "urban" covers up differences which deserve to be highlighted in considering programs for domestic water supply and sanitation. It is well known that definition of urban and rural vary from nation to nation that they are based upon the total size of settlement, and that these differences are sufficiently great so that it becomes extremely difficult to compare aggregate figures from one country to another. In the circumstances, it would be more meaningful to ask national authorities concerned with water supply and health to estimate populations in each of five separate classes, doing so by regions or province if convenient, but if this is not convenient, attempting rough estimates for the nation as a whole. The five suggested classes are:

1) population living in peripheral squatter settlements--shanty towns, barrios, bidonvilles, etc.,
2) population living in slum situations with high density and low quality of housing facilities in the organized sector of the city,
3) populations served with ordinary multiple taps,
4) other populations living in nuclear settlements with and without central piped supply, and
5) populations living in dispersed patterns of settlement.

These classes are suggested because they group populations according to common configurations with similar problems of technique and cost in the provision of water supply. The distinctions among squatter, city slum (whether served with single taps, patio taps or standpipes) and multiple tap service are basic to delimiting the type of improvements that may be desirable. The distinction between squatter settlements and nuclear settlements, regardless of size, is highly significant in planning for change. In many instances interrupted service is typical of urban slums. In many countries the rural population is found wholly in nuclear settlements or, as in parts of East Africa, largely in dispersed patterns with a few small settlements of rural character. In many areas the notion of "rurban" may turn out to be appropriate.

Squatter settlements and self help

Probably the most acute problem of domestic water supply in the Third World from the standpoint of public health is that of the squatter settlement. These are the areas where the most rapid urban growth is taking place, where municipal organization and public services are least adequate, and where conventional means of excreta disposal generally are lacking. Even though the municipal and national authorities in a number of countries have departed from their colonial heritage of either suppressing or denying the existence of the shanty town excresence, governments have been slow to deal with sanitary problems in such areas and have lacked in many instances suitable administrative, financial, and technical instruments for dealing with them. Squatter populations have shown considerable ingenuity in obtaining water but often at serious hazard to health. They typically are inventive and industrious in using meager resources, and a primary challenge is to find ways of enabling them to help themselves. Perhaps the most innovative set of approaches to the problem have been in the "sites and services" program of the World Bank, a series of experiments which have revealed some hard lessons but which also have stimulated practical thinking about better ways of contending with the shanty town phenomenon.

Urban slums and water-borne waste

Not restricted to squatter settlements and a major problem in the growing slums of urban areas is the question of how domestic water supply facilities are reconciled with the heavy constraints of cost and organization that are imposed by providing for water-borne excreta disposal. This problem which now has been confronted in a candid and imaginative fashion by the World Bank (Ref. 8), rests essentially upon recognition that the cost of water-borne excreta disposal, generally running three times that of domestic water supply, are so heavy that it is quite impracticable for many urban areas to think of any solution within the foreseeable future which requires building sewers and waste treatment plants to handle excreta. The alternatives include a wide variety of methods such as vault collection, aqua privies, and daily bucket collection. These alternatives to water-borne waste have received extraordinarily little attention both from researchers and from the designers of new municipal systems. We are now witnessing a sober reappraisal of the fiscal practicability of trying to fit out every city in a developing country after the manner of Amsterdam or Chicago. This is described in the paper by Kalbermatten.

What one would like to know in this instance is the extent to which alternatives to water-borne excreta disposal are being planned in urban slum areas. In many cities and national ministries statistics on the planning of alternatives might be regarded as confessions of failure or of ignorance, but I suspect that over the next few decades they will be measures of the extent to which genuinely practicable solutions will be found for urban waste disposal problems. Those solutions will influence the magnitude of water use which new supplies will be designed to serve.

Rural population involved in community development

In rural areas the conditions governing the rates of improvements are partly those of the physical environment--humid, tropical and arid regions present quite different challenges to technology and organization--and to the mode of assistance provided by regional and national government. A few tentative generalizations may be offered as to the extent to which sectors of the rural population will receive potable water supply within the physical constraints of their environment.

a) Where the population is aware of and sensitive to the effects of unsuitable water supply upon public health it is widely inclined to take appropriate action insofar as it has any facilities for community organization.

b) The more involved a community is in some form of rural development and learns to use the assistance of technicians and community facilitators the more likely it is to improve its water supply and sanitary facilities.

c) To the extent that a community develops habits of contributing to improvements for the common good it is more likely to contribute to water supply improvement than otherwise.

Taking these as working hypotheses subject to testing, an important measure of the extent to which the rural sector of the national population is moving toward or has the capacity to move toward improved water supply is the extent to which it is involved in some kind of cooperative community development. This is more significant for those populations that are in nucleated settlements than those that are dispersed. In the latter, the question of participation of the population in programs of information and education may be crucial.

Government involvement of users in development programs

There is a good deal of reason to think that the degree to which a government pursues the practice of involving users in the planning and execution of improvement programs influences the capacity of the communities to themselves act and to bring about changes that would lead to improved public health. One can think of a spectrum of government policy ranging between the position that the central or provincial government will decide which communities need improved supplies, build those supplies, and operate them to the other extreme of communities which initiate their own improvements and draw, at best, from the central or provincial government only bits of technical advice or exotic materials. All governments have some policy in this regard and it is possible to rate that policy along a three-part scale. If *the national program is low in user involvement it's capacity to act becomes a function of* heavy inputs of capital, supervision, and labor from the center. If it is high, the likelihood of local contributions of capital and labor to construction, and maintenance of community improvements is enhanced.

Government investments per capita in improvements

At any given time it is practicable to make a rough estimate of the per capita investment by the national government in water supply and sanitary improvements in cities and in rural areas. It is also possible with less accuracy to divide these allocations among the subclassifications of construction, technical assistance, and public information and education. From such a statement one can judge the extent to which government investment meets what might be considered minimal conditions for support of water supply improvements. Here, the crucial consideration is the way in which expenditure is allocated. If the investment is heavy but is concentrated in situations in which the government acts largely independent of the users one can expect that the per capita benefits for the user group as a whole will be small. If the percentage of funds used for purposes of community information programs, promotional efforts, and technical assistance for works instigated by the local populations, as in either "sites and services" or in rural developments and plans, is high, one may expect a relatively large return for the money invested.

Opportunities and difficulties

If we were to have this kind of series of measures we would be better able to indicate the prospects for domestic water supply improvement. Let us take the six measures and apply them to two hypothetical nations. The description of country conditions is drawn from experience in developing countries but is not presented as the actual condition. (Table 2).

TABLE 2. Hypothetical application of six suggested measures of community water supply

Suggested Measures	Country A	Country B
Percent of population living in:		
Squatter settlements	5	5
Urban slums	15	10
Multiple-tap urban water service	20	10
Other nuclear settlement with central supply	60	5
Dispersed settlement	0	70
Percent of squatter settlement population in self-help programs	0	35
Percent of urban slums and squatter settlements with studies of alternative excreta disposal	0	25
Percent rural population involved in organized community development	80	40
Degree to which government involves users in planning new improvements--High, medium, low, not at all	Low	High
Annual governmental expenditure in $ per capita in:		
Water supply improvements	3	4
Waste disposal improvements	2	1
Percent in information, promotion and technical assistance	Low	Medium

Country A has major problems of mobilizing user participation in nucleated settlements and in urban slums. It promotes rural development but handles water supply separately. To the extent it can invest in supply facilities for the village dweller, it is able to provide generally adequate quality of water through standpipes but maintenance is difficult. In the city it is severely handicapped by lack of community involvement and of any examination of the alternatives to water-borne waste disposal for the mounting population receiving multiple-tap service.

Country B faces problems of assisting squatter and urban slum residents, and of reaching its large dispersed population in agricultural areas. It has begun to instigate self-help among the squatters and to study possible alternatives for disposing of urban excreta. Although it involves users in planning new improvements its allocation of funds for information, promotion, and technical assistance is still modest by comparison to construction outlays, it has many communities not involved in organized rural development, and it has trouble assuring maintenance of completed works.

Admittedly it may be difficult to convince experts that this set of measures would be worth calculating for a given nation. Unless estimated by people in technical positions who believe the figures might have any meaning for their future activities, it probably would not be helpful. In some instances there would, of course, be strong resistance to such calculations because they might reveal weaknesses in the current policies of planning and administration. At the same time, these additional measures, unlike those which purport to give numbers of population provided with various qualities of water service, may be rather readily estimated by persons who do not have primary responsibility for government operations.

In terms of accuracy they probably would be no less wanting than the aggregate estimates that now come from developing countries.

It might be salutory for experts who are working with the current intergovernmental and consulting organizations to attempt rough estimates for a number of the countries with which they are familiar. The basic aim would be to identify the current ability of the nation to advance water supply improvement in the interest of public health and welfare.

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RURAL WATER DEVELOPMENT IN ARID REGIONS

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Abstract
The general characteristics of arid regions are described with the particular water requirements of their pastoral communities. Limited sources of water are available to these communities, and this calls for special measures for developing and using these sources.

INTRODUCTION

Arid regions

More than 600 million people or 14% of the world's population live in arid regions which cover some 30% of the earth's land surface. Arid regions may be defined as areas where the climate is too dry (or arid) to permit the successful growth of crops. Climatologists distinguish three levels of aridity: semi-arid, arid and desert. In semi-arid areas, with an annual rainfall in the 400 to 600 mm range, crops are sometimes grown, but at considerable risk of failure. Desert conditions are usually defined as those where twelve consecutive months without rainfall are normal.

The arid regions lie mainly within sub-tropical latitudes in the Middle and Near East and in the northern and eastern parts of Africa. There are also arid zones in the southern and western parts of the United States, and parts of South America, southern Africa, central USSR, northern China and Australia.

The characteristic features of arid regions are generally parched conditions, sparse vegetation comprising mainly drought resistant species, barren land, soil erosion and very limited water resources. Human activity in these regions is adjusted to the harsh conditions, and although cultivation is practised sporadically, livelihood tends to be dependent on livestock, and this in turn has led to the nomadic way of life.

Where major rivers flow through arid lands, such as the Nile in Egypt, the Indus in Pakistan, and the Ganges in northern India, water has been used for irrigation, and settled arable farming is practised.

Pastoral communities

In recent years the drought disasters throughout the "sahel" belt of Africa, in Ethiopia, and in other arid zones have drawn attention to the problems of pastoral communities. The U.N. conference on Desertification at Nairobi in August/September 1977 focussed on a particular aspect of this problem. In most developing countries the pastoral communities are the last to benefit from technological and institutional development. Because they are widely dispersed over large areas of land, often remote from major centres and modern communication routes, and because they are frequently on the move with their livestock, they do not fit into the normal framework of government administration and services. It has therefore been difficult to reach these people with education, medical care, water supplies and other services. These difficulties are sometimes aggravated by the vigorous independence of the people themselves.

WATER RESOURCES

Water requirements

In most rural situations the distinctions often made by professional people between water for domestic use, water for livestock and water for irrigation do not exist. For pastoral communities, water is a scarce resource needed for and used by human beings and animals alike. Quantitatively, animal needs are the greater. Taking as an example a typical family unit in the

Ogaden region of Ethiopia, average daily requirements might be (1,2):-

Family unit	Litres per head per day	Litres per day	%
6 people	20	120	30
12 cattle, mules, donkeys	15	180)	
4 camels	15	60}	70
26 goats and sheep	1	26)	
		386	100

The animals, in fact would not be watered every day. In upland and well-watered areas cattle, mules and donkeys may be watered daily, and, drinking their fill at each watering, will consume more water than their counterparts in the arid lowlands. In the arid areas cattle, mules and donkeys may be watered every 3 or 4 days, goats and sheep every 7 or 8 days and camels at even longer intervals.

In areas such as the Ogaden, where up to 70% of the population are pastoralists, an agency which declares (as the writer once heard from one of its officials) that its objectives are to supply water to people and not to animals, has not fully understood the interdependence of human beings and their livestock. A water-supply point must clearly be designed to meet the community needs as they exist.

Sources of water

Where there are permanent rivers they provide permanent but often highly polluted sources of surface water. Surface run-off accumulated in depressions to form temporary lakes or lagoons provide temporary sources which are popular because they are usually associated with good grazing. They may also be highly polluted. The most common permanent source of water in arid regions is groundwater. Shallow groundwater is drawn from water-holes in the sandy beds of water courses. Deeper groundwater is tapped by traditional hand-dug wells, or with modern machinery, by boreholes. Springs are much-coveted natural sources of groundwater with little or no risk of pollution except where the spring feeds an unprotected pool.

Groundwater may not always be drinkable because of salinity, and there are many instances of saline springs in north and east Africa and in the Middle East. The usually accepted upper limit for dissolved salts in drinking water is 1,500 mg/l, although there are people (such as the fishing communities on the Makran coast in Pakistan) who, by virtue of necessity, are drinking water with up to 4,000 mg/l of dissolved salts(3).

WATER DEVELOPMENT

Surface water

One hundred millimetres of rain falling on one hectare amounts to 1000 cu. metres of water. If all this water could be recovered it could supply 40 people and their animals (on the basis of the typical family unit described above)for a year. If this water forms part of the run-off of a river system in an arid region, 95 to 100% of the water will be lost on its way. Under arid conditions, the advantages of collecting rainfall at or near to the land-surface on which it falls will be self-evident.

In practice it is impossible to collect 100% run-off. Even roof or paved catchment systems lose some precipitation by direct evaporation and other losses, and about 80% can be collected. On small land catchments of less than 100 hectares, a feasible yield of 15 to 20% is a ten-fold improvement on the yield of a natural drainage system. With a 15% run-off coefficient, 100 mm of rain on 10 ha would yield 1,500 m^3. If half of this were lost in storage by evaporation and seepage, the useful storage of 750 m^3 would supply 30 people and their animals for a year. The collection and storage of rainwater from small catchment units is, thus, a practical solution to water problems in arid regions with as little as 100 mm. of rain in a short wet season. It has, in fact, been practised in some parts of the world for a long time. Two and a half thousand years ago it was being done in the Middle East; and the "hafirs" of the Sudan and the "birket" of Somalia are present-day examples of the same system.

Storage

Evaporation from open water surfaces may be as much as 8 to 10 mm a day under arid conditions, and in 10 months a reservoir may therefore lose 2½ metres of water. Under such conditions a storage less than 2½ metres deep will lose all its water by evaporation only. A roof cover to a storage greatly reduces evaporation by keeping the water surface in the shade and by sheltering it from the wind.

In addition to air losses, a reservoir in natural ground will lose water through percolation and seepage. These ground losses will be reduced by lining. If a suitable clay is available, this will be the cheapest lining. Otherwise masonry and cement plaster, concrete or synthetic membranes may be used. Low-cost linings of thin polythene interlaid with mud have been used successfully on a small scale in the Sudan, southern Africa, Jamaica and Brazil.

Special care is needed to protect storage systems from pollution. In the Sudan the "hafirs" are fenced which prevents direct access to the water, which is drawn from a watering point outside the fence.

Groundwater

In many arid regions inhabited by pastoral communities the only available source of water may be groundwater. Traditionally groundwater is used where it emerges, as springs, or where it is easily accessible by relatively shallow hand-dug wells. Traditional systems have usually achieved some measure of balance between demand and supply (or recharge). The introduction of modern mechanical drilling technology, enabling much more water to be drawn from an aquifer, often produces immediate benefit, but it may, in the long term, create more problems than it solves. The rational development of groundwater requires careful water balance and recharge investigations, and regulation to prevent an aquifer being overdrawn. A deep borehole with a powerful pump may cause other groundwater sources to run dry.

Probably the most prevalent defect of borehole supplies in remote rural situations is their tendency to be out of working order. Of 17 boreholes drilled at Jijiga, in the Ogaden, Ethiopia, only two were working and supplying water in November 1974(4). The dependence upon a mechanically-pumped borehole can sometimes lead to very serious consequences when the machinery breaks down and there is no alternative source of water. While the exploitation of deep groundwater by hand is clearly impractical, there is considerable scope for the hand-excavation of shallow wells, which can then be equipped with hand or wind-pumps and which, because of their greater diameter, can be provided with man-holes for rope and bucket extraction when the machinery breaks down.

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EVALUATION OF RURAL WATER SUPPLIES IN EASTERN AND SOUTHERN AFRICA

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Abstract
A description is given of an evaluation methodology which considers how the criteria water quality, technology, operation and maintenance, costs and utilization are experienced by the categories consumers, pump attendants and water authorities. This is followed by a report on the findings from evaluations of SIDA supported rural water supply programmes in eastern and southern Africa. The findings suggest that donor agencies cannot limit their support to the development of new schemes since the developing countries have difficulty in raising sufficient funds and finding trained manpower for operation and maintenance. The feasibility of charging for water from communal water points is also questioned.

INTRODUCTION

SIDA's support to rural water supplies

Since the mid-sixties SIDA has supported the development of water supplies in 14 countries with grants, loans and technical assistance. The total financial aid, which amounts to Skr 1,093 million, is distributed as shown in Table 1.

TABLE 1. SIDA's bilateral support to the water sector distributed per country

Country	Skr million	Country	Skr million
Bangladesh	30	Somalia	10
Botswana	65	Sudan	50
Brazil	26	Tanzania	483
Ethiopia	24	Tunisia	152
India	10	Turkey	15
Kenya	192	Zambia	2
Lesotho	13	Special programme	
Pakistan	9	and research	12

In addition to the above bilateral support SIDA is also contributing to the water sector through the UN organization and through regional development banks. In Table 2 the bilateral support is broken down into various categories within the water sector.

TABLE 2. SIDA's bilateral support to the water sector distributed per category within the water sector

Category	Skr million
Precipitation, evaporation, run-off, erosion	28
Water use (irrigation, forests, water supply)	589
Hydropower	208
Planning, operation, programming, costs	82
Effects (social, medical, ecological, environmental)	42
Water re-use	14
Research and education	130

Evaluation studies have been carried out in Botswana, Ethiopia, Kenya and Tanzania by various agencies to investigate the success of SIDA supported water supply schemes in these countries.

EVALUATION METHODOLOGY

A methodology of evaluating rural water supplies was used by SWECO in Ethiopia in 1976 and was further developed in Botswana in 1977. The methodology is described by Harlaut (1) and is briefly presented below.

Data collection

Data of interest for an evaluation comprise general background information, data on water consumers, water sources, the distribution system, operation and maintenance, costs and revenues and utilization.

As far as possible, data are collected in the field through direct observations and interviews. Water samples are taken for subsequent analysis and data stored in archives are checked on site. A clear distinction is made between first- and second-hand information.

Data processing

Collected data are tabulated and water analysis results are added. Historic data from accounts are often difficult to utilize in order to establish construction costs and are not directly comparable since they cover different years and different construction practices, e.g. contractors and direct labour. It is more reliable to quantify each scheme and cost them using recent unit rates. This was done in the case of Botswana (2) and the results are illustrated in Fig. 1.

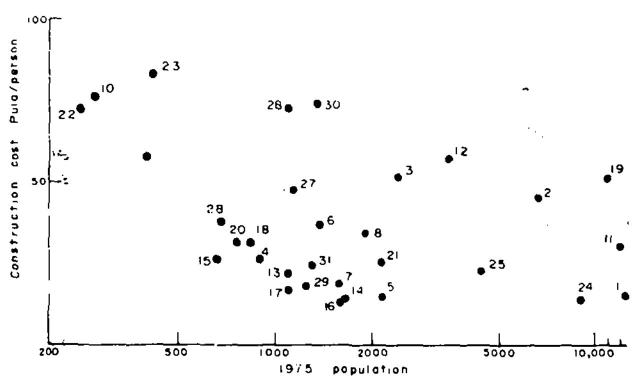

Fig. 1. Construction cost per capita related to size of village

Evaluation criteria

In order to minimize the number of subjective judgements it is necessary to clearly define the evaluation process. The evaluation criteria were grouped as follows:

Water quality and health. Water analyses and field observations are judged from water standards set by local authorities.

Technology. Evaluation of the technical system including capacity of source and installation, function and layout of treatment plant and reticulation system, appropriate technology etc.

Operation and maintenance. The operation routines should be designed to avoid queuing and interruptions in the supply. Maintenance routines should be established and a sufficient number of qualified staff engaged.

Cost. Specific construction costs and operation and maintenance costs are compared and assessed against costs for similar schemes.

Utilization. Analysis of water charges, distance to water points, reliability of the schemes and consumer participation in the construction and operation.

Environmental impact of the schemes such as overgrazing and construction of dams and the consequent occurrence of malaria or shistosomiasis were assessed.

Parties involved
The principal parties involved in a rural water scheme are the consumers, the operators and the water authority. Each party applies a different scale of values to the various criterion. In the case of water quality, for instance, it should comply with the local standards to satisfy the water authority, taste good to suit the consumers whereas the operator may have no opinion on the matter whatsoever.

Evaluation
The evaluation of the various schemes was made by the consultant based on a scale of values in which it was assumed that the three parties involved would apply to the criteria described above. No sub-criteria are shown in the evaluation matrix illustrated in Fig. 2.

Criteria	Consumers				Operators				Authority			
Scheme	1	2	3	...	1	2	3	...	1	2	3	...
Water quality	+	0	0		0	0	0		+	0	-	
Technology	+	0	-		+	-	+		+	0	-	
Op. and maint.	+	0	-		-	+	+		+	-	-	
Cost	0	0	0		0	0	0		+	+	-	
Utilization	+	0	-		0	0	0		0	0	0	
Environment	0	0	0		0	0	0		0	0	0	
Score	10	6	3		6	6	8		10	6	2	

Fig. 2. Evaluation matrix

A score was given for each scheme by each party. It is impossible to design an accurate weight scale and, following long discussions, it was decided that the various criteria should be given the same weight. The scores must obviously be utilized carefully since an unacceptable water quality, for instance, would make the scheme unacceptable.

It is now possible to give an order of preference for each scheme. A scheme unacceptable to one of the parties is given low preference regardless of the total score from all three parties. Schemes with high scores are acceptable to two or three of the parties and analyses may be made to find out the factors giving rise to the high score so that these factors may be utilized in the development of new schemes. The material can also be treated statistically to find the strong and weak points in the programme.

FINDINGS

Evaluations of the SIDA supported rural water supply programmes have been carried out in Botswana, Ethiopia, Kenya and Tanzania. Since the evaluations have been made by different agencies at different times (References 2, 3, 4, 5) with different methodologies, it is impossible to tabulate the findings. However, it may be of interest to give general comments on different criteria.

Water quality and health
Normally, local water quality standards are established. They may allow higher contents of certain substances than WHO's International Drinking Water Standard when it has been established that the higher content does not affect the health of the consumers. Water quality is only checked intermittently if at all. The availability of water has not been shown to have any effect on the health situation. To improve the standard of health in rural areas

it is not simply a question of providing water; health education is also necessary. The creation of dams, in conjunction with water supply schemes, represents a potential risk for the spreading of waterborne diseases.

In Botswana, an increasing content of nitrates in borehole water has been observed and values as high as 600 mg/l NO_3 have been recorded. WHO suggests that contents in excess of 45 mg/l may present a health hazard to children, but a survey carried out by the public health authority has failed to establish that the high nitrate content constitutes any change to health.

In Tanzania, a temporary local standard allows fluoride contents up to 8 mg/l (highest permissible level set by WHO is 1.5 mg/l) as well as contents of a number of other substances higher than WHO's permissible figures. A study of a rural water quality programme is being initiated by SIDA and will review important aspects of water quality and health in Tanzania, evaluate the existing situation and recommend a water quality programme.

Technology

Although the water source varies depending on the hydrological and hydrogeological situation, it is also affected by local traditions. As illustrated in Table 3, surface water sources are more frequent in Kenya than in neighbouring countries although it is likely that more ground water sources may be developed. Accordingly, water treatment plants are more frequent in Kenya and the schemes serve greater areas.

TABLE 3. Rural water supply sources, per cent

Water source	Botswana	Ethiopia	Kenya	Tanzania
Sample, Nos.	31	58	35	1062 a)
Rivers	-	5	49	28
Dams	6	10	7	14
Lakes	-	-	7	
Rainwater collection	-	7	-	-
Total surface water	6	22	63	42
Springs	-	7	20	16
Shallow wells	-	3	-	9
Boreholes	94	67	17	33
Total groundwater	94	77	37	58

Manually excavated shallow wells properly protected and equipped with a hand pump have proved to be the least expensive water supply source when water is available at shallow depths.

The specific consumption rates from communal water points and individual connections assumed in the designs are 15-30 l/pd and 50-70 l/pd. These figures have been verified by measurements taken in Kenya (4).

Water treatment. Although most rural water supplies do not have water treatment plants, provision is often made for chlorination in the event of an epidemic. In Kenya, treatment plants are more frequent and chemical precipitation combined with rapid sand filtration is the most common and effective treatment process.

Pumping. Motor pumps are normally powered by electricity when available but in rural areas diesel-driven pumps are more frequent. Attempts to utilize wind-driven pumps have not been successful. Hand pumps are utilized for schemes without reticulation systems.

Reticulation systems normally comprise a rising main to a reservoir. Communal water points and a limited number of individual connections are connected to the rising main. In bigger villages two or more distribution lines are constructed. The maximum walking distance to a communal water point should

Note a: Excluding dams without distribution systems and hand pumped schemes not be more than 400 m. Water is pumped up to 10 hours a day and reservoirs are used to provide water during the remaining hours and to cater for peak demand. Wide use is currently being made of PVC and polyethylene pipes in water supply schemes.

The general impression gained from the various evaluations is that the technology used is acceptable but that more emphasis should be placed on finding low-cost groundwater sources.

Operation and maintenance
Operation and maintenance has proved to be the weakest element in the rural water supply programmes.

Staff. The operation and maintenance staff are normally inadequately trained and too few in number. Massive training programmes have started but it will take several years to raise the level of education for everybody concerned with the programmes. Furthermore, many of those who have received training are assimilated into other sectors where there is also a large demand for trained personnel.

Facilities. Transport, spare parts, workshops and other facilities for operation and maintenance are often inadequate and, as a result of bad management systems, are frequently badly utilized.

Costs
Construction costs vary with the size of the schemes as illustrated in Fig. 1. Development funds are provided by donor agencies up to a level of 90-100 %.

Recurrent funds are provided by the developing countries. Owing to limited resources and local priorities, the funds allocated for operation and maintenance are insufficient. In Tanzania, WHO/IBRD (6) estimate that the present funds only meet one third of the demand. In Kenya, the recurrent funds correspond to only two per cent of the accumulated investment. The lack of funds is causing deterioration in the condition of the installations and rehabilitation programmes have been proposed in the two countries.

Utilization
Although a scheme might be well designed and constructed and be operated at reasonable costs it may still be a failure if it is not utilized.

Water rates should be acceptable to the consumers. They must not be too high for the poor consumers and tend therefore to be too low to be worthwhile collecting.

Convenience. The distance to the tap should be short compared with the distance to unimproved water sources and the supply should be reliable.

Participation. The consumers should, through their local authorities, be able to influence the selection and design of schemes and in some way in order to inspire a feeling of affinity with the scheme, be encouraged to contribute to the development. This participation increases public support for operation and maintenance and reduces the risk of vandalism.

MAIN CONCLUSIONS

Operation and maintenance
Due to limited financial, personnel and administrative resources in the developing countries the operation and maintenance of the schemes is the weak spot in the rural water supply programmes. This leads to unrealistic supplies and deterioration of the installations. Donor agencies should realize these constraints and share their support between development and operation and maintenance of the schemes.

Training
It is necessary to initiate massive training programmes for all staff involved in the development and operation and maintenance of the schemes.

Water rates
Water rates high enough to make a worthwhile contribution to the costs of a scheme are often too high for the poorest consumer. Water from commercial water points should be supplied free of charge and costs should be recovered through taxes.

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POTABLE WATER AND VILLAGE HEALTH: IS PRIMARY PREVENTION AFFORDABLE?

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Abstract

The biological quality of drinking water in 50 villages of Fars Province, Iran was measured to determine if contamination problems exist. With only one exception, all villages use drinking water in which sources are contaminated, i.e. exceed and often far surpass an acceptable level of coliform count. This condition is found whether a rural primary health care system exists or is absent. An examination of the cost of establishing a potable water supply indicates that the annual cost of establishing and maintaining such a system is equal to 0.5% of the national per capita income or 3% of the rural per capita income. By combining the national resources and the local resources it is suggested that primary prevention in respect to diarrheal diseases is affordable.

INTRODUCTION

Economically developed nations allocated substantial sums to water supply, excreta disposal, and general sanitary measures long before planned efforts were made to establish a network of personal health care services. Consequently, primary prevention lead the way in the control of enteric diseases, largely because there were no satisfactory alternative secondary strategies. In developing nations the attack on basic health problems is reversed. Secondary prevention is the order of the day. Allocation of resources and basic environmental improvements such as potable water supply are secondary in emphasis, even though various chemical and antibiotic treatment systems are often readily available.

In order to examine this issue, we selected a rural area of Fars Province in Iran where an ambitious village health worker (VHW) project is underway (1). The environmental and socioeconomic circumstances are believed to be typical of many rural situations worldwide. The rural population of Fars Province is 1,003,000 persons, distributed among 3,708 villages. Approximately 50% of the population live in villages with 500 or more residents. The economy of these villages is based on agriculture consisting of wheat, rice, barley, sugar beets, citrus fruits, and on sheep and goat raising. The annual per capita cash income is approximately $250. Villages are divided into compounds, each surrounded by a wall constructed of mud bricks. Each household has from 2-12 residents. Animals, sheep and an occasional donkey are housed within the compounds, and thus fecal material is ubiquitous.

Gastroenteritis is a principal cause of disease and child mortality, accompanied by diarrhea or dysentery. This complex of conditions is responsible for 25% of visits made to rural outpatient clinics and accounts for a significant proportion of hospital admissions of children. Gastroenteritis also contributes to malnutrition and to death from respiratory disease (1,2).

Water contaminated with fecal material is a principal means for the transmission of organisms causing gastroenteritis. Consequently, the primary preventive measure to control gastroenteritis is the establishment of a water supply free of contamination and easily available as the sole source for drinking and for preparation of food. To determine the availability of such primary prevention in respect to gastroenteritis, a survey of a sample of villages in Fars Province was undertaken. The purpose of this survey was to determine the type and location of water sources, the biological quality of the water, and the effect of village size and the presence of an auxiliary health worker on these characteristics. The survey findings are reported as a basis for examining the practicability of primary prevention as a principal means of controlling gastroenteritis.

SURVEY DESIGN

No previous assessment of the biological quality of drinking water has been made for villages of Fars Province. The extent of variability between villages was unknown at the beginning of the investigation. Estimates were sought for a universe of villages served by VHW's (40) and for the remainder of villages in Fars Province, i.e. those not served by VHW's. An initial sample of 25 of the VHW villages was selected and the same number was chosen by stratified random sampling from the remainder of the villages (stratification being structured on a geographic framework). Sequential sampling of additional villages was planned if the initial sample findings indicated the necessity for added information or increased precision.

The standard total coliform-count was determined for each village water supply by use of the Millipore Coli-count sampler. The validity of this procedure has been thoroughly demonstrated (5). The criterion for an acceptable water supply was a count of less than 100/100 ml, which under the conditions of test was met if each of the 2 aliquots examined for each village was free of colonies or if one aliquot was free and the second aliquot had a count not exceeding 1 colony per ml. This is a liberal criterion to use. A more rigid requirement would be one consistent with the usual standard for potable water, namely an MPN of less than 3/100 ml.

Water samples were collected in sterilized bottles from the sources for drinking water in the individual villages, put on ice, and reached the laboratory within 4 hours. For each sample, water was introduced into the holding chamber of two millipore samplers and treated in accordance with the manufacturer's specifications for total coliform count.

RESULTS

The biological quality of water for the 50 villages studied is shown in Table 1. With only one exception (a village with a spring as the source) no water supply used for drinking and for preparation of food is potable. Wells without pipe distribution are universally contaminated. Wells with pipe distribution are also all contaminated but this category of water supply is quantitatively less contaminated than wells without pipe distribution. Springs with canal distribution (generally open canals) are universally grossly contaminated. Springs with pipe distribution, although contaminated, appear to provide the best water quality of the various types of water supply sampled.

TABLE 1. Bacteriological quality of water according to type of water supply in 50 villages

Type of water supply		Total coliform (#/100 ml)				
Source	Distribution	<10	10-99	100-999	1000+	Total
Well	Pipe	0	0	5	7	12
Well	None	0	0	1	24	25
	Total	0	0	6	31	37
Spring	Pipe	1	0	2	0	3
Spring	Canal	0	0	0	10	10
	Total	1	0	2	10	13
Total all villages		1	0	8	41	50

The relationship of type of water supply to size of village population is shown in Table 2. The frequency of use of piping to assist in distribution is consistently related to size of population ranging from 0% (0/15) for villages of less than 500 to 88% (7/8) for villages of 2,000 persons and over.

TABLE 2. Distribution of villages by population and by type of water supply in 50 villages

Type of water supply		Village population				
Source	Distribution	<500	500-999	1000-1999	2000+	Total
Well	Pipe	-	3	2	7	12
Well	None	9	13	2	1	25
Spring	Pipe	-	3	-	-	3
Spring	Canal	6	4	-	-	10

TABLE 3. Bacteriological quality of water supply in villages with and without village health workers

Presence of VHW	Total coliform count (#/100 ml)				
	10	10-99	100-999	1000+	Total
Yes	1	0	5	19	25
No	0	0	3	22	25

The possible relationship of the village health worker on the quality of the water supply is seen in Tables 3 and 4. Having found that 98% of villages did not have a potable water supply, it is not unexpected that the communities served by VHWs are subject to the same risk of contaminated water as those communities with no assigned VHW (Table 3). In an examination of the type of water supply found in the various villages, it is of some interest to find that the VHW-served communities with wells have a significantly higher proportion with pipe distribution (10/18) than communities without VHW personnel (2/19).

TABLE 4. Type of water supply in villages with and without village health workers

Presence of VHW	Well			Spring			All Villages
	Piped	Not piped	Total	Piped	Canal	Total	
Yes	10	8	18	3	4	7	25
No	2	17	19	0	6	6	25
Total	12	25	37	3	10	13	50

The obvious explanation that the VHW was instrumental in stimulating the introduction of the piped distribution was not supported by the historical evidence. In all of the ten villages served by a VHW, the piped distribution system was present before the arrival of the VHW or was established through initiative independent of the VHW. Part of this initiative derived out of the village size. Although presence or absence of a VHW did not vary significantly with village size, the number of villages of 2,000+ residents served by the VHW exceeded that of the non-VHW sample, 6 versus 2.

DISCUSSION

The almost universal contamination of drinking water available to rural residents of Fars Province is indicative of a near total failure of providing effective primary prevention in respect to gastroenteritis. The requirements for a potable water supply are known to the various authorities, but there is no firm priority for establishing a hygienic base for the promotion of rural health, a plan for capitalizing and maintaining the necessary system, and a realistic assignment of responsibility to a defined sector of government for the attainment of this objective.

There is the possibility that primary prevention as exemplified by potable water may be economically unobtainable for developing countries and thus secondary efforts, early detection, and remediable intervention may be cost effective. It is difficult to equate disease treated with disease prevented, in terms of benefit to the individual. However, we feel it relevant to examine the costs of providing a potable water supply to rural communities in Fars Province. For a village of 1,000 residents, the physical elements of a satisfactory system with current cost expressed in dollars are as follows:

1. Construction of well including adequate cover and encasement (average depth 15 meters)	$1,500
2. Purchase and installation of tank or reservoir (daily delivered volume 100,000 liters)	20,000
3. Purchase and installation of water pump	2,500
4. Distribution to each household (pipe)	11,000
5. Total	$35,000
6. Per capita cost	35
7. Per household cost (average household size = 6.5)	227

The total cost of capitalizing an acceptable primary attack on gastroenteritis is then $35 per person, which if conservatively amortized over a seven year period amounts to $7 per capita per year. An annual interest rate of 10% on existing balance is used for amortization purposes. The operational cost including manual chlorination, on an annual basis, would be $4 per capita. Thus the capital and operational cost of a potable water supply would be $8 per capita per year, or about 3% of the per capita income of the rural family. However, when related to the national per capita annual income of approximately $2,000, the annual cost of $8 equates to less than 0.5%. When one considers the benefits of less national expenditures for drugs for diarrheal disease, less expenditure of effort by nationally trained and paid auxiliary health workers in the treatment of diarrheal disease, and a reduced requirement of pediatric beds for severe diarrheal cases, the investment in potable water could be regarded as a saving rather than an additional cost.

Since both the nation and the individual have a critical interest in the benefit cost characteristics of a potable water supply, the cost-sharing is practical and commonly acceptable. The model described for a village of 1,000 would be applicable to villages of populations ranging from 300-5,000, with adjustments in scale, but with no significant difference in basic elements nor in cost per capita. It should also be noted that elements of a potable water supply may currently exist in some villages, e.g. a well, tank or motor, so that the total cost cited may exaggerate the expenditures necessary to obtain a satisfactory water supply. The provision of a potable water supply for villages of less than 300 residents will require careful planning to assure cost feasibility of the general dimensions cited above. The major elements would include a protected source, spring or well; a pump sufficient to move water at the volume of 25 gallons per capita per day to an appropriate reservoir; a reservoir constructed from locally available materials and by local labor; manual chlorination; and two centrally located distribution points from the reservoir. In the small village situation, each household would have the option of extending the distribution system to their own compound at their own expense.

With the goal of a potable water supply as the essential base upon which gastroenteritis in rural populations is to be controlled, the question arises as to the appropriate agency or organizations to be assigned responsibility for this task and the role of the rural primary health care system in this effort. Within Fars Province we have identified 3 sources of initiative for attainment of potable water supply: the village people themselves, the Ministry of Agriculture and Rural Cooperative Agency, and the Ministry of Health and Social Welfare. The initiative of the village people is to be encouraged to a maximum. This cannot be sufficient, however, to provide the necessary technology nor can one village acting on its own obtain the economy of large scale purchase nor standardization of design. The choice of the Ministry of Agriculture or the Ministry of Health as the lead organization should rest on the following criteria: (1) availability of technical expertise in water supply, (2) recent positive relations with rural communities including logistical capacity in respect to purchase and delivery of equipment and supplies, (3) ability to enter into cooperative financial relationships with rural communities for joint financing of capital improvement projects.

What role should be given to the primary health care worker or team? To the extent that the village health worker is trained in and performs clinical duties (personal care) he or she inevitably is preoccupied with this function. This worker cannot be all things to all people. Thus the concept that the village health worker can be a vigorous expert and leader in environmental hygiene as well as a competent personal care attendant is not realistic. Somehow a sanitarian must be built into the rural scene with close connection to the authorities responsible for establishing potable water supply and answering to the health authority. The pursuit of primary prevention in rural areas through environmental control requires comprehension of technology, attention to detail, and logistics. This dictates the assignment of such responsibility to a division within the provincial health department, consisting of a supervisory unit and a field service consisting of sanitarians (12 grades of general education and 1 year of special training) assigned in a ratio of one worker per 10,000 population. The village health worker, based upon observations from his personal care experience, should be encouraged to notify the sanitarian of any breakdown in water sanitation or in other aspects of environmental hygiene.

SUMMARY

The question posed by this paper, "Is Primary Prevention Affordable" in connection with potable water can be relatively easily answered, as has been demonstrated in this paper. Within the area studied, potable water can be established and maintained by an investment of 0.5% or less than 1% of the national per capita income, or by an investment of 3% of the annual income of the rural population to be served. When these costs are balanced against the gains of less pediatric beds devoted to diarrheal diseases, even these modest figures are exaggerated statements of the net cost of potable water. The conclusion is, "Primary Prevention is Affordable".

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OF TYPHOID FEVER AND TELEPHONE POLES: DECEPTIVE DATA ON THE EFFECT OF WATER SUPPLY AND PRIVIES ON HEALTH IN TROPICAL COUNTRIES

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Abstract
Literature on the influence of water supply and privies on the health of populations in tropical countries where enteric diseases abound is cloudy. This paper re-examines some of the basic parameters of several papers to see what were the confounding factors that led to opposing conclusions of their values. Whether the right questions were asked and whether the assumptions made were in fact true are discussed.

Some years back an epidemiology professor at one of the schools of public health in the United States showed that a perfect inverse correlation between the decline in typhoid fever deaths and the increase in the number of telephone poles erected in the U.S. could be made. He, of course, went on to say that there was no direct relationship that he could see between these two observations. Yet, to some there is a feeling that there must be some relationship because "figures don't lie", and some will go to the extreme - *credo quia absurdum est*. The literature on the effect of water supply and privies on the health of the population in tropical countries where enteric diseases abound is cloudy. There are respected research scientists who have concluded that provisions of water supply and privies have been effective in reducing diarrhoeal diseases, and there are equally respected scientists who have arrived at opposite conclusions. This paper re-examines some of the basic environmental parameters in several of the papers to see what were the confounding factors that led to these conclusions.

Typical of papers that are likely to mislead is one from Bangladesh (1) having a provocative title, *Failure of Sanitary Wells to Protect Against Cholera and Other Diarrhoeas in Bangladesh*. The reader cannot help but believe that the introduction of sanitary wells may have actually exacerbated the already existing poor health state of the community when he sees data presented in the paper as seen in Table 1. The cholera rate among the tubewell users was 1.7 times that of non-tubewell users, and the non-cholera diarrhoeal rate among the tubewell users was 2.3 times that of non-tubewell users. Based simply on these rates a prudent administrator would be forced to eschew tubewell installations as a means of promoting health. However, what were the confounding factors here? Q ref.

There were 88 families in the study and the average family size was 6.7 persons. This computes to a population of 590 that had access to the three public tubewells during the period of the analysis. Each tubewell, if used by the entire population, would have had to serve on the average of 197 persons or 29.3 families. This is hardly adequate to supply the volume of water required by families for their domestic needs at peak demand times without long queues, since the deliveries of manually operated tubewells are not high. Alternate sources of water would, therefore, be sought. The paper further refers to official records of the Subdivision Public Health Engineering Office which indicated mechanical breakdowns occuring 2 to 3 times per well annually and to the village residents' report that the usual length of interruption after a breakdown was 3 weeks. On these bases, it can be calculated that each tubewell was out of commission 11.5 to 17.3% of the time. No public utility can have one-third of its system down for this length of time and be considered adequate. It can be readily understood why families used sources other than the tubewell the water from which was also disagreeable because of the high iron content. Tubewell users were also said to have used 35% more water for all purposes than non-users, including more surface water.

Samples of the tubewell water were shown to be free of coliform organisms but samples of the surface water had coliform counts as high as 1800 per 100 ml. Clearly the tubewell water met the bacteriological drinking water standard but the surface water test showed that it was badly polluted. The bacteriological results simply confirmed the authors' observation

TABLE 1. Tubewell use and diarrhoeal disease

	Cases	Person-yrs.	Annual Rate/1000
Cholera:			
Tubewell users	53	3725	14.2
Tubewell non-users	13	1545	8.4
Non-cholera diarrhoeas:			
Tubewell users	28	3725	7.5
Tubewell non-users	5	1545	3.2

of the contamination taking place. They noted urination and defecation taking place into the water and manual bathing of the perianal region at surface water sources also used for other purposes. This observation is corroborated by the descriptions in the epidemiologic study of endemic cholera in Dacca and surrounding areas by Martin *et al.* (2). Since the tubewell water showed no contamination, a logical conclusion that can be made is that the pathogens were not transmitted via the tubewell. The problem with the data was the designation of who were tubewell users and who were tubewell non-users. Both groups, in fact, drew water for various domestic needs from surface courses; all were *surface water users* and none were *surface water non-users*. What was revealing in the paper was information noted from two days of discreet observation of water use by the village people. Of those that claimed regular tubewell use, 77% did not draw water from the tubewells. In effect, categories of water use designations were unfortunately inappropriate. The authors concluded that the use of sanitary pipe wells did not protect against cholera or related non-cholera diarrhoeas because well users also used contaminated water sources regularly enough to maintain high infection rates. The failure was not the tubewells *per se* to protect the community against diseases, but the failure was in the inadequacy of the design to provide sufficient quantity and quality of water reliably so that people would not seek water from contaminated sources so readily available to them. It was the investment in the water supply provisions that was far short of the threshold to show improvements in the health state of the population. and omitting 'Health Education': importance of exclusive use of tubewell water for health related purposes. (drinking, food

Sommer and Woodward (3) reported on the influence of protected water supplies on the spread of classical/Inaba and El Tor/Ogawa cholera in rural East Bengal. The site of the study was a crowded Hindu fishing village of Meheran with a population of 1763 on July 1, 1968. During the first year of the study (1968-1969) there was an outbreak of the classical/Inaba cholera; during the second year (1969-1970) the outbreak involved the El Tor/Ogawa cholera. 102 children from infants to age eleven were in the study during the first year, and in the second year 194 children were included. The authors looked at cholera infection rates by tubewell proximity zones. These zones were simply "inner", for areas within 50-foot radii around each tubewell, and "outer", for areas outside the 50-foot radii. An assumption was made that people living immediately around tubewells were more likely to use them than those living further away. Their paper does not confirm whether the assumption was in fact correct.

Results of their study are summarized in Table 2 shown below. These results suggested to the authors that "the relatively simple expedient of providing safe supplies of drinking water, found so useful in controlling the spread of classical strains of the disease, may prove ineffective against the El Tor biotype."

TABLE 2. Cholera epidemic infection rates by tubewell proximity zones

Tubewell zone	Classical/Inaba epidemic 1968-1969 Pos./No. at risk	Rate, %	El Tor/Ogawa epidemic 1969-1970 Pos./No. at risk	Rate, %
Inner	1/27	3.7	16/54	29.6
Outer	19/75	25.3	37/140	26.4

The authors cited records of the lowering of cholera incidence rates where installation of central water works have taken place in developing countries. They noted that programs of tubewell construction in rural areas have been based on the premise that provisions of water supply will have health benefits. They went on to state that "when operated properly their (tubewell) water has generally been found safe and free of *V. cholerae;* even so, their effectiveness as a general prophylactic agent, especially in areas like rural Bengal where alternative sources of unprotected water abound, has never been adequately demonstrated."

There were nine tubewells in the village, but only six of them were operating at the time of the study. Other sources of water for the population included the village ponds and the small branch of the Meghna River. These sources were important for washing and bathing as well as water supply for cooking and drinking. People defecated in the open, usually along the banks of the river or of the many tanks. Opportunities for contamination were, therefore, ample.

From the engineer's view there is little question as to the inadequacy of the tubewell supplies. Only six pumps operating for 1763 population is a pump to population ratio of 1 to 294. There is little question as to the use of "other waters" by the bulk of the people. The wear and tear on a pitcher-type pump is tremendous in a one year time, especially if it is used by a very large number of families. It is not inconceivable for a life of a pump to be used up within a very short span of time since it is the pumpage and not the age that determines its life. Furthermore, a pump old before its age will show considerable drop in delivery and will require more effort by the villagers to obtain water. The condition of the pumps in the village during the second year may have been very different from that of the first year. Only six out of nine pumps operating emphasizes the problem of reliability of service.

In contrast to the Bangladesh data, Hollister *et al.* (4) in a study in migratory farm labor camps of California's central valley in 1950, Stewart *et al.* (5) in their study in southwest Georgia in 1949-1953, and Rubenstein *et al.* (6) in their study in a Hopi village reported in 1969 showed benefits of improved sanitary facilities. Shigella positivity rates and infant diarrhoea cases were seen to decline with improvements. Unlike Bangaldesh there were no alternative water supply sources to the improved supply in the camps, town and villages in the U.S. studies. The analysis of the data did not suffer from the problem of the variety of poor quality water that was available to and used by the people in Bangladesh.

Another research paper reported on a diarrhoeal disease study in 31 Panamanian communities (7). In that paper the prevalence of pathogenic enteric bacteria in children under 11 years of age was reported as shown in Table 3. Contrary to their expectations the authors noted that the frequency of infection was slightly greater among children who drank water from faucets (piped water) and had access to flush toilets for the disposal of excreta than among those who did not have or use such sanitary facilities. Statistically no significant difference in infection in children between those who had access to piped water and those who used water from other sources could be seen. This was also true for those who had access to flush toilets and those who used other excreta disposal sites.

TABLE 3. Prevalence of pathogenic enterobacteriacae in children by selected sanitary facilities in 31 communities of Panama, 1967

Sanitary facilities	Children examined No.	Children examined %	Children with pathogens No.	Children with pathogens %
Water source				
Piped	372	31.6	18	4.8
Well	640	54.3	19	3.0
Stream	129	11.0	4	3.1
Rain	27	2.3	2	7.4
No information	10	0.8	0	0.0
Total	1,178	100.0	43	3.7
Excreta disposal site				
Ground	189	16.0	5	2.6
Pit privy	727	61.7	28	3.9
Flush toilet	161	13.7	8	5.0
River or sea	88	7.5	1	1.1
No information	13	1.1	1	7.7
Total	1,178	100.0	43	3.7

The authors went on to say that the analysis of data and visits to the children's houses, however, disclosed that the majority of children who reported using piped water and flush toilets were from Panama City and lived in substandard dwellings or multifamily tenement slums, where these facilities, although present, are notoriously inadequate and must be shared communally. Reference was made to an earlier paper by two of the authors which described the housing and socioenvironmental factors in Panamanian communities that played important roles in maintaining a high endemic rate of diarrhoeal diseases. The prevalence rates of enterobacterial pathogens in infants by types of dwelling along with information as to water supply and waste disposal facilities in these types and by general socioeconomic status are given in Table 4.

From these descriptions and infection rates it can be noted that, with the exception of those infants living in single-family houses and apartments afforded by families in the middle to high socioeconomic levels, infants living in other dwelling types experienced high rates of infections and that the rise and fall of the infection rates did not follow

TABLE 4. Prevalence of enterobacterial pathogens in infants by dwelling types and socioeconomic status in Panama, 1967

Dwelling type	Water supply/waste disposal facilities	Socioeconmic status	Percent pos. infants
Panama City:			
Single-family houses and apartments	Piped city water with very few exceptions; connections to sewers or septic tanks; toilets in good or excellent conditions	middle to high	0.0
Multifamily tenements	One or two sets of toilets and sinks connected to city sewers on each floor and must be shared; water for cooking must be carried to rooms; sanitary facilities inadequate, generally dirty and in poor condition	low	8.6
Squatter	Few public faucets served by city available to every 20 to 30 families; numerous families share few improvised pit privies	very low	6.3
Rustic homes in semirural areas within city limits	Piped water from city or local community supplies to about one-third of dwellings; remainder of population has access to wells or obtain water from unprotected sources; toilets are poor and inadequate, usually pit privies shared by many families	low to middle	10.2
Near Panama City:			
Varied, single- and multifamily structures, urban/rural	Most served by piped water from local aqueducts or drilled wells on or near premises; in communities lacking sewerage, septic tanks common; few houses have indoor flush toilets	low	6.0
Rustic and varied dwellings, rural	Few drilled wells, individually owned and public; latter defective most of time due to lack of maintenance, located some distance from dwellings and used by many families; other major sources, unprotected surface water; few pit privies shared communally; otherwise toilets almost nonexistent	very low	9.0

the socioecomic status in an inverse relationship. What is evident are inadequacies of the water supply and waste disposal provisions for all the *other* categories of dwelling types. Since the health of infants is so dependent upon other members of the household these inadequacies tend to have even more profound effect on them. The important question that should have been asked related to the level of services and not simply to whether people had access to faucets and to flush toilets.

Another study of note is one that was conducted in the Calyube Province in Egypt beginning in 1948 (9). The study was a cooperative venture between the International Health Division of the Rockefeller Foundation and the Ministry of Public Health of the government of Egypt. Five villages were selected and various levels of preventive and sanitary services were provided. The study was conducted to determine among other things the effectiveness of the measures in improving the health state of the population. The measures included the installation of wells and latrines, the installation of refuse disposal service, fly control by insecticides, and general preventive medical activities such as visiting nurses, venereal disease control, and tuberculosis control. Table 5 shows the villages that were selected, the measures applied and the infant mortality rates experienced by the villages during 1950 and 1951.

It was recognized in the study that the burden of disease carried by the population was heavy and that the bulk of the conditions was the result of poor sanitation in all its aspect. The study, however, concluded that the installations of water supplies and latrines in a village, without parallel improvement in housing, social and economic status, do not have a marked effect upon the death rate in infants and therefore presumably little or no effect on the rate of dysenteries in infants.

From the analysis of the data the authors concluded that the only sanitary service that had an effect on infant mortality was the fly control measure. The relatively low rates of 115 and 135 infant mortality rate per 1,000 live births in Sindbis and Quaranfil, respec-

can't to say, no mention of realistic health education as intermediate measure

TABLE 5. Infant mortality rates for the villages in the study in 1950 and 1951

Village	Sanitation Measures	Infant Mortality Rate/1000 Live Births 1950	1951
Sindbis	wells, latrines, refuse disposal, fly control, preventive medicine service	115	245
Quaranfil	wells, latrines, refuse disposal, fly control	135	232
Barada	wells, latrines, refuse disposal,	241	203
Aghour El Sughra	wells, fly control	223	206
Aghour El Kubra	no improvements (control)	273	175

tively in 1950 occurred during the period of excellent control of flies even while the subsidiary services of water supply and latrines were not completely installed. During 1951, in spite of the complete coverage of both villages with sanitary sources of water and latrines the infant mortality rate rose when the loss of fly control occurred. Fly control measures have problems because of the relatively early development of resistance to insecticides by the domestic flies. The rather high infant mortality rate in Aghour El Sughra in 1950 was not explained, except for the inference that might be made from the data that for about two months at the start of the fly season benzene hexachloride used for fly control was ineffective and required the use of chlordane in its stead to achieve reductions in fly numbers. Chlordane was effective, but even so the infant mortality rate was high and remained high.

With respect to water supply provisions the question that must be asked is whether there was in fact a significant improvement in quantity and quality. The paper records information from the base line survey conducted with ratings of the five villages by the scoring system of B.R. Dyer. All five villages were rated equally poor. This was very true for the water supply component. The authors noted a surprising number of houses with latrine and wells but recognized that these facilities were in general more of a hazard than a benefit. Latrines were the unsanitary pit type which bred large number of flies. Wells were universally contaminated for lack of provisions to protect against surface contaminants and too often they were simple handpumps driven into the ground adjoining the latrines. The canal was also used as a source of water by the villagers. Table 6 summarizes the number of latrines and wells existing in the five villages.

TABLE 6. Occupied houses and houses having wells or latrines in 1948 with census information in February, 1951

	Sindbis	Quaranfil	Barada	Aghour El Sughra	Aghour El Kubra
Population	4232	4098	5102	4206	9060
Occupied houses	759	724	894	753	1748
Houses with wells	130	51	132	17	173
Houses with latrines	204	181	211	145	767

In the study scheme water supply provisions were made for four of the villages. The basis of the supply was to be one simple handpump for 200 population. The number of wells constructed were 28 in Sindbis, 29 in Quaranfil, 29 in Barada and 30 in Aghour El Sughra. Aghour El Kubra served as the control village. Criteria adopted for the sanitary water supply were: (a) it must be available to individual homes in such a fashion that it would be easier to use the supply than to utilize canals or other unsanitary sources, (b) its installation should be cheap enough to permit countrywide installation in other villages, and (c) its installation should be sufficiently simple to permit maintenance by local labor. At the rate of one pump per 200 population it was obviously not possible to provide water directly to each house. The authors realized that the bathing and washing facilities would continue to remain inadequate. This statement, in itself, is a clue to the high infant mortality rates since infants depend so much on others for their health and well being. Shortage of water for bathing and washing in an environment characterized by poor sanitation would pose as a serious threat to them through those who cared for them.

The selection of the handpump was based on availability on the local market, low cost and easy maintenance. The authors recognized in the choosing of the pitcher pump the possibility of contamination from the outside, but felt that the factors of cheap and easy maintenance outweighed this disadvantage. The wells were said to have been used at once by the villagers. It was stated: "It is doubtful whether any family used other sources of water after the installation of the wells." The paper followed this statement with: "Maintenance due to breakage or theft of pump parts was difficult at the start but within a few weeks the villagers themselves stopped abuse of the pumps either by insisting that new parts be purchased by the individual responsible for the damage or by placing the pump handle in the adjacent house for use by those needing water."

From these descriptions it is difficult to agree with the authors that after the installations of the new wells the families did not use other sources of water. It was claimed that these pumps were capable of yields of 260 to 300 gallons per hour. At the rate of 260 gallons per hour 8 hour continuous pumping is capable of providing a maximum of 10 gallons per person to the design population of 200 persons; at the yield of 300 gallons per hour the amount is 12 gallons per person. It is doubtful that pitcher type handpumps can continue to deliver such high volumes as they are used, and it is also highly unlikely that the pumps in any setting will be used continuously. Therefore, if water was taken for domestic needs from these pumps, it must be concluded that amounts taken were small. Furthermore, should it be considered reasonable for a handpump of this type to last a family of 5 ten years, then a pump provided to 200 persons drawing the same amount of water per capita can be expected to last 1/40th of the time. This calculates to 1/4th of a year. The wear and tear of the handpump should have been expected. The provisions to provide sufficient water to the population from the new wells were woefully inadequate and unreliable. It is inconceivable that the placing of the pump handle in the adjacent house added to efficiency in management of the system. In the light of this it must be asked whether the old wells were, in fact, used. They were readily available. The canal was also a ready source.

Bacteriological samples were also taken from the new wells at weekly intervals. Although the pumps were constructed to seal out surface contamination, the authors reported that bacterial counts exceeding 10 lactose fermenters for 10 cc of water were found periodically in most wells. The 10 per 10 cc (or 100 per 100 ml) exceeds the International Drinking Water Standards for untreated water source by a factor of 10. The ground water table was 7 to 10 feet below the ground level. The pumps were not the self priming type. The question, therefore, must be asked whether the pumps were being contaminated by the use of unsafe water for priming.

Latrines were constructed in three of the villages. However, according to the paper they were used readily by the villagers when it was convenient for them to do so. Outside defecation was seen to have decreased but the families stated that they continued to use the fields when it was necessary.

That the sanitary conditions within the test villages had improved was noted by the survey in 1951, again using the scoring system of B.R. Dyer. The comparison is given in Table 7. These improvements, if in fact they were improvements, may not have been sufficient to have made the difference. The average score for water supply in Sindbis went from 6.6 to 16.3 or an increase from 30% to 74% of maximum possible score; for latrines the score went from 2.5 to 6.7 or an increase from 19% to 52% of maximum. More recent information (10) tends to indicate that the level of investment was insufficient to have crossed the threshold where health benefit response can be demonstrated.

TABLE 7. Sanitary score before and after sanitation program*

	Avg. sanitary score		Avg. score water supply		Avg. scores latrines	
Village	1948	1951	1948	1951	1948	1951
Sindbis	19.8	46.1	6.6	16.3	2.5	6.7
Quaranfil	19.1	44.9	6.0	15.3	1.3	7.6
Barada	21.0	41.1	7.6	15.3	1.5	7.2
Aghour El Sughra	21.8	31.1	7.4	15.2	1.6	2.8
Aghour El Kubra	23.8	25.3	7.9	5.9	2.6	2.9

* sanitary score: max. all component = 106.5; max. water supply = 22; max latrine = 13.

Wray (11) in the presentation of a paper at the Workshop on Effective Interventions to Reduce Infections in Malnourished populations showed epidemiologic data of diarrhoeal disease rates among children in Candelaria, Columbia living in homes with flush toilets compared to those living in homes without flush toilets. There was no apparent significant difference in the rates in the two groups. In his explanation he said, "That's what the data showed, but let me tell you what *really* happened," and proceeded to discuss the finer points not evident in the simple classification of children into "with flush toilets" and "witout flush toilet" categories.

Krusé in his historical review of water supply and health pointed to evidence that water alone can dramatically lower death rates from enteric diseases. Indeed, this has been the premise on which many of the water supply programs are based. However, what is evident is that too often the half measures of programs have been instituted with results that are at times no better than no program at all or even worse. A poor community system is veritably capable of delivering dilute sewage from door to door. Much too often in epidemiological studies on the influence of water supply on enteric diseases in a given community the assumption has been made that because the provision was made some benefit should result. When one handpump for 200 population is supplied and positive health effect is not seen, a conclusion is too often reached that the provision of water supply is not effective in reducing enteric diseases. The real probelm is in the quantum of investment. In medicine no yaws control campaign could succeed with injections of very small fraction of the required dose of penicillin. This is true in engineering for health. Water supply provisions and health can also be viewed in a dose-response relationship and there is a threshold below which no benefit can be seen.

Krusé (10) realizes that water supply provisions alone cannot completely eliminate enteric diseases. The concomitant reduction in pathogens in the environment must also go on. History of public health reveals that typhoid mortality was controlled in many of the developed countries when effective wastewater control and milk pasteurization were also instituted. Quantum of investment also applies here.

Some of the epidemiologic studies have also been remiss in asking the right questions or made assumptions that may not have been true. Were the handpumps constructed really used? If so, were they used all the time? What were the sources of water when the pumps were down? Were they down often enough to have driven people too often to unsafe sources? How often has this to happen in order to maintain the infection within the population? Were they truly tubewell users? Or were they truly surface water non-users? Were some of the handpumps constructed in such a way to provide contaminated supply? In each of the cases discussed in this paper there were grave uncertainties, so that a prudent reviewer must say to Wray and to others, "Yes, tell us what *really* happened."

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ENVIRONMENTAL HEALTH AMONG THE MASAI OF SOUTHERN KENYA: THE EFFECT OF WATER SUPPLY CHANGES*

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ABSTRACT

This is a preliminary report on a pilot study aimed at elucidating the relationships between hygiene and health in a pastoral semi-nomadic setting. Obligatory migration of herds and the pastoralist's traditional conservatism make objective assessment difficult. Data are presented on water, morbidity and boma environment.

BACKGROUND - THE MASAI

The Amboseli Masai occupy the flatlands around the northern slopes of Mount Kilimanjaro. The altitude is around 1,200 m and the rainfall 250-400 mm.

Practical considerations

Five matters are important in this setting: Water is scarce. Cowdung is prevalent and important. The diet is predominately milk, with little feces resulting. Flies are super-abundant and grazing mobility is the key to survival. (Masai instincts are finely tuned to the constant fluctuations of quantity, quality and location of grass and water. They must be adept in moving their cattle to the right place at the right time).

Psychological considerations

Three things are important here: Spiritual fixation on their cattle, cultural conservatism and, importantly, historical experience of exploitation at the hands of non-Masais in places like Laikipia, Kinangop, Mau Narok, OlMolog and OITukai.

BACKGROUND - THE PROJECT

In 1975 an agreement was reached under which the Amboseli Masai would remove their cattle from their traditional dry season grazing areas inside the Amboseli National (Wildlife) Park. In exchange they would be provided with a system which would pipe the abundant and clear water from Amboseli's springs out of the park to grazing areas around it. This improved accessibility of water for cattle would expand their grazing range enough to compansate for the loss of Amboseli swamp forage. Besides its effect upon grazing patterns, this piped water meant that abundant clear water would be brought within a few kilometers of the majority of bomas versus the previous 6 - 12 km.

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It was thought that this significant change of accessibility of water to the Masai might result in significant changes in the prevalence among them of water related diseases - if they used more water!

Unfortunately for us, the water pipeline project progrssed faster than did our efforts to secure funding. The pipes were in and the tanks full before we could secure a "pre-pipeline baseline" prevalence study. Nevertheless a project was embarked upon whose aim was to relate each boma's water status with its pattern of morbidity according to the following general scheme.

			Morbidity	
			High	Low
Water	Quantity (l/pers/day)	High		
		Low		
	Quality	High (piped)		
		Low (non-piped)		

RESULTS - WATER AND HEALTH

Handicaps

Regretfully, but not too surprisingly, the Masai experience cannot be fitted readily into our neat little boxes, for the following reasons: Water utilization: They all use very little water domestically and have very little sense of quantities. Water sources: Because of migration most bomas may use two or three different sources during a year. One boma may move from pipeline to river-bed well to Landrover ruts for their source, depending upon the season. Attitude. The Masai tend to exhibit a supercilious or suspecious attitude towards outsiders, especially if they are "question askers". They are not much less refractory to local Masai field assistants.

Nevertheless a few preliminary findings are reportable at this point, though they are based on statistically scanty numbers.

Water Quantity

It is anticipated, from preliminary responses, that domestic utilization figures will average well below 5 l/person/day. Purpose. To the question "What is the water used for" the commonest response concerns cooking maize meal when milk runs short. Washing of the body is not a commonly volunteered response. Quality. The respondents volunteer little or no comment on qualitative differences between various sources (piped, river, surface etc.). In fact, there is an enormous difference. If there is still grass in the area, a rain pond may be used (by both man and beast) until it is virtually a sludge. On the other hand the piped water is exceptionally good, coming by underground flow from Kilimanjaro's rain forest.

Morbidity Correlations

Thus far there seems to be little or no consistency or correlation between quality of water sources and morbidity findings (percentage of children under 5 years having trachoma, fungus infections or low hemoglobin (below 10 gm). Table 1 summarizes.

On a general questioning survey for "health complaints" headaches were most often mentioned (49% of responses) followed by cough (32%) with eyes and diarrhea each having 7%.

Parasite ova (principally ascaris) were found in the stools of 13% of the under-5s.

Asurprising finding was the 20% prevalence of low hemoglobin (< 10 gm)which was fairly evenly distributed geographically among the bomas.

TABLE 1 - Morbidity of Under-5s (in percentages)

Boma nos. & Location	Movement & Water	Trachoma (any grade)	Fungus	Ova	Hb. 10gm
1-6 south	Permanent site Borehole sources	76	Not rec.	33	21
7-14 eastern	Migrants between piped & non-piped	83	46	20	20
15-23 north	Migrant between poor BH & surface sources	84	31	33	16
24-35 northwest	Migrant between piped, BH & surface sources	89	31	30	16
36-38 southeast	Permanent bomas; access to river and BH	94	70	Not done	0

Child growth

Anthropometrics on 486 under-5s produced Height-for-Weight patterns similar to those found in a Kenya-wide survey.

BOMA SANITARY ENVIRONMENT

The boma is comprised of a circular thorn fence on the immediate inside of which are built the huts (average 9.5 per boma). There is generally one gate per senior elder (average 6 per boma). Each night the cattle stay in the circular central area which is encompassed by the huts and the fence. Dung accumulates with time, and in the rainy season the area is a total quagmire.

The huts are oval shaped flat-topped structures made of wickerwork plastered with cowdung. Dimensions show very little variation from the following: Height 1.50 - 1.75 m; Circumference 9-13 meters. The volume is thus around 20m^3.With an average occupancy of 5 people there is 4 cubic meters per person of air space.

The only ventilation is through the short curved entry passage. A small amount of light comes in through a 5 cm hole in the wall over the fireplace which smoulders and smokes much of the time.

Within the dark confines of the hut one would expect to find a rich harvest of vermin such as rats, lice, ticks etc. But we have found only bedbugs so far, and those only in very patchy distribution in selected bomas. Perhaps the vermin are suppressed by the smoke saturation.

Such a prevalence of fresh cowdung of course attracts large populations offlies. They migrate freely between the dung and the faces of the children with their attractive collections of mucus, pus, milk and tears. The ear canal is an attractive place for oviposition hence maggot ear is not uncommon. Attempts are being made to quantitate fly prevalence, but there is no reliable method yet. Fly paper counts seem very variable.

CONCLUSION

A start has been made in assessing the relationship between water and health in a pastoral semi-nomadic setting. There are many confounding practical variables to account for as well as cultural situations to adapt to in our approach. The Masai may eventually provide us with a new perspective on the interrelationship between water, hygiene, food and health.

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CHILD HEALTH AND DIARRHOEAL DISEASE IN RELATION TO SUPPLY AND USE OF WATER IN AFRICAN COMMUNITIES

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Abstract
In a community study of acute morbidity of children in Addis Ababa it was observed that children under the age of 2 years were on the average ill with diarrhoeal disease for 2 months per year. Exploratory statistical methods showed personal hygiene and quantity of water to be powerful predictors of diarrhoeal disease. Later aetiological studies have yielded putative agents, mainly rotaviruses, in 60 % of the ill children during the rainy season. Water wells and river water were often found to contain both classical enteropathogenic serotypes of E.coli and enteroto.igenic. Knowledge from cholera epidemics and recent epidemiological studies of new pathogens makes it very probable that African waters have unique characters as sources of infection. Intermediate technologies and community involvement are needed in the multidisciplinary efforts to solve child health problems.

INTRODUCTION

High morbidity and mortality rates among large child populations constitute a major health problem in most developing countries. Child health programs have traditionally emphasized clinical and curative approaches, often overlooking that important or more effective actions for health may be taken by changing socio-environmental and other ecological factors. There are situations where it might be the duty of health workers to identify "non-medical solutions to medical problems" (1) and to advocate social and environmental or even political changes rather than the extension of traditional medical services. This holistic view of health implies an interdisciplinary approach in the study of health determinants. The technologists as well as medical people involved in health promotion programs should thus be prepared to integrate their respective technical solutions with the total efforts to solve health problems. The level of sophistication must also be adjusted to the cultural and social setting.

A recent estimate indicates that over 500 million episodes of diarrhoea occur annually among children in Asia, Africa and Latin America. Diarrhoeal disease is the most important form of acute childhood morbidity in Africa, well known to clinicians and health workers all over the continent. Data on diarrhoeal disease and its background with respect to varying hygienic and sanitary conditions, its relations to quality and quantity of water, its microbiological aetiologies and its modes of transmission are, however, scarce.

ACUTE MORBIDITY IN DIARRHOEAL DISEASE AS A SOCIO-MEDICAL PROBLEM

A community study of child health was carried out in 1972-73 and in 1974-75 in the Kirkos area of Addis Ababa, an underprivileged community where a large proportion of households lacked adequate housingand sanitation, Background data on demographic, socio-economic conditions, hygiene and sanitation,education and cultural characteristics were obtained at an interview survey from a sample of 600 households. Ten % of the households had private water taps, 65 % had shared water taps or bought water from neighbours and 24 % fetched water from a community stand pipe. The median water consumption was 11.4 litres/household member and day (range 1.7-120). Only 5 % of the households had private water flush toilet, 11 % had a private pit latrine and the rest had shared pit-latrines or could use public pit latrine. Morbidity data on 749 children were obtained during one year of fortnightly home-visits carried out by non-medical interviewers. Recalled information, shown to be inaccurate (3), was not used. Instead the children were recorded as ill or not ill on the day of the homevisit according to their mothers' reports. Illnesses were classified into the main groups of gastroenteritis, respiratory infection and "other illness".

Gastroenteritis was diagnosed if the child had diarrhoea (at least 4 loose stools or one watery stool during the 24 hours) and/or vomiting. Survey procedures and basic data are described elsewhere (2,3).

The proportion (p) of home-visits on which illness was recorded for individual children and for groups of children ($\bar{p}$) was taken as an estimator of illness load in terms of time spent in various states of illness and used as a measure of morbidity for the purpose of this study. In the evaluation of the goodness of this measure, reported elsewhere (3), the pattern of illness occurrence over time was regarded as a stochastic process made up of illness episodes according to their frequency and duration. Matnematical models for this process were suggested and tested by means of data from a smaller supplementary study (3). The derived models served as tools in the evaluation of the study design which yielded satisfactory precision within the frame of available staff and economic resources.

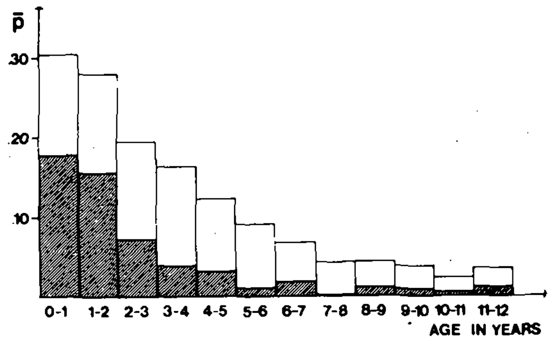
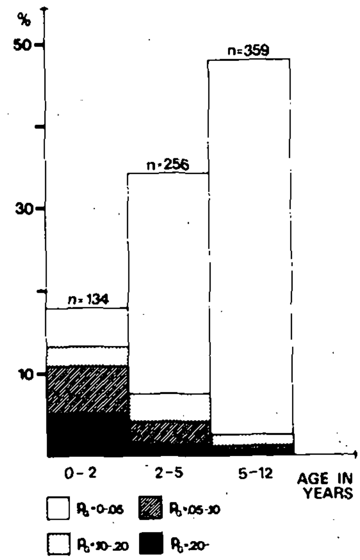


FIGURE 1 (a):
(a): Average total morbidity ($\bar{p}$) by age and the proportion due to gastroenteritis (shaded areas)
(b): Percentage distribution of number of children by age group sub-classified by level of morbidity in gastroenteritis (p_G).



Diarrhoeal disease and age

Fig. 1 reveals large variations in morbidity due to the age factor. The mere quantitative domination of acute illness, in the younger age groups, particularly children under the age of 2 years, identifies these as target groups for preventive and curative health care. Children under the age of 2 years could on the average be estimated to have some kind of illness symptoms during 104 days of the year, out of which 59 days were due to diarrhoeal disease. The corresponding figure in children over the age of 5 years was 4 days of diarrhoea per year (Fig. 1a). A conceptually different approach in the display of morbidity patterns is to regard morbidity not as a continuum but as an ordered categorical variable. Fig. 1b thus illustrates in an even more dramatic way that the younger age groups are responsible for the bulk of diarrhoeal disease. Although , for instance, children under the age of 2 years constitute only 18 % of the total sample of children, almost 60 % of all the children with a morbidity in diarrhoea (p_G) of over 0.20 were found in this group.

Research concepts

The Kirkos study basically deals with the causal structure of child health and attention therefore has to be paid to the conceptual framework and the logic of the research process. Limited knowledge about relevant factors involved in a child health system and their complex interrelationships as well as about their measurement implied that an exploratory research approach be taken. This was seen as a process of inductive reasoning where a basic conceptual model is revised in confrontation with data to create a sound basis for the postulation of formal causal models which can be used by the health planner for the stimation of quantitative effects of health promotion programs. Since health objectives must be assessed in relation to other social goals it was relevant to regard health from a social system point of view. An interpretation of data is in fact impossible without some theoretical assumptions at least about the levels on which different factors operate and about their degree of logical priority in relation to the criterion variable. When drawing inferences from an empirical study, as in case, it is however, important to note that it deals with variables only on the individual and household levels.

Prediction of morbidity

The analyses of variation aimed at the identification of important predictors for morbidity. This was done by means of exploratory methods, the AID, the AID-regression and the THAID methods (4,5), classifying the individuals into disjoint homogeneous sub-groups with regard to the morbidity criterion variable. These methods offer the advantage that they can deal with mixtures of metric and categorical variables, often encountered in materials from developing countries. Among 18 explanatory variables chosen for the analysis, those which expressed hygiene and sanitation were found among the powerful predictors of diarrhoeal disease. As these variables may have a causal relationship to diarrhoeal disease and also may possibly be influenced in practical action programs, they were included in a simple revised model of diarrhoeal disease (Fig. 2) which was the basis for further causal and quantitative considerations.

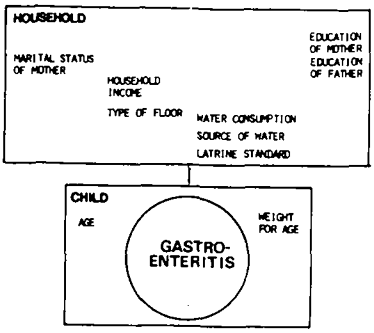


FIGURE 2. Variabls used in a path-analytical model of gastroenteritis.

Attempts to causal interpretation

The finding that a variable is an important predictor is, however, of limited relevance unless this can be given a causal and quantitative interpretation and related to other variables. Path-analysis (6) is an analytical tool that permits a causal interpretation of a postulated model where each dependent variable is related to its postulated determinants by multiple linear functions.

FIGURE 3. Interactions between Latrine standard, Source of water and Water consumption in their effects on morbidity in gastroenteritis (p_G). (a=shared water tap, b=community stand pipe, c=private latrine, d=non-private latrine, e=private latrine. The broken lines indicate divisions made to construct dummy variables for the purpose of the path-analysis).

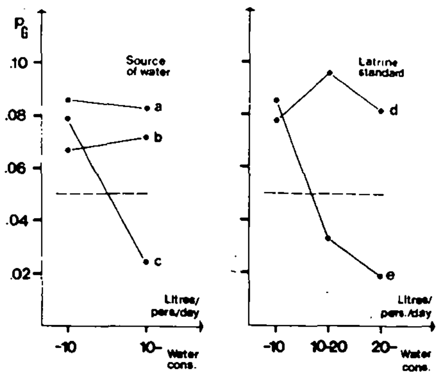
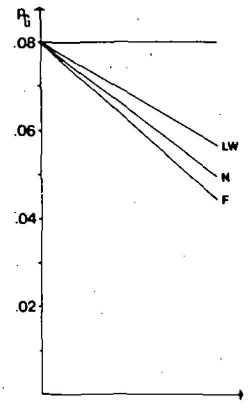


Fig. 3 illustrates that for instance the effect of water consumption on p_G is dependent on what source of water and what kind of latrine are used in the household. These quantitatively important effects were incorporated in the postulated pathanalytic model as special indicator variables. The analysis was perfomed for children under the age of 5 years. Weight for age was considered as the most immediate causal factor, whereas hygiene and sanitation variables were considered to have direct causal effects as well as indirect effects via the Weight-for-age variable on the occurrence of gastroenteritis. Socio-economic characteristics such as income and education were postulated to play most logically a prior role in the causal chain.

Fig. 4, which is based on the results of the path-analysis, illustrates the quantitative implications of maximal changes in some of the variables postulated to be causally related to gastroenteritis. Thus, the provision of private latrines and of at least 10 litres of water per person and day (LW) to all the households would result in a substantial reduction of the rate of gastroenteritis if the causal assumptions are true. Additional but smaller reductions would be achieved if all the children were made well-nourished (N) and if all the houses were provided with proper floors (F).

These examples are given merely to illustrate the quantitative implications of the postulated causal model. A realistic path-model would serve as a useful tool for the health planner in comparing alternative intervention programs in terms of effectiveness and efficiency if combined with cost-functions of the various programs. If the model assumptions are realistic, the empirical data thus imply that nutrition and factors in the field of hygiene and sanitation, as demonstrated by the interaction between "Water consumption" and "Latrine standard", have definite quantitative implications of practical relevance in health planning situations.

FIGURE 4. Hypothetical effetcs of maximal changes in variables causally directly related to morbidity in gastroenteritis (p_G). (see text)



Spread of diarrhoeal disease

This study thus indicates the importance of quantity of water for the occurrence of diarrhoeal disease, whereas the quality aspects of water and the transmission of diarrhoeal diseases were not studied in detail. Some data on the rates of introduction and spread of diarrhoeal disease within the households are, however, available. The households had on an average 0.49 outbreaks of diarrhoeal disease per month. Children under the age of 2 years were the main introducers with 0.42 family outbreaks initiated per child and month against an expected value of 0.17 in relation to group sice and morbidity rates. This group was also most susceptible to secondary infection judging from the secondary attack rates,(36 % against 5 % among children over the age of 5 years). The number of outbreaks initiated by two or more siblings simultaneously was low(multiple introduction rate=1/51) which gives the impression that the major routes of transmission have less to do with food and water borne epidemic spread of these infections than with a low general level of personal hygiene and an improper use of water.

WATER-BORNE INFECTIONS: SOME ASPECTS ON NEW AETIOLOGIES OF INFANTILE DIARRHOEA

Epidemiological studies in different parts of the world have until recently shown that established pathogens were isolated in less than half of the sick children. The discovery of new intestinal pathogens, such as enterotoxigenic bacteria and rotavirus, have re-emphasized the need for an epidemiological approach. The general opinion now seems to be that rotavirus infections are the dominating cause of acute diarrhoea in early childhood in temperate climates during the winter season while the major cause during the summer season is still unknown.

Studies on water-borne infections with Vibrio cholerae in Bangladesh recently showed discouragingly that improvement of public water supplies did not yield a parallel decrease in cholera infections (7). Other enterotoxigenic bacteria (ETB), especially enterotoxigenic E.coli (ETEC), seem to be the major cause of intestinal infections in older children (8). In a report from Africa it was shown that ETEC and other ETB accounted for the majority of diarrhoeal episodes even in early childhood (9). It is tempting to speculate that the immunological cross-reactions between different enterotoxins can cause different levels of immunity in different age groups in endemic cholera areas and countries like Ethiopia which only had a short episode of cholera in 1971 (10).

Cholera and typhoid are the two classical water-borne infections prevented by improvement of water quality, while a great variety of bacterial, viral and parasitic infections belong to the group of "water-washed" infections resulting from lack of water for washing and personal hygiene, i.e. depending on the access to and quality of domestic water (11,12). However, the recent annual report (1975) om water-borne infections in the US recorded that the largest outbreak of watertransmitted infection of known aetiology was caused by an ETEC strain in park water in Crater Lake National Park, Oregon (Crater Lake outbreak).

The ETEC strain was isolated both from the water and from several of the more than 2000 victims of this outbreak (13). This first report of water-borne ETEC and recent reports on the survival of Yersinia enterocolitica, different Campylobacter species and Aeromonas hydrophila "new" human intestinal pathogens in water have not yet led to studies in the tropics or subtropics on the ecology of these organisms in the environment. As in the case of V.cholerae (15), animal reservoirs have been suspected to be important vehicles and sources of human infections.

Seasonal variations in intestinal pathogens

The isolation of intestinal pathogens in children of Addis Ababa during the dry and rainy seasons in 1977 is shown in Table 1. Stool cultures and microscopical examination for intestinal parasites were performed by standard methods (9,14). Enteroviruses and adenoviruses showed a similar distribution in sick children and in a control group and were not further studied. Rotavirusses detected by electron microscopy in specimens transported to Sweden were by far a more common pathogen in the rainy season, while there was no drastic difference in the isolation rates of the other pathogens in the dry and rainy seasons. It should also be noted that despite the new diagnostic procedures for rotavirus and ETEC, putative agents could only be isolated in 28 % of all children with diarrhoea in the dry season compared to 60 % in the rainy season.

TABLE 1. Isolation of intestinal pathogens in children attending the Ethio-Swedish Pediatric Clinic Addis Ababa in March to June 1977.

	Dry season (March-April)		Rainy season (May-June)	
	%	n	%	n
Enteropathogenic E.coli	0,9[1]	1	6,2	12
Enterotoxigenic E.coli (ETEC) and other ETB	5,7	6	7,8	15
Shigella	2,5	3	5,1	10
Rotavirus	11,3	12	34,2	67
Parasites[2]	7,5	8	6,2	12
Total number of patients		106		193

1 Not done in March
2 Giardia and E.histolytica

Water sources and pathogens

The high inoculum dose for both cholera and ETEC (around 10^9 organisms) required to cause infections indicates that a highly contaminated source or sufficient time for replication is needed to achieve such large doses in vehicles of transmission (13). For this reason only food and water rather than person to person contact serve as a means of transmission of diarrhoeagenic ETEC and related coliform pathogens. In contrast, relatively small inocula of invasive enteric pathogens such as Shigella organisms are needed to cause disease. This means that cholera and ETEC infections require grossly unsanitary environments for transmission and for diarrhoeal outbreaks to occur and explains why infections with enterotoxigenic bacteria are rare in countries with a general high water hygiene.

This made us investigate some village water wells in the Addis Ababa area besides the municipal water supply and a few river waters during the dry and rainy seasons. Water samples were transported to the laboratory in refrigerated thermostated cans and subjected to membrane filtration (Millipore, 0.45 mu filters) according to standard procedures. Filters were cultivated on the following media: MacConkey, deoxycholate citrate (DC), thiosulphate citrate bile salts sucrose (TCBS) and ampicillin agars as previously reported for stool cultures (9,14). Isolates of different colony morphology were subjected to oxidase test (for vibrios, Aeromonas and Plesiomonas), to biotyping by the commercial API 20E system and to serotyping for E.coli (EPEC) and Shigella. Strains were put on deep-agar slants and sent to Sweden where they were frozen and stored at -70° C in glycerol borth within one month of isolation.

Table 2 summarizes the results of this study, The municipal water on 4 different occasions was of acceptable drinking-water standard according to WHO (10 coliforms per 100 ml at 43° C) while only 9 of 13 well-water samples and none of the river water taken during rainy and dry seasons were acceptable. Enterotoxigenic bacteria including ETEC and classical enteropathogenic (EPEC) serotypes (O11, O55 and O42) were isolated from both well and river water samples. Five strains of "non-choleravibrios" (Vibrio enteritidis) and more than fifty strains of other oxidase-positive organisms such as Aeromonas hydrophila were alsc isolated; however, only 4 or 5 of these were found to produce enterotoxins in the classical choleratoxin assay (the rabbit intestinal loop test) or in the Y1 adrenal or Chinese hamster ovary (CHO) cell tests (9).

Only five water samples were found to contain Salmonella or Shigella even with enrichment procedures used (14). On the other hand two specimens from a village outbreak (Wollo province) contained Salmonella menek which produced a heat-stable enterotoxin. Further studies on water-borne outbreaks in Ethiopia in collaboration with the Central Medical Laboratory in Addis Ababa (Dr Afework G. Yohannes and Dr Haile Selassie) showed growth of E.coli producing both heat-labile enterotoxin (LT) and heat-stable enterotoxin (ST) in two out of seven outbreaks investigated where Shigella, Salmonella and other conventional pathogens were excluded.

TABLE 2. Occurrence of pathogenic E.coli in different water sources[1]

	Enteropathogenic (EPEC)	Enterotoxigenic (ETEC)	Enteroinvasive
Wells	8/15	5/35	2/10[2]
River water			
dry season	9/10	3/10	0/5
rainy season	5/10	8/10	1/5

[1] Standard procedures on Endoagar (BBL) cultured at 37°and 44° C (for "fresh faecal coliform organism"); 8-10 colonies picked at random from each cultures and assayed for enterotoxins and tested in the CHO cell test for heat-labile enterotoxin.

[2] Measured as invasive properties in the guinea-pig eye Serény test (14); a laborious and expensive test which explains the limited number of isolates investigated.

E.coli as an indicator of water quality

E.coli is a generally accepted indicator organism for evaluation of water quality on an international level (11,12). However, its value has been questioned in recent years. Studies over the past 10 years on the nature of E.coli that can colonize human and animal intestinal tracts by virtue of different colonizing factor antigens (K88 in piglets, K99 antigen in calves and lambs, colonizing factor antigens (CFA) and other factors in human strains) and the fact that certain serotypes are prevalent in harbouring these plasmid-mediated adherence factors makes the issue even more complex. To this should also be added that different serotypes of this water-indicator standard organism are diarrhoeagenic by different mechanisms and fall into at least three groups. The fact that colonizing factors and enterotoxins are plasmid-mediated properties makes this issue even more complex since nonpathogenic strains can probably acquire these intestinal virulence factors in the environment. The selective pressure for such events to occur in waterenvironments is as yet unknown, Studies along these lines are important in the future to obtain a better understanding of the so called "harmless indicator organism E.coli".

Spread of cholera in Africa

Historical notes clearly show that cholera was introduced to Ethiopia in the seventeenth century from India. During the third cholera pandemic (1852 to 1868) the East Africa coast and Ethiopia were infected several times and at least 33 major cholera epidemics originated in Mecca following different transportation routes. The seventh cholera pandemic affected Ethiopia in 1970, later than other areas of East and West Africa, and more recently Tanzania (10).

Studies on the spread of cholera in this epidemic and of non-cholera vibrios in Algerian waters (10) indicate many unique characters related to African waters as a source of infection. For example, the alkaline vater-holes of Somalia and Ethiopia (10) and the brackish coastal-water lagoons of West Africa were found to especially favour growth and survival of cholera vibrios. The diffusion along rivers in West Africa and continuing drought related outbreaks indicate the unique conditions of spread on the African continent compared to countries like India and Bangladesh. Further studies on the ecology of water-borne intestinal pathogens besides cholera vibrios will most probably reveal unique features also for other pathogens.

Development of simple diagnostic procedures (membrane filtration equipment, incubators, biochemical test kits for bacteriology and new filtration and immune methods for rotavirus and other new viral pathogens) will greatly facilitate diagnostic work in a near future. This will also hopefully provide simple tools for evalution of water projects at the village level to ascertain if such projects are successful and contribute to a better health of the population.

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POLLUTED WATER AND CHILDHOOD DIARRHOEA IN JAKARTA, INDONESIA

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Abstract

In many so-called developing countries diarrhoeal diseases and malnutrition are major causes of ill-health and death, especially among infants and young children. Evidence is presented from work done in Jakarta, supporting the view that environmental pollution, especially of water, is a major contributor to such diseases in crowded, tropical, urban environments. Despite contrasts of climate, water supplies and life styles, the "Malnutrition - Diarrhoea Cycle" is also an important problem in remote Australian Aboriginal communities. There is a need for further documentation of the multiple environmental factors causing these disease patterns. Effective preventive health measures will depend on appropriate application of this knowledge in underprivileged communities.

DIARRHOEAL DISEASE AND THE UPPER INTESTINAL MICROFLORA

In Jakarta, as in other cities in South-East Asia, gastrointestinal diseases are major causes of ill-health and death among young children (1). There is little doubt that the high prevalence of gut infections and infestations is due to gross contamination of living conditions in overcrowded Asian cities and towns making diarrhoeal diseases still one of the "Big Three" killers of children in the tropics, along with protein-energy malnutrition and respiratory tract infections (2).

Despite the importance of diarrhoeal diseases in malnourished children in these regions, the pathogenic mechanisms causing diarrhoea are complex and inadequately understood. Recent reports from South-East Asia, Central America and West Africa (3-6) have shown children from these areas have significant bacterial overgrowth in their upper intestines and it has been suggested that this abnormality contributes to diarrhoea in these children (7). The finding of an abnormally profuse upper intestinal microflora in this situation raises other important questions including delineation of the factors which allow such an abnormal flora to become established in the upper gut, an organ which is normally kept relatively free of micro-organisms by the combined effects of gastric acid secretion, intestinal motility, mucus, immunoglobulins and products of bacterial metabolism.

Although it is widely recognized that water supplies in Asian cities are often badly polluted, there is little published quantitative information about the *degree* of environmental pollution in these places. We have some information which documents this problem in metropolitan Jakarta, one of the cities from where bacterial contamination of upper gut secretions in children has been reported.

CONTAMINATION OF SURFACE WATERS IN BATAVIA IN THE 1930s

In 1937, Professor Dinger showed contamination of surface waters by *Salmonella typhi* and *Salmonella paratyphi B* in various parts of what was then called Batavia (8). Dinger's report was accompanied by a detailed map of that city, which is now called Jakarta, showing clearly the twenty sites at which samples were taken from the Ciliwung River which runs through the middle of the city and from adjoining canals which criss-cross the city and suburbs which lie on a flat coastal plain adjoining the Java Sea.

POLLUTION OF SURFACE WATERS IN METROPOLITAN JAKARTA IN THE 1970s

Like many other cities in so-called developing countries, Jakarta has experienced an enormous increase in its population in recent years, partly because of heavy migration from rural areas of Java and from outlying islands in the Republic. This has put a heavy burden on the city's resources including housing, education, employment and the provision of public facilities including water supplies and waste removal. As part of an organized effort to overcome these problems, the Government is sponsoring a transmigration policy to help lessen the ill effects of urban over-population. Meanwhile, the inadequacy of public services tends to perpetuate the health problems of the poorer sections of the community, especially the problem of diarrhoeal disease in young children.

Dinger's findings made 40 years earlier, and the obviously filthy state of surface waters running through metropolitan Jakarta prompted us to repeat his study recently at the same sites which could be readily identified from his map.

Collection of specimens and microbiological technique (9)
Samples of surface water were taken from the Ciliwung River and adjoining canals which are fed from the watershed of Puncak Pass and run through central Jakarta to drain into the Java Sea. 20 ml samples were aspirated with a sterile syringe, injected into a sterile container, secured by a screw-top, frozen and kept at $-20^{o}C$ until the microbiological studies were done 6 to 10 weeks later.

Before cultivation each specimen was thawed at room temperature, passed through a millipore filter (0.45μm pore size) and the filter then washed thoroughly in 2 ml of transport medium (containing 10% glycerol) to resuspend the bacteria. Serial ten-fold dilutions from 10^{-1} to 10^{-5} were made from this mixture into glucose broth. Using standardised pipettes, aliquots were distributed on plates divided into five segments. Specimens were cultured aerobically on horse blood agar, MacConkey's agar and Hektoen-enteric agar plates. Two additional broths, strontium selenite A and strontium chloride, were also inoculated and incubated overnight at $37^{o}C$. Samples from these cultures were then plated onto Hektoen-enteric agar. This technique inhibits the growth of lactose fermenting organisms thus enabling easy detection of small numbers of *Salmonella* and *Shigella*. Organisms were identified macroscopically, microscopically and according to biochemical reactions using the API micro-technique."(Note a)".

Results
All 20 specimens grew large numbers of *Enterobacteriaciae* with individual counts ranging from 1.3×10^5 per 100 ml to 7.9×10^6 per 100 ml (mean = 1.7×10^6 per 100 ml). Fifteen out of the 20 specimens grew *E. coli* (range = 3.1×10^3 per 100 ml to 3.1×10^6 per 100 ml); *Klebsiella* were present in large numbers in 7 specimens, Citrobacter from 4, *E. cloacae* from 5 and *E. agglomerans* from 7. *Salmonella* were isolated from 3 specimens and *Shigella* from one. Various other *Enterobacteriaciae* were isolated from 11 specimens.

Discussion
This investigation showed that large numbers of *Enterobacteriaciae* were recovered from samples of surface waters from widely scattered parts of the city of Jakarta when examined in the early part of a recent monsoon season. This confirmed our suspicions about the polluted condition of these waters and strengthened our suspicion about the importance of this environmental factor in causing a high rate of infectious diarrhoeal disease in young children there; it is probably also closely related to the observation that children with diarrhoeal diseases living there have significant bacterial contamination of their upper intestinal secretions. It must be understood that the Ciliwung River and its tributaries and interlacing canals make an integral part of the life of the city of Jakarta and particularly for the poorer sections of its population many of whom live in inadequate squatter settlements (*Fig. 1 a and b*) and who use the river for washing, laundering, washing food and for the removal of human and domestic waste. The waters are also used by the children for swimming, playing and cooling off from the tropic heat. Such an intimate association with waters which persist in the "foul condition" commented on by Professor Dinger 40 years earlier, undoubtedly contribute very significantly to the heavy load of gastrointestinal infections found there.

SOME OTHER EVIDENCE RELATING ENVIRONMENTAL POLLUTION AND DIARRHOEAL DISEASE

These findings re-inforce the results of an earlier study (10) in which we found a very high degree of bacterial contamination of specimens of water and environmental surfaces in and around the General Hospital in Jakarta. In that study we found very large numbers of micro-organisms (3.1×10^4 to 3.6×10^7 bacteria per ml) in all 7 specimens taken from sites in the Ciliwung River adjoining the hospital in central Jakarta. Enteric pathogens were isolated in 3 out of the 7 specimens; including *Salmonella paratyphi B* and *Shigella flexner*. Six out of 7 of the specimens grew strict anaerobes (2.5×10^2 to 1.0×10^7 per ml) including *Clostridium sp.*, *Bacteroides sp.*, peptostreptococci and gram-negative curved and spiral rods. Specimens from various sites in suburbs surrounding the hospital had 1.9×10^3 to 1.8×10^8 micro-organisms per ml. Four out of the 9 specimens grew enteric pathogens, five grew *E. coli* and five grew anaerobes. There was also heavy faecal pollution of environmental surfaces examined in the children's gastroenteritis ward, acting as a potential source of serious hospital cross-infection.

Obviously, it is difficult to causally relate, environmental pollution with diarrhoeal diseases which are largely a heterogeneous collection of infectious disorders. It is interesting, however, to note the very significant degree of bacterial contamination of

Note a: API(TM) Analytab Products Inc., New York upper intestinal secretions in children with diarrhoeal disorders in Jakarta when compared to a group of well nourished, city dwelling, Australian white children with a variety of underlying gastrointestinal disorders (3). The Indonesian children had a marked increase in the numbers of micro-organisms isolated from aspirates of upper intestinal juice as shown in Table 1 while in Table 2 the types of micro-organisms found are shown.

Fig. 1 a and b. Typical riverside squatter encampments underneath a bridge crossing the Ciliwung River, Jakarta. This is one of the sampling sites included in this study.

The potential clinical importance of bacterial contamination of the upper intestine in such children with malnutrition is unclear. Many of the micro-organisms isolated from these children in Jakarta, as seen in Table 2, are not generally considered to be enteric pathogens. However, doubts have recently been cast on the relevance of traditional tests of enteric pathogenicity (11) while our knowledge of the potential for enterotoxin production appears to be progressively extending to include such micro-organisms as *Klebsiella*, *Enterobacter* (12) *Aeromonas serriata* and *Proteus* (13). With that in mind we performed a series of experiments in laboratory animals to investigate this question further.

In one series of experiments, the effect of micro-organisms contaminating the upper intestinal contents of malnourished children on the intestinal absorption of sugar and fatty acid was studied in rats *in vivo* (14). Micro-organisms isolated from upper intestinal aspirates of children in Jakarta were grown aerobically overnight in a 1% peptone broth in Krebs-Henseleit buffer (15) at 37°C. The resulting broths were centrifuged at 1,000 g for 30 min. and the supernatant (with micro-organisms present in similar numbers to those in the human intestinal aspirates) used as the basic solution for the experiments. In another series of experiments the bacterial supernatant was millipore filtered to produce a cell-free filtrate. For the control experiments the culture medium was treated in exactly the same way but with the bacterial inoculations omitted. The solutions contained 2 mg/ml of polyethylene glycol 4000 as a non-absorbable marker of intestinal water movement; the substrates used were 20 mM 3-0 methyl-α-D-glucopyranose (3-MG) a non-metabolized analogue of D-glucose and the fatty acid, oleic acid made up as a micellar solution at a concentration of 1 mM with 15 mM sodium taurocholate. The osmolality of test solutions was 283 ± 23.5 mOsm/kg. The effects of bacterial suspensions and their cell-free filtrates on intestinal sugar absorption are shown in Table 3.

TABLE 1.* Small intestinal microflora in 21 Australian children and 20 malnourished Indonesian children

	Gram positive bacteria	*Candida*	Entero-bacteria	Faecal bacteria	Total Aerobes	Anaerobes	Total Organisms
Controls							
L_1	1.7	0.1	0.5	0.1	2.2	1.9	2.2
Mean	2.3	0.5	1.1	0.6	2.8	0.1	2.8
L_2	2.9	0.9	1.7	1.1	3.4	0.3	3.4
Range[a]	$0\text{-}4x10^4$	$0\text{-}1.3x10^3$	$0\text{-}3.2x10^4$	$0\text{-}2x10^3$	$0\text{-}5x10^4$	$0\text{-}7.9x10^2$	$0\text{-}5x10^4$
Indonesian patients							
L_1	3.8	0.7	3.7	0.6	4.6	0.9	4.6
Mean	4.8	2.4	4.5	1.4	5.5	2.0	5.5
L_2	5.8	4.1	5.3	2.2	6.4	3.1	6.4
Range	$0\text{-}1x10^8$	$0\text{-}2x10^6$	$0\text{-}1.3x10^9$	$0\text{-}4x10^6$	$0\text{-}1.3x10^9$	$0\text{-}1x10^8$	$0\text{-}1.3x10^9$
P	<0.005	<0.025	<0.0005	0.3<*P* <0.35	<0.0025	<0.05	<0.0025

Results indicate populations of various species and total flora expressed as the $\log_{10}$ of the mean viable colony count per milliliter of specimens. Upper and lower limits of these populations determined at the 95% confidence level using a standard method of logarithmic transformation.

[a] Arithmetical

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TABLE 2.* Bacterial contamination of the upper intestine in 20 Indonesian children with malnutrition and diarrhoea

Organism	No. of isolations $> 10^4$/ml	Range $\log_{10}$ organisms/ml
Coagulase-positive *Staphylococci*	8	0-7.8
Other *Staphylococci*	9	0-7.0
Haemophilus influenzae		
Corynebacterium sp.		0-3.9
Candida sp.	8	0-6.3
Escherichia coli	7	0-8.0
Klebsiella sp.	3	0-8.9
Pseudomonas sp.	5	0-8.6
Salmonella paratyphi	2	0-4.4
Shigella sp.	1	4.1
Other *enterobacteria*	8	0-8.7
Aerobic lactobacilli	4	0-5.7
Streptococcus faecalis		0-3.5
α-Haemolytic *Streptococci*	4	0-6.1
β-Haemolytic *Streptococci*		
Other *Streptococci*	9	0-8.0
Anaerobes	6	0-8.0
Total flora	18	0-9.1

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TABLE 3.* Effect of bacterial suspensions and their cell-free filtrates on intestinal absorption of 20 mM 3 methyl glucose in closed jejunal loops *in vivo*

Organism	Bacterial suspensions		Cell-free filtrates	
	Absorption**	p	Absorption**	p
Controls (27)	1.34 ± 0.16			
Gram positive cocci				
Staphylococcus aureus (5)	0.86 ± 0.16	<0.0125	1.00 ± 0.22	<0.0025
Streptococcus faecalis (6)	1.20 ± 0.10	<0.025	1.12 ± 0.22	<0.0125
Enterobacteriaciae				
Non-pathogenic *E. coli* (6)	1.14 ± 0.16	<0.01	1.20 ± 0.14	<0.05
E.coli 055 (6)	1.02 ± 0.30	<0.01	1.22 ± 0.20	n.s.
E.coli 0111 (4)	0.98 ± 0.14	<0.0005	1.24 ± 0.10	n.s.
Salmonella paratyphi B (6)	1.34 ± 0.14	n.s.	1.40 ± 0.10	n.s.
Shigella sonnei (6)	1.36 ± 0.18	n.s.	1.22 ± 0.18	n.s.
Proteus sp. (6)	1.28 ± 0.10	n.s.	1.24 ± 0.10	<0.05
Klebsiella sp. (5)	1.32 ± 0.28	n.s.	1.12 ± 0.20	<0.01
Gram negative rod				
Pseudomonas sp.	1.26 ± 0.12	n.s.	1.16 ± 0.20	<0.0025
Candida species				
Candida albicans (6)	1.16 ± 0.10	<0.0025	1.00 ± 0.24	<0.0025
Candida parapsilosis (6)	1.20 ± 0.10	<0.0125	1.20 ± 0.08	<0.005
Candida tropicalis (6)	1.10 ± 0.08	<0.0005	1.30 ± 0.10	n.s.

** Absorption expressed as μ moles 3-M.G. absorbed per cm of intestine. Results are given as means and standard deviations. Figures in parentheses indicate numbers of experiments.

n.s. = not significant

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Inhibition of sugar absorption occurred with bacterial suspensions of *Staphylococcus aureus*, *Streptococcus faecalis*, *E. coli* and *Candida sp.* and with cell-free preparations of *Staphylococcus aureus*, *Streptococcus faecalis* a non-pathogenic *E. coli*, *Proteus sp.*, *Klebsiella sp.*, *Pseudomonas sp.* and *Candida sp.* The effects on oleic acid absorption are shown on Table 4.

TABLE 4.* Effects of bacterial suspensions on intestinal absorption of 1 mM oleic acid in closed jejunal loops of anaesthetized rats *in vivo*

Organism	Absorption^Δ	p value
Controls (9)	1.40 ± 0.16	
Non pathogenic *E. coli* (6)	1.38 ± 0.10	n.s.
E. coli 0111 (4)	1.30 ± 0.12	<0.025
Salmonella paratyphi B (10)	1.10 ± 0.02	<0.0005
Shigella sonnei (6)	1.08 ± 0.18	<0.0005
Candida albicans (6)	1.24 ± 0.12	<0.0025
Candida tropicalis (7)	1.16 ± 0.14	<0.0005
Candida parapsilosis (6)	1.08 ± 0.24	<0.0025

Δ μ moles of oleic acid absorbed per cm of intestine. Results are given as means and standard deviations. Figures in brackets indicate numbers of experiments.

n.s. = not significant

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Oleic acid absorption was unaffected by non-pathogenic *E. coli* but decreased by *E. coli* 0111, *Salmonella paratyphi B*, *Shigella sonnei* and *Candida sp.* However, these apparent effects could be explained by intestinal secretion diluting the test solution leading to a decreased diffusion gradient for solubilized fatty acid. The effects on intestinal sugar absorption could not be explained in this way.

In a more recent series of experiments (16) the possible effects of intestinal micro-organisms on fluid and electrolyte transport across the small intestine were investigated. These results are shown in Tables 5 to 7.

TABLE 5.* Effect of cell-free culture filtrates on net flux of water** after perfusion^Δ of rat jejunum *in vivo* for 1 hour.

Organism	Number of experiments	Mean net water flux from lumen (S.E. in parenthesis)	p value
Controls	10	0.041 (0.001)	
Gram positive cocci			
Staphylococcus saphrophyticus	12	0.007 (0.003)	<0.0005
Streptococcus faecalis	12	0.049 (0.001)	n.s.
Enterobacteriacae			
Non pathogenic *E. coli*	6	0.051 (0.002)	n.s.
E. coli 055	9	-0.047 (0.003)	<0.005
E. coli B7A	12	0.023 (0.001)	<0.0025
Salmonella paratyphi B	12	0.042 (0.001)	n.s.
Shigella sonnei	12	0.020 (0.001)	<0.005
Klebsiella pneumoniae	11	0.001 (0.002)	<0.0025
Candida species			
Candida albicans	11	0.022 (0.002)	<0.0025
Candida tropicalis	11	0.019 (0.001)	<0.0005

** Expressed in ml per cm intestine per hour (S.E.M.)

n.s. = not significant

Δ Perfusion flow rate = 2 ml per minute

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TABLE 6.* Effect of cell-free culture filtrates on net water flux after after perfusion** of rat jejunum *in vivo* for 15, 30 and 60 min.

Organism	Net water flux from lumen (ml per cm per h) 15 min.		30 min.		60 min.	
Controls	0.055	(0.003)	0.055	(0.001)	0.051	(0.001)
Gram positive cocci						
Staphylococcus saphrophyticus	**0.020**	(0.001)	**0.018**	(0.001)	**0.016**	(0.003)
Streptococcus faecalis	0.062	(0.003)	0.056	(0.002)	0.053	(0.002)
Enterobacteriacae						
Non pathogenic *E. coli*	0.058	(0.003)	0.060	(0.002)	0.058	(0.004)
E. coli 055	**0.022**	(0.002)	**0.015**	(0.001)	**-0.033**	(0.002)
E. coli B7A	**0.034**	(0.002)	**0.025**	(0.002)	**0.013**	(0.001)
Salmonella paratyphi B	0.063	(0.004)	0.048	(0.003)	0.049	(0.001)
Shigella sonnei	**0.022**	(0.001)	**0.012**	(0.002)	**0.005**	(0.001)
Klebsiella	**0.018**	(0.001)	**0.008**	(0.001)	**0.001**	(0.004)
Candida species						
Candida albicans	**0.039**	(0.003)	**0.031**	(0.001)	**0.029**	(0.002)
Candida tropicalis	**0.041**	(0.003)	**0.029**	(0.002)	**0.022**	(0.001)

** Perfusion flow rate = 10 ml per min.

Δ Significant difference from control values p<0.01 are underlined

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Decreased net movement from the intestinal lumen or actual secretion of water, sodium or potassium into the intestinal lumen was observed with *Staphylococcus saprophyticus*, *E. coli* 055, *E. coli* B7A, *Shigella sonnei*, *Klebsiella*, *Candida albicans* and *Candida tropicalis*. These observations would seem to add weight to the suggestion that when a profuse, mixed bacterial microflora becomes established in the upper small intestine (as in children with malnutrition) that various micro-organisms exert their combined, harmful effects on intestinal transport mechanisms thus contributing to diarrhoea in this situation.

TABLE 7.* Effect of cell-free culture filtrates on net intestinal flux of sodium and potassium after perfusion of rat jejunum *in vivo* for 1 h.

Organism	Mean net ion flux (μmoles per cm per h) from lumen (S.E. in parenthesis) Sodium		Potassium	
Controls	6.16	(0.11)	0.29	(0.08)
Gram positive cocci				
Staphylococcus saprophyticus	2.41$^{\Delta}$	(0.21)	0.01$^{\Delta}$	(0.008)
Streptococcus faecalis	7.27	(0.13)	0.20	(0.004)
Enterobacteriacae				
Non pathogenic *E. coli*	6.45	(0.14)	0.18	(0.004)
E. coli 055	-5.23$^{\Delta}$	(0.13)	-0.33$^{\Delta}$	(0.006)
E. coli B7A	2.73$^{\Delta}$	(0.12)	-0.06$^{\Delta}$	(0.006)
Salmonella paratyphi B	5.44	(0.16)	0.12	(0.009)
Shigella sonnei	5.89	(0.22)	0.11	(0.008)
Klebsiella	-0.34$^{\Delta}$	(0.30)	-0.13$^{\Delta}$	(0.002)
Candida species				
Candida albicans	3.12$^{\Delta}$	(0.16)	0.05$^{\Delta}$	(0.009)
Candida tropicalis	0.41$^{\Delta}$	(0.12)	-0.13$^{\Delta}$	(0.01)

Δ Values that are significantly less than control ($p<0.05$)

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OROPHARYNGEAL MICROFLORA

When studying the microflora of mouth and throat secretions we found enteric bacteria not normally present there quite commonly in Aboriginal and Indonesian children in whom malnutrition is prevelant and whose living conditions are poor (17). We have since found the microflora reflects faecal pollution of living conditions. Rates of isolation of enteric bacteria were higher (42%) when comparing Aboriginal children from remote and arid areas of the Great Victoria Desert and Kimberley Region of far northern Western Australia to rates in well nourished white children in Perth (9%) (ref. 9).

THE DIARRHOEA-MALNUTRITION CYCLE AND THE ENVIRONMENT

Amongst the factors which cause diarrhoeal diseases in young children, environmental conditions clearly play an important role. The studies reported here have attempted to relate bacterial contamination of the upper gut and its potentially harmful effects on intestinal absorption and nutritional status with the faecal pollution of living conditions for poor sections of the community in metropolitan Jakarta. The evidence presented suggests that this type of pollution can be readily identified in communities of young children by examining the bacterial flora of their oropharyngeal secretions. On this basis, groups of young Australian Aborigines and Indonesian children have been shown to have significant contamination of their mouth and throat secretions when compared to well nourished white children living in the suburbs of Perth, Western Australia. It is interesting to consider contrasts in living conditions between the Aboriginal and Indonesian children. The Aboriginal subjects were living in remote, semi-desert parts of Western Australia, mostly in sub-standard housing while the Indonesians were mostly from squatter or slum settlements in central Jakarta, in an area of very heavy rainfall situated almost on the Equator. Very little is known of the cleanliness of water supplies for these Aboriginal communities and it remains to be seen if they are significant potential sources of gastrointestinal disease as are the waters in Jakarta.

It is interesting to speculate on the real importance of polluted water supplies in determining disease patterns in such groups of underpriveleged children. Water plays a major part in the day to day lives of young children in Jakarta and is related to regular epidemics of gastrointestinal disease, including cholera, in that city during the floods of the monsoon season. Its importance as a potential source of endemic intestinal infections in semi-desert dwelling Australian Aborigines, where water supplies are quite restricted, may be much less and other sources of contamination including food, feeding bottles and eating utensils may be more important. More studies are needed to document the relative contributions of these environmental factors in such communities where intestinal infections are major health problems especially among infants and young children.

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ASSESSMENT AND CONTROL OF WATER QUALITY IN A TOWN DISTRIBUTION SYSTEM WITH REFERENCE TO THE INCIDENCE OF GASTRO-INTESTINAL DISEASES

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1.0 INTRODUCTION

In the town of Aurangabad located in the state of Maharashtra in India, there had been recurrent outbreaks of enteric diseases. At the instance of the Government of Maharashtra, the National Environmental Engineering Research Institute, Nagpur carried out investigations at Aurangabad in 1972 to scientifically assess the possibility of pollution existing in the public water supply system, which could have bearing on the outbreak of infectious hepatitis and other gastro-intestinal diseases that occurred recurrently, and in epidemic form in 1972.

The scope of the studies consisted of:

(i) engineering and sanitary survey of water sources and especially water distribution system (which includes waste flow assessment, leakage survey and control);

(ii) chemical and bacteriological survey of the quality of waters in distribution system and supply sources;

(iii) collection of epidemiological data, and conducting random survey of houses for disease incidence, and

(iv) formulation of recommendations, if any, and the effectiveness of possible control measures.

Aurangabad, a district headquarters town and a centre of tourist attraction, located about 300 km north east of Bombay, has grown into a large town with a population of 1,550,000 and was receiving 3.0 to 3.5 million gallons per day of water supply (13.5 to 15.8 million litres per day) drawn from two main lakes Harsul and Kam (situation as in 1972) and treated in conventional rapid gravity sand filtration system followed by chlorination. The supply is distributed to the town through overhead reservoirs.

2.0 MATERIALS AND METHODS

Multifaceted approach namely, sanitary survey, engineering studies (leakage assessment, detection and control in water distribution), chemical and bacteriological survey of the water system and random epidemiological survey were carried out in four pilot water distribution zones for a period of four months. (Fig. 1).

Guided by the relative incidence rate in different areas given in the epidemiological data provided by the State Health Department, four pilot distribution zones with total population of 15,000 and covering an area of 0.582 square miles were selected for pilot investigations. One of the zones, zone No. 4 had few recorded infection cases, while the other three were "affected" areas.

Table 1 provides the basic data for the pilot zones.

3.0 OBSERVATIONS

3.1 Sanitary survey

The catchment areas of the main sources Harsul and Nahar Ambari were free from human habitation. A survey of the distribution system revealed the following facts. Service connections and service mains in the different areas including the "affected" pilot zones revealed extremely unsatisfactory conditions. The branch pipes or lateral pipes providing connections to house service pipes run parallel to and below the drains carrying sewage and sullage. Many of these pipes made of galvanised iron were corroded.

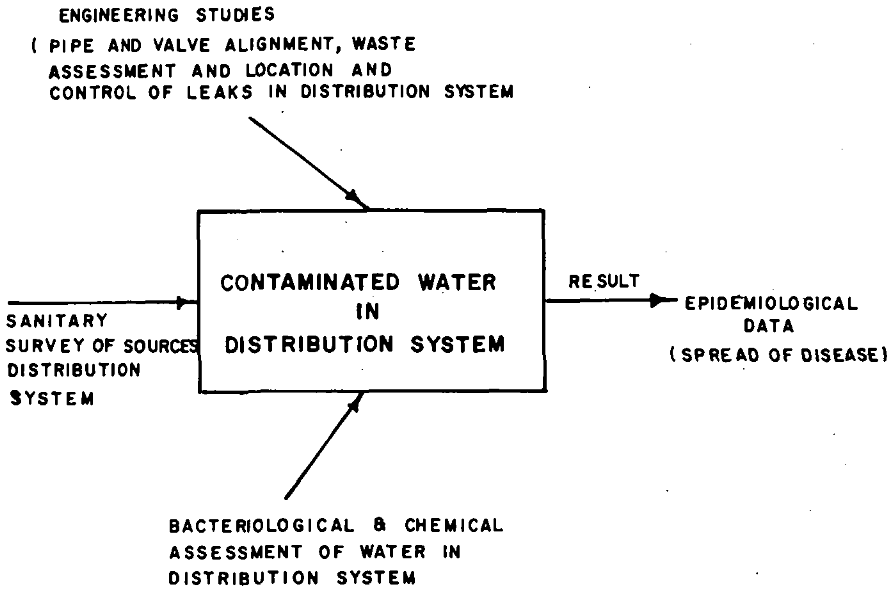

Fig. 1. Multidisciplinary approach and deduction.

Table 1. Data for the pilot zones of Aurangabad

Zone No.	Area of Zone Sq. miles	Total population	No. of house connections	Name of the areas
1	0.196	6177	377	Chelipura and Shahbazar.
2	0.200	4218	222	Aurangpura, Nageshwarwada and Kumarwada.
3(A&B)	0.097	4138	202	Saraswati Bhuwan Colony & Dalalwadi
4	0.089	687	60	Samarthnagar.

Due to non-commissioning of sewerage system (as in 1972), domestic wastewaters were led into open drains. Many of the service pipes cross these drains at the surface or below the drain bottom, and children are seen defecating over the service pipes.

The low pressures existing at the taps in many areas and the intermittent nature of supply to the town had forced consumers to dig pits (or construct small masonry tanks near or below the ground level) and collect water in buckets near the pavement of road after breaking the house connections. The pipes were not plugged during non-supply hours, where by the stagnant water in the pits could possibly re-enter the pipelines during non-supply hours. The splashing of water from the pits and drains can result in the contamination of the collected water in buckets.

3.2 Epidemiological survey

A fact finding survey of the incidence of gastro-intestinal diseases in the pilot zones can reveal a possible correlation of "polluted" water and the disease incidence, taking into account also the environmental factors.

The random survey in each of the zones was done (in collaboration with State Health Department) by visiting every fourth household in each zone and the information was gathered from one of the families in each household by personal interview of the history of incidence of disease, symptoms and entered in a standard proforma. Only, the incidence distribution and the period and duration of the disease were included in the random survey. In addition, the epidemiological statistics of the State Health Department based on hospital records were also made use of. Tables 2A and 3 present the epidemiological statistics of Aurangabad of State Health Department and the results of the random survey respectively, while Table 2B shows the reported cases of diseases in the areas constituting the pilot zones.

The total cases recorded in Aurangabad till April, 1972 were 719 (Table 2A) for a population

Table 2A Statistics of epidemic outbreaks in Aurangabad (reported)* number of attacks

Year	Cholera	Infectious hepatitis	Enteric fever
1970	266	nil	nil
1972 (upto April)	nil	719	106

Table 2B Number of cases of infectious hepatitis and enteric fever in selected areas*(reported)

Name of area	Infectious hepatitis	Enteric fever
Nageshwarwadi ..	9	13
Aurangpura ..	49	13
Saraswathi colony ..	37	3
Dalalwadi ..	16	11
Kumbarwada & Rangargali ..	62	-
Chelipura ..	27	10
Sahahbazar ..	12	37

* From State Health Department, 1972 up to April.

Table 3. Incidence of infectious hepatitis, typhoid and gastro-ententis in the pilot zones for the period December 1971 to June 1972 based on random sample survey

Zone no.	Total population	No. of household	Population surveyed	Number of cases		Percentage* total occurence of cases	
				Infectious Hepatetis	Gastro ententis and typhoid	Inf. Hep.	Gast. Ent.
1	6177	50	255	14	12	5.0	5.0
2	4218	60	330	25	9	8.0	3.0
3	3210	55	303	56	11	18.0	4.0
4	687	8	44	2	nil	5.0	nil

* Percentage occurrence of cases: $\frac{\text{Total number of cases in the zone}}{\text{Population surveyed in the zone (Random)}}$

of 1,500,000 which works out at 0.4 percent.

The random survey (Table 3) revealed an attack rate for infectious hepatitis of 5.0, 8.0, 18.0 and 5.0 in zones Nos. 1, 2, 3 and 4 respectively. The incidence of enteric fever was also high in the zones except zone No. 2.

Referring back to the epidemic of infectious hepatitis that occurred in Delhi in 1956, the attack rate was 2.05 percent of all the population of all areas provided by Municipal Water Supply, and the massive infection occurred simultaneously in all the areas supplied by municipal supply. The source was traced to the highly polluted water contaminated by intermixture of sewage with water at the source supplying water to Delhi.

In Aurangabad, the distribution of infectious hepatitis and enteric fever was uneven, and the overall attack rate was low. This factor naturally leads to the hypothesis that the sources of water supply or water treatment works were not mainly responsible for the transmission of disease.

The chloride concentration of raw water at Aurangabad was 20 mg/l, while during the epidemic eposode at Delhi the chloride concentration rose sharply to 90 mg/l. It is, therefore, surmised that low incidence and uneven concentration of cases of infectious hepatitis may be mainly due to the possible fecal contamination occurring in the distribution system. This was also substantiated by the sanitary survey and the results of bacteriological analysis of water samples from distribution system.

3.3 Chemical and bacteriological assessment

The waters at the sources are moderately turbid (9 to 40 units) with suspended solids varying from 80 to 180 mg/l and total dissolved solids 200 to 300 mg/l. Chloride and sulphate content are low. The waters do not appear to be highly polluted at the source.

In selected taps and public standposts in the pilot zones and elsewhere the samples of water were collected aseptically during the first flush after the water supply is released and also minutes after the first flush in the water system, and examined for total coliforms, fecal coliforms, fecal streptococci and Salmonella group. Residual chlorine in the water samples were also determined simultaneously. The water supply was usually released in the morning hours lasting for 2 to 3 hours.

The residual chlorine in water during first flush from all the taps was nil; and high counts of coliforms and fecal coliforms (500 to 5000 or more per 100 ml) were present (exceeding sometimes the WHO recommended limits even for raw water for public water supply) in Zones nos. 1 and 2. Waters collected 10 minutes after the first flush also showed the same characteristics. (Table 4).

Few of the taps in the zones showed the presence of Salmonella, indicating the ingress of fecal pollution in the main or service pipes during non-supply hours.

Table 4. Bacteriological quality of waters from the distribution system

Organisms	Zone no	No. of samples examined	No. of samples with count equal to 0	0-100	>100
Coliforms	1	15	6	4	5
	2	26	8	15	3
	3	16	12	3	1
	4	5	4	1	0
F.Coliforms	1	15	7	4	4
	2	26	13	10	3
	3	16	13	3	0
	4	5	4	1	0
F.Streptocci	1	15	5	9	1
	2	15	11	11	4
	3	16	10	6	0
	4	5	5	0	0
Salmonella	1	11	1 positive,	10 negative	
	2	17	2 positive,	15 negative	
	3	8	------	8 negative	
	4	-	-------	---	

The waters just after leaving the treatment plant and reservoirs did not show the presence of indicator organisms.

Subsequently, when the chlorine dose was raised, residual chlorine could be detected in many taps with the absence of indicator organisms.

The main and service pipes must have been partly filled with contaminated water due to back syphonage through leaks in mains, service pipes etc. during the non-supply hours. Some of the areas are low lying and the polluted water entering the mains and pipes at places of higher elevation gravitate to lower areas.

As was revealed by the presence of coliforms, fecal coliforms and fecal streptococci in the tap waters during the initial period of survey, the water in the distribution system and service pipes of same zones was receiving contamination due to suction of extraneous polluted water, through leaky joints, corroded holes etc. during non-supply hours. In these zones, high incidence of infectious hepatitis was noted; while in the control zone 4, most of the samples collected did not reveal the presence of indicator organisms.

3.4 Engineering survey

Detailed engineering investigations were carried out in the four pilot zones (Fig. 2) to collect data relating to the wastage of water through leaky mains and fixtures in the distribution system, the nature and location of leaks and to study the feasibility of controlling or reducing leakages.

The average per capita consumption in each zone was measured initially by a revenue meter serving a group of 10 houses, and found to vary from 9.5 to 12.5 gallons per capita per day in the three "affected" zones.

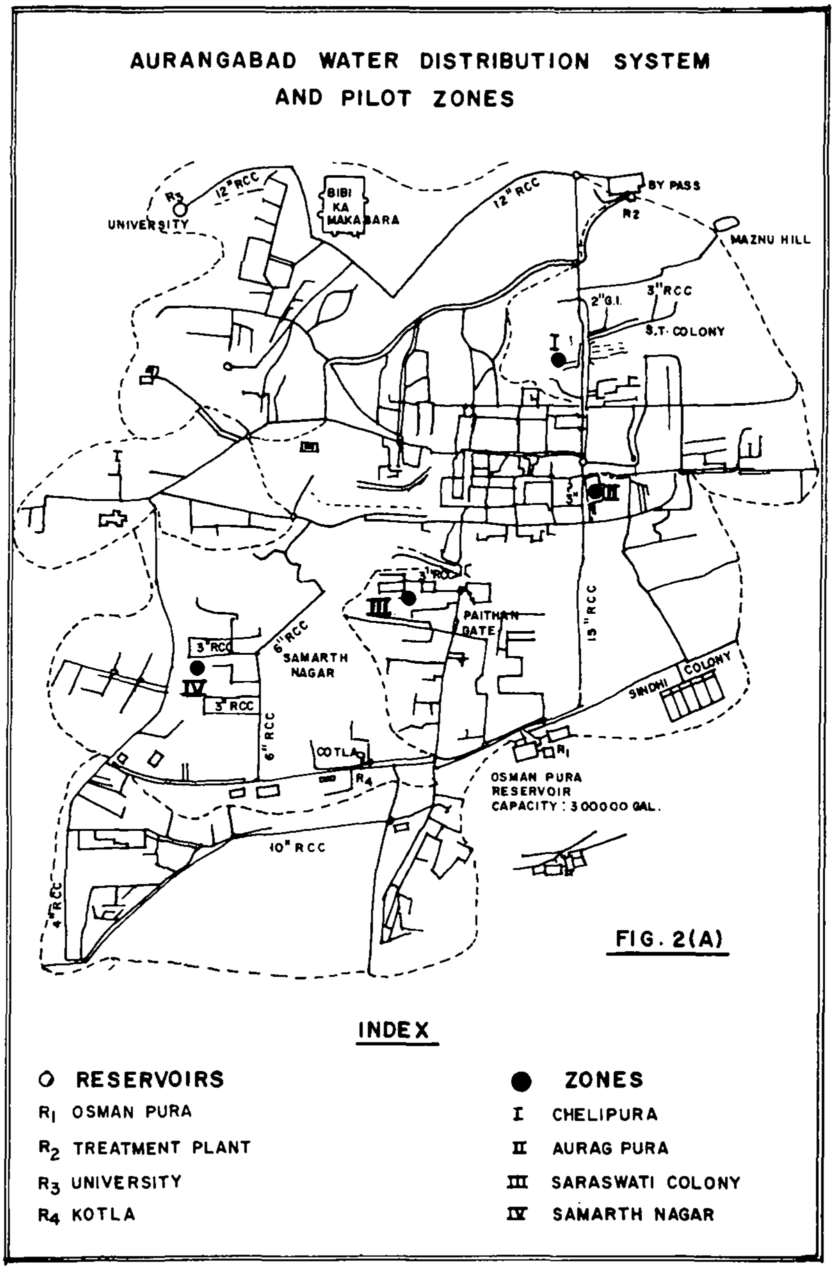

Fig. 2A.

Each zone was first checked for hydraulic isolation from the rest. For measuring the waste-flow (unaccounted for water) in the zone, the flow was by-passed through a meter (Kent's mobile waste flow meter recorder) by means of two hydrants, hose pipes and controlled by a bypass valve. All the boundary valves except the inlet valve were closed and the house connections were plugged. The water was then gradually led into the zone bypassing through the meter. The consistently recorded flow was considered as the waste flow in the zone due to leaks in pipes and service connections. By stepwise closing of intermediate valves, it was possible to ascertain the leakage in each leg of pipeline between valves; and later the underground leaks were detected and pinpointed by means of sounding rod and electronic leak detector during midnight when the system was energised. The leaks were repaired, and it was possible to bring down the leakage level by 60 to 70 percent. This could also result in improved flow in the houses.

Table 5 shows the data and results for the four zones. Most of the leaks occured in distributory laterals, house service pipe and ferrule connections. With an average per capita supply varying from 8 to 12 gallons per day, about 1.5 to 2.5 gallons per capita per day could be saved by prompt leakage control when supply was restricted to 3½ hours. In the control zone No. 4, the number of leaks noticed were only two, while in the others they varied

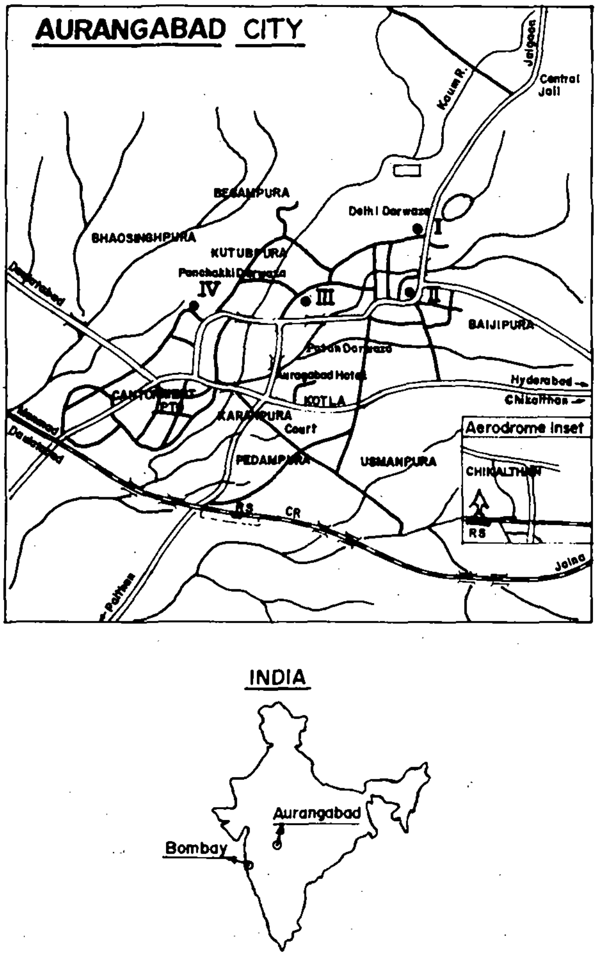

FIG. 2 (B)

Fig. 2B.

from 12 to 35.

4. CONCLUSIONS

The multi-faceted approach such as bacteriological survey, sanitary survey, random epidemiological survey and engineering studies point towards the contamination of water in the distribution system which could be one of the causes for the epidemic of infectious hepatitis and other gastro-intestinal diseases in Aurangabad.

The uneven distribution of the occurrence of infectious hepatitis in Aurangabad (unlike the uniform distribution of cases occuring all over Delhi in the infectious hepatitis epidemic episode of 1956) may be attributed to the localised contamination of the water system in the zones where the leaks are predominant, and where the crossings of the pipes and drains occur.

The bacteriological investigations reveal that the water in the distribution system in some of the zones is contaminated by extraneous pollution due to ingress of sewage or polluted water entering the pipelines through leaks due to suction during non-supply hours in the

Table 5. Waste flow in distribution before and after control in pilot zones (excluding consumer premises)

Zone No.	Population souls	Per capita water supply gpd	Measured waste flow gph	Final measured waste flow after leak repairs gph	Per capita saving in water after leak repairs gpd	Remarks
(1)	(2)	(3)	(4)	(5)	(4)-(5) / (2) x hrs of supply	*
1	6177	12.5	6300	2800	1.98	
2	4218	9.5	3600	1200	2.00	
3A	2276	9.5	4100**	2660	2.21	
3B	1862	9.5	4000**	2800	2.24	
4	687	19.5	1200	-	-	

*: Hours of supply: 3.5
**: Few connections were suspected to be open
Average % leakage: 30
Per capita waste flow: 3 to 3.5. gph
gph: gallons per hour
gpd: gallons per day

intermittent system of supply being practiced over there.

The contamination in some cases was so high that even enteric pathogens like Salmonella could be detected (in addition to fecal coliforms and fecal striptococci) in tap waters during the initial period of supply, while the residual chlorine was nil.

The engineering survey revealed that 20 to 30 percent of the water meant for the consumers was going to waste through leakages in main pipes and communication or service pipe, and it was possible to bring down the waste level by 60 to 70 percent. Most of the leaks occurred in corroded service pipes and ferrule joints in the three "affected" zones 1, 2 and 3. Prevention of waste flow through leakages in the distribution has, therefore, economic as well as public health benefits.

5. RECOMMENDATIONS

1. The municipality should take measures to supply water at adequate pressure throughout the day.
2. Early commissioning of sewerage system and collecting all the domestic sewage and sullage to sewers can mitigate the possibility of polluted water entering the house service pipes which cross or embed below drains carrying at present sewage and sullage.
3. Systematic and routine programme of survey and control for leakages in mains and service pipes should be carried out.
4. Installation of mobile or booster chlorinators at intermediate points in the distribution system will be extremely useful in taking care of any subsequent entry of pollution.
5. All the wells which are used during the scarcity period should be sanitary protected and disinfected.
6. At regular intervals, there must be a systematic programme of replacing the house service pipes (usually of galvanised iron pipe) which are corroded.

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THE SURVIVAL OF VIRAL PATHOGENS IN WATER AND WASTE IN THE TROPICS

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Abstract

The factors influencing the persistence of viruses in the environment are reviewed with special attention to tropical situations. The viruses of tropical waters are the same types as found in other areas. The higher rate of thermal inactivation in warm climates may more than compensate for the possible higher load of viruses in waste waters. Composting may be an efficient method for destroying virus in sludges and faecal wastes.

INTRODUCTION. It has been a great challenge to compile information about the survival of viruses under tropical conditions in water and waste. Virology is a rather young science, although viral diseases have been known since the beginning of historic times. The methodology of the virology calls for rather specialized people, patience, equipment and a lot of money. The quick and easy methods are not yet there, so it is no wonder that literature dealing with the special tropical problems is scarce. If specific information on viruses is hard to find, it seems obvious to look into the literature on bacteria and on organic loads and from there deduce or guess about the fate of viruses, although it is known that viruses do not behave like the bacterial pathogens. After having scanned a mountain of papers one has to admit that not much came out of this effort, because the one necessary parameter, that might make the material useful was missing: The temperature. There is a lot of discussion about the importance of temperature, but next to no indication of the actual temperatures. It has been a lesson in the importance of stating all "trivial" data when describing an experiment or writing a report. The following report is not a complete review of the subject. It is an attempt to quote pertinent examples from the different fields of study.

CLASSIFICATION OF VIRUSES. The human viruses as we know them to day are grouped in the following families

TABLE 1. Virus families

DNA viruses	size in nm	RNA viruses	size in nm
1. Poxviridae	200-300	6. Reoviridae	75- 80
2. Herpetoviridae	100-150	7. Retraviridae	100
3. Adenoviridae	70- 90	8. Paramyxoviridae	150
4. Papovaviridae	40- 50	9. Ortomyxoviridae	100
5. Parvoviridae	20	lo. Rhabdoviridae	175
		11. Bunyaviridae	90-100
		12. Togaviridae	20- 70
		13. Coronaviridae	70-120
		14. Arenaviridae	100
		15. Picornaviridae	20- 30

This is not the place to go into a more detailed description, but without mentioning the diseases involved or the different genera and types included it is stille possible to make a practical grouping among the viruses according to their stability in the environment. Thus three groups may be identified: I. The ones that are extremely labile and normally only can cause infections by direct contact or through aerosols. These viruses are in the families 2, 7, 8, 9, 10, 11 and 12 of Table 1. The group could be exemplified by mentioning influenza viruses (no. 9), herpes viruses (no. 2), all sorts of arboviruses (essentially nos. 11 and 12) e.g. yellow fever virus, denque virus and a number of encephalitis viruses that belong especially in the tropical rain forest, rabies virus (no. 10), Lassa fever virus and other viruses causing fatal hemorrhagic fevers (no. 14) and many others. These sometimes highly pathogenic viruses must normally get right into the blood stream through bites or open lesions of the skin and they are so labile, that they do not have to be mentioned in connection with a review of problems connected with contamination of the environment.

II. Another group contains the viruses that withstand drying more or less well and thus may be transferred passively and cause infection even after having been dried out under natural environmental conditions. This group include 1, 4, 5 and probably 13 of Table 1. They are not especially important in connection with water pollution as they are not faecally excreted. There are not so many viruses known to be pathogenic to man in this category and they are essentially species specific. An example would be the virus of hepatitis B (serum hepatitis) of man, another the virus of smallpox which may become extinct in the near future.

III. The remaining viruses are more stable than the ones of group I, but do not withstand drying like the ones of group II. They belong to the families 3, 6, 14 and 15.

Enteric viruses. The viruses that are excreted with faeces belong to group III. They are all quite stable at acid pH. They could not otherwise have become enteric viruses because they would have been destroyed by the acidity of the stomach. Several of the more than a hundred different types of human enteric viruses: Adenoviruses, reoviruses and enteroviruses (a genus of picornaviruses) have frequently been found in domestic waste waters, in fact practically every time somebody has made a serious effort to detect them. This could theoretically be expected. The virus of infectious hepatitis (hepatitis A) may be present in faecally polluted water also, but no method for its cultivation exists so far.

Only viruses that may cause disease in man has been mentioned, but different animal species, especially other mammals, have each their own set of the same types of viruses as mentioned for man. They are species specific to a high degree and are potentially at least as important as the human enteric viruses spread by the water route, but this is not the occasion for a discussion of viruses other than the human ones.

We do not really know why the climate influences the occurrence of the enteric viral diseases the way it does. Perhaps a more direct contact among people is a result of the warmer climate. The respiratory viruses are prevalent in the temperate zones in the early winter. This is perhaps typical for aerosol transmitted virus infections.

THE EXCRETION OF ENTERIC VIRUSES

It is characteristic for enteric virus infections that the number of clinically mute infections by far exceeds the ones with clinical symptoms. An example from Ghana (1) could be used to illustrate this quite generally occurring phenomenon: By taking faecal samples from randomly selected infants every two months it was shown that in 18 months the average healthy child had 4 enterovirus infections and nearly half of the store samples were positive throughout the year. Among 156 isolates 25 different enterovirus types were identified and a few remained unidentified. Among the isolates were all three types of poliovirus (no vaccinations had been performed), three types of coxsackievirus and 19 types of echovirus. From Thailand (2) it is reported that during a three year period 557 faecal samples were virus positive out of 1823 collected from healthy preschool children at a rate of 50 samples per month. Polioviruses, coxsackieviruses A and B were found as well as echovirus strains and a number of strains that were not identified. Altogether 45 serotypes of enteric viruses were identified and more than 30 types including the three poliotypes were found each year.

The findings of these two reports must be considered quite typical for the warm climates. It is the same types of viruses that may be found in a material from temperate zones, both in America (3) and Europe (4), but it is possible that a higher number of different viruses may be present at the same time in the tropical area. In the tropical areas the presence of enteric viruses is a all year round occurrence with perhaps about the same concentration of virus throughout the year. Epidemiological signs indicate the same thing. In the temperate zone the enteric viruses, as judged from the epidemiological evidence, is an occurrence of the late summer (e.g. 5), but it has been demonstrated both in Scandinavia (4) and Israel (6) through studies of the occurrence of virus in waste water that the viruses may be present all year round, although with a peak concentration in the late summer. It remains to be decided whether the frequence of clinical cases reflects a higher load of viruses in the water in the tropical areas. The reported figures do not necessarily support this assumption. From U.S.A. a figure of 820 PFU gal^{-1}. i.e. around 250 infectious units (IU) l^{-1}, has been reported as a maximum from sewage (7), from India and Israel (6) 10^{6} IU l^{-1}, South Africa (8) 10^{5} l^{-1} and Scandinavia (4) 10^{5} ID l^{-1}. It is not possible to deduce anything decisive from these figures, because the methods employed may be quite different in efficiency, and we have at best semiquantitative methods so far. It must, however, be safe to assume the highest figures obtained, i.e. 10^{6} IU l^{-1}, as the minimal amount for tropical waste water. It must also be taken into account, that the daily water consumption in some difficult areas is from less than 20 l per person, when no piped supplies are available, to 40-50 l with piped supplies, whereas the European-American consumption may be 300-500 l per day. The uneven distribution of water between seasons and areas makes the streams, if they exist at all, consist perhaps totally of waste water with very high BOD values. Taking into consideration all these factors it may not be unrealistic to assume that a waste water in a tropical area may contain 10^{7} infectious units of enteric viruses per liter.

VIRUSES IN DRINKINGWATER. Conventional waste water treatment in the temperate zones does not give an effluent free from viruses, although the reduction obtained may be of the order of 2-3 log units or perhaps even more. The situation in a number of underdeveloped, especially tropical areas of the world is different. If there is sewage there is often no treatment. In some areas waste water is not released into streams, because it is used directly on the fields (9). In other areas the streams consist in the dry season of undiluted waste water (9).

As the situation is to day in tropical areas the domestic water comes from untreated sources which have been polluted by untreated waste waters. The results of a Ghana report (10, 11) may illustrate this situation, although it seems likely that a much higher virus load is in fact present than the one demonstrated: In two deep wells sampled no virus was demonstrated, but in 10 out of 33 rivers, streams, ponds, shallow wells, and puddles used for drinking water, viruses were demonstrated.

From knowledge accumulated from Western history we are inclined to believe that the most important problem of all is the hygienic quality of the drinking water. The bacteriologists are concerned about faecal bacteria in the environment, because a number of the enteric bacteria may multiply outside the human intestinal tract given proper conditions in terms of humidity, temperature and nutrition. This is not the case for viruses. Outside the living cell the virus either remains intact or it may lose infectivity. Statements like: "A direct relationship between safe water supplies and high standards of public health is not obvious and undisputed" (12) may now be found. Maybe the quantity rather than the quality of water available is the most important factor. From Ghana it was reported (1) that improvements in lavatory facilities, but not in the quality of water supplies reduced the rate of virus excreter in the community.

INACTIVATION AND REMOVAL OF VIRUSES

The natural inactivation or purification processes in water are very complex phenomena. Among the factors influencing the content of virus in water are (in addition to the concentration of viruses) temperature, pH, UV-light, adsorption to and sedimentation with suspended matter and a number of biological processes probably connected with bacterial and other biological activities. The nature and kinetics of most of the processes are not yet elucidated.

Among the known enteric viruses the adenoviruses and in many cases the reoviruses are more sensitive than the enteroviruses. Therefore, it will be sufficient to deal with the enteroviruses in the following discussion.

Temperature. The rate of inactivation of enteroviruses is extremely dependent on temperature. The activation energy for spontaneous activation varies very much with the temperature in the range 0^{o}-50^{o}C (e.g. 13, 14). It seems that at least at temperatures around 50^{o}C the spontaneous inactivation has to do with protein denaturation.

TABLE 2

Rates of thermal inactivation of enterovirus (13, 14)

Virustype	Activation energy	temperature range	Q_{10}	Temperature range for Q_{10}-value
Poliotype I	17,000 cal	5-37	2,6	20-30
"	34,000 cal	25-55	6,8	20-30
"	56,400 cal	25-55	19	30-40
"	67,500 cal	37-50	35	30-40
Poliotype II	76,500 cal	37-50	56	30-40
Poliotype III	106,000 cal	37-50	267	30-40
Coxsackie B_5	88,000 cal	37-50	103	30-40
Coxsackie B_3	56,400 cal	32-35	19	30-40

Within each type of enterovirus there are pronounced strain differences in thermal inactivation, but for all viruses there is a very steep curve for the temperature dependence of the spontaneous inactivation. Thus from 2 hours to 3 days may be required for one log unit reduction at 37°C and consequently something like 2 days to 60 days may be required at 27°C with sufficient humidity and a neutral pH. At 50°C and at least at e.g. 60°C most enterovirus strains will be inactivated within a few minutes in water at pH 7. Within the range of pH from 5-9 the thermostability remains essentially the same. Outside that range and especially fast at a high pH the rate of inactivation increases.

As a consequence of the important temperature dependence of virus inactivation it is to be expected that virus in a tropical climate would be inactivated very fast. Unfortunately, the inactivation rate is also very much dependent on the organic load of the water. As an example it could be mentioned, that at 32°C around 3 log units reduction in infectivity was obtained in 2 weeks for coxsackievirus suspended in 10 per cent calf serum, while the infectivity of the same virus was reduced by 6 log units in the same time when the suspension medium was buffered saline (15). As waste water probably could not have a higher load of organic material than 10 per cent serum, it seems possible to conclude that the rate of inactivation of virus suspended in heavily polluted water may be at least around one log unit in 5 days at 32°C and at least one log unit in 1 day at 35°C.

UV light has an important virus inactivating capacity, but the penetration power through turbid water is very limited. No data seems available from field investigations.

Adsorption to and sedimentation with solids. There is evidence accumulating through many reports (e.g. 16, 17 and 18) that in tropical areas properly managed stabilization ponds, especially if 2 or more ponds are used in series, may give at least the removal efficiency of activated sludge systems in the temperate zones and may work with much higher loads. It is reported (19) that the BOD reduction may be from 1000 mg l^{-1} to 25 mg l^{-1}, and the reduction in faecal coliforms may be from 4 x 10^7 per 100 ml to 100 per 100 ml. From New England it was reported (20) that excellent removal of faecal coliforms could be obtained in summer time, but viruses could even then be demonstrated in the effluent. From South Africa it was reported (8) that treatment in a maturation pond system could reduce the virus load from 4400 infectious units per liter to 10 per liter.

In an experimental holding pond system (21) in Texas it was found that some poliovirus attach to solids and sediment within 6 days. During summer over 99% of added virus was lost in the water within 5 days. About 10 per cent of the virus was found in the sediment, but after 2 weeks in summer time virus could not be recovered from the sediment. In winter time the virus of the sediment survived with unchanged titer for more than 7 weeks.

Biological or biochemical virus inactivation. In digesting sludge (15, 22) in sea water (e.g.23), in sanitary landfills (24), in activated sludge and probably in a number of other situations where it could be suspected that activities from microorganisms play a role viruses are inactivated faster than could be expected from spontaneous thermal inactivation. Little information exists as to the nature of these processes.

The persistence of virus infectivity in soil and on vegetables. Land application of waste water seems attractive especially as a final treatment and in areas with water shortage. In the winter in temperate zones around (around $0^{o}C$) virus may survive e.g. 5 months in the topsoil (25); a 5 log unit reduction in 5 months was demonstrated. Transcribed to $20^{o}C$ that might mean a 5 log unit reduction in perhaps one month, whereas the same reduction at $30^{o}C$ might be obtained in perhaps a few days (Table 2).

In Cincinnati, Ohio, at 20^{o}-$30^{o}C$ the virus reduction in soil was around 1 log unit per day and virus could be demonstrated on vegetables at around 14-36 days after exposure to virus seeded effluents, but not later (26). The vegetables had been exposed to spray irrigation for 4 consecutive weeks with concentrations of virus of around 10^{5} per ml. added to sludge or secondary effluents. Visible particulate material was retained on the plant surfaces. There were "extensive periods of direct sunlight, high temperatures and periodic rainfalls" during the crop seasons. The temperature on the soil surface was observed to be as high as $45^{o}C$ during the warm afternoons. It seems important to stress that the virus load of the water or sludge employed was around 10^{8} infectious units per l, i.e. higher than the one suggested in this review for waste water. On the other hand the method employed for virus recovery may not find viruses that were bound to solids, so the results obtained may be pertinent to the question of survival times for viruses on vegetables irrigated with waste water or sludge. In a report from the Sovjet Union only obtained as an abstract (27) and a table it was reported that fruits and vegetables obtained at a public marketing place was contaminated with viruses in detectable amounts in 41 out of 457 samples. Coxsackieviruses of types A9, B3 and B5 were found as well as echoviruses type 7, 8, 11 and 19, i.e. the corresponding types to the ones that have been isolated from all parts of the world in faecally polluted materials.

VIRUSES IN WASTES

Viruses are protected to some degree against the inactivating effects of drying and heat treatments by a high concentration of organic matter, so it is very difficult to give exact figures for the resistance of viruses under varied environment conditions from laboratory experiments. The viruses resistent to drying are not very resistent against inactivation at elevated temperatures. Also the way a material is dried influences the infectivity as many producers of freezedried vaccines have experienced. Sludge digestion may take place at $30^{o}C$ in tropical areas without heating and as mentioned virus inactivating factors develop during digestion as well as in sanitary land fills. It seems possible to assume that the treatment at $60^{o}C$ with an exposure time of 10 min. suggested for the decontamination of night soil (28) in order to destroy the parasites, may be quite efficient in destroying most of the viruses present. From China it is reported (29) that the biogas systems are efficient in destroying E.coli (a 3-4 log unit reduction) and a number of parasites. It would appear reasonable to assume an important reduction in the virus load at the same time, but no data are available on this point.

Composting. A great many publications have appeared on composting and on the effect of composting on pathogens (30). The temperatures mentioned are essentially 50-$70^{o}C$, but no examinations for viruses have apparently been carried out. The conclusions by several authors that $70^{o}C$ for an extended composting period would be sufficient for the destruction of pathogens, can, however, be accepted to include most viruses as no sterilization, but a substantial decrease in the load of infective viruses is required. The County Sanitation Districts of Los Angeles, Calif., are composting anaerobically digested, centrifuged primary sludges in the windrow process (31). It is sometimes difficult to obtain a sufficiently low level of salmonellas to meet the Californian standards. The final bacterial contents are caused by regrowth in the compost. The virus content was reduced below detectable limits. Thus it is for once shown that it may be possible to have a virus free material which contains intestinal bacteria. In all other cases the problem is that water or sludge may be free from bacteria, but, due to the generally higher resistance of viruses the absence of bacteria does not guarantee the absence of infective human pathogenic viruses.

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in the process of cleaning up the environment, the water supply factor becomes more important

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SANITATION VERSUS IMMUNIZATION IN CONTROL OF ENTERIC AND DIARRHOEAL DISEASES

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Abstract - In the control of cholera, typhoid, dysentery and other enteric and diarrhoeal diseases, both sanitation and immunization are used. Each of them have some advantages and disadvantages in certain circumstances and in certain epidemiological situations. The decision-makers have to adapt the control strategy to actual situation in circumstances in order to obtain the highest health benefits for the efforts and resources invested.

The effect of immunization is temporary and disease specific. Immunization in fact represents from an economic point of view, provision of consumable commodity, while sanitation, such as provision of potable water, and safe excreta disposal, is capital investment of permanent value. Investment in sanitation has a cumulative effect as more resources are allocated to it. However, in order to obtain the best possible health benefits from the investments in sanitary facilities, there is need to make efforts that these facilities are properly and extensively used and also well maintained. This requires some investment in health education, and possibly some other items such as drainage of used water, provision of soap etc.

The simple methods, as well as complex ones such as mathematical models are available and should be used for evaluation of alternative strategies for control of enteric infections based on sanitation or vaccination. Cost-effectiveness and cost-benefit analyses will indicate the relative value of these two control measures. The actual studies carried out in developing countries along these lines point out to the higher effectiveness and more favourable benefit cost-ratio of sanitation than vaccination in control of enteric infections.

1. INTRODUCTION

Sanitation and/or immunization are applied for the control of enteric fevers, dysentery, cholera and other diarrhoeal diseases.

Sanitation (for the purpose of this presentation means environmental sanitation) provision of safe excreta disposal supported by health education aimed at appropriate use and maintenance of sanitary facilities. Various components of sanitation such as: (a) safe excreta disposal; (b) provision of safe water, and (c) food control can be blended with health education and/or personal hygiene in various ways and degrees both as their quality and their quantity is concerned. Thus sanitation programmes of different intensity and effectiveness for control of above diseases can be set up at varying costs.

Immunization (for the purpose of this presentation means active immunization) against specific diseases with an effective vaccine. Typhoid, paratyphoid B and anticholera vaccines are widely used in public health practice. There are also the vaccines against bacillary dysentery and B. coli infections but they are not available for large scale use. Some are still in the experimental stage. Immunization is therefore limited only to enteric infections listed above and number of other diarrhoeal diseases are not affected by vaccination.

Each of the above two control methods has certain advantages and drawbacks in specific epidemiological circumstances. As said above, the effect of immunization is limited to enteric fevers and cholera, while sanitation covers all diseases of "dirty hands" and "poor hygiene".

It seems logical therefore, in order to proceed with the comparison of the effect of sanitation versus immunization, to compare effectiveness of these two control measures against those diseases for control for which both measures are applicable.

The comparison of the effectiveness of these two control measures should be considered in the context of the real epidemiological situations as they are evolving and changing with time. Such comparison proves to be useful in decision-making processes and formulation of the programmes for enteric and diarrhoeal diseases control.

2. MEASUREMENT OF THE EFFECTIVENESS AND THE BENEFITS

In the measurement of the effectiveness of a control programme the morbidity and mortality rates (in the absence of reliable indices for positive health) are taken as a most important indicator of health benefits derived from the preventive measures. Some control measures bring, besides health benefits, also other (namely economic) benefits, such as increased productivity and gains in trade and tourism.

While the incidence rates of specific diseases and of undifferentiated diarrhoeal diseases can be accurately assessed through an effective diseases surveillance, the measurement of other health benefits besides disease prevention and of economic benefits is rather difficult, as many health and economic factors are interrelated.

Effectiveness of the control measures will be expressed in terms of decrease of incidence rates and the other health benefits, for obvious reasons, will be expressed rather in descriptive unquantifiable terms. Economic benefits of above preventive measures will be express quantitatively mainly in terms of savings on treatment, while other economic benefits will be expressed in descriptive terms.

In the measurement of the effectiveness, of the cost-effectiveness and of the cost-benefit of various control programmes of typhoid[1] and cholera[2] we have used epidemiological models[1,2] which enable simulation of the trends of the diseases without and with application of certain control programmes. The epidemiological models are relatively complex but they provide rather precise projections of the incidence and then also for the cost and benefits of certain control programmes. On the other hand, simple nomogrammes which we have developed for rough determination of cost-benefit balance points of sanitation[3] and immunization[4] give approximations and only for a short period of time (a year or so) while models are suitable for long term projections. These methods can, of course, be alternatively used in the practice in view of the aims of the analysis, available facilities and the degree of accuracy required.

In this paper, we will refer in particular to the epidemiological models as they seem to be a suitable tool for the measurement of the relative effectiveness, costs and benefits of sanitation and immunization programmes.

3. COMPARISON OF THE EFFECTIVENESS AND THE BENEFITS

As said above, the comparison will first be made for specific diseases for which both immunization and sanitation is applicable and then the totality of enteric and diarrhoeal diseases will be considered.

3.1. Diseases for control of which immunization and sanitation are applied

3.1.1. Enteric fevers. *Vaccination* against enteric fevers, namely against typhoid and paratyphoid are effective as shown in numerous controlled field trials[5]. These vaccines protect in the first year about 80% of those immunized and then immunity gradually decreases, but in general terms it can be said that the routinely used vaccines protect over 50% for a period of 5 years or more.

Sanitation has been shown to have an effect on enteric infections although it is difficult to quantify it as the epidemiological conditions differ. However, available evidence[6,7] seems to indicate that it is reasonable to assume that provision of sanitary privies e.g., would decrease the transmission for 50% or so for an indefinite period.

Effectiveness, cost and *benefits* of vaccination programmes in control of typhoid in general terms is comparable to the effectiveness, costs and benefits of sanitation as it can be seen from a study carried out by means of epidemiological model in view of the situation in W. Samoa. The projected effect on incidence, cost and benefit (expressed in terms of savings on treatment only) of the two control measures applied in a period of 30 years are shown in the self explanatory Fig. 1. It goes without saying that this applied strictly to the place and time concerned as in different places and epidemiological situations the simulated trends of incidence costs and benefits would change.

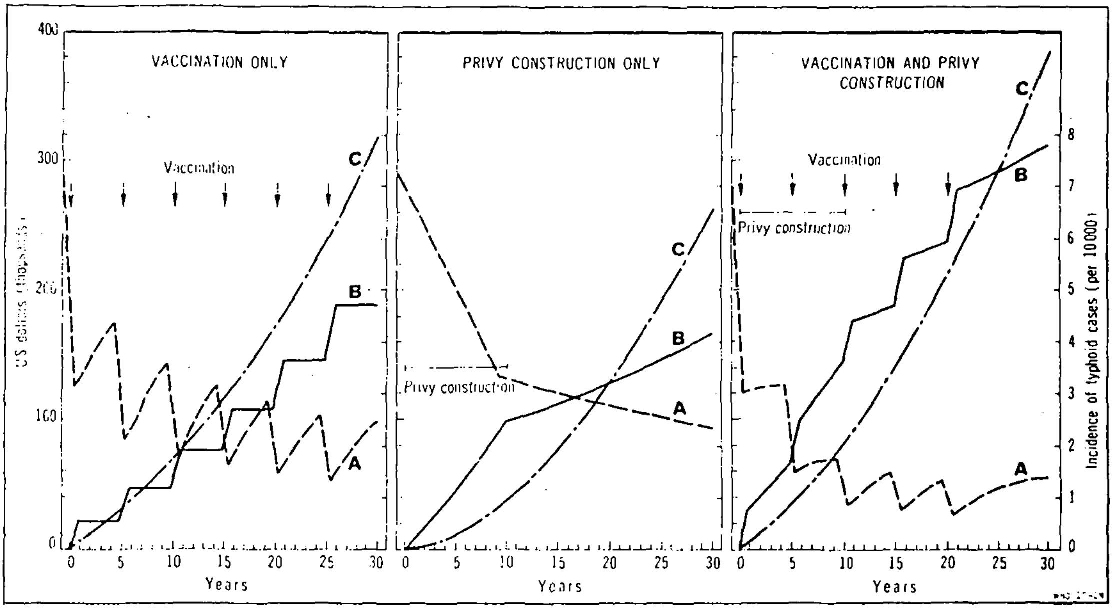

Fig. Impact of different typhoid control programmes on the incidence of the disease and on the cumulative costs and benefits.
(A) = incidence of typhoid cases (per 10,000 population);
(B) = cumulative costs; (C) = cumulative benefits. *per capita* cost of immunization US$ 0.20 - vaccine efficacy: 80%, immunization coverage 75%; sanitation US$0.50; treatment US$100.00.

The reason that immunization when compared with sanitation in the control of typhoid is so favourable is long lasting immunity after administration of the typhoid vaccine. Nevertheless in the long run, sanitation becomes more cost-effective as resources put into sanitation represent lasting investment, while those put in vaccination because of its temporary effect more resemble the purchase of consumable goods.

The relative merits of the two control measures in cholera are quite different.

3.1.2. Cholera. *Vaccination* against cholera with routinely used vaccine is of low effectiveness. It gives about 50% protection for 6 months or so[8]. However, it can be considered that one dose of vaccine every year would be sufficient to control cholera during that year in view of its seasonal character. Immunization against cholera, although vaccine is rather inexpensive in view of the short duration of immunity turns out to be, per year and per capita, several times more costly than the one against typhoid.

Sanitation has been proved definitely effective in control of cholera. In one particular controlled study, construction of sanitary privies, as well as the provision of safe water supply have brought about 50% reduction of infection each year in a cumulative way. When the provision of sanitary privies and safe water were combined, the results were somewhat better and ultimately led to the eradication of the infection[9].

Effectiveness, costs and benefits of immunization and sanitation have been studied and the data of one of our simulations with the epidemiological model[2] for the period of 10 years are presented in the self-explanatory Table 1.

The costs have been taken as in 1971 in some developing countries. The costs since have changed. It goes without saying that in other areas and at other times, the values would change and therefore no general conclusion should be drawn from the above table except that in a programme when both sanitation and vaccination are applied, it seems that sanitation contributes much more to the control of the disease than vaccination. In the long run, sanitation is both more effective and less costly than immunization.

3.1.3. Bacillary dysentery and other diarrhoeal diseases. *Vaccination* against bacillary dysentery is effective[10] but because this vaccine is a live one and difficult to make, maintain and administer, it is not used on a large scale in public health practice. The vaccine protects hardly for a year and does not prevent the carrier state[11]. Therefore, its effectiveness is rather limited for a relatively high cost and it cannot compete with sanitation.

TABLE 1. The total number of cases of cholera and costs of treatment and control measures over 3650 days in a community of 1,000,000 population

Control measure	(1) No. of cases	(2) No. of cases pre-vented	(3) % Prevented	Cost per million population (US$)[a]						(11) Cost per prevented case of cholera (9)/(2)	Benefit(+) or loss(-) resulting from preventive measure (5)-(9)
				(4) Hospital treatment	(5) Hospital treatment saved	Preventive measures			(10) Total expenditure (4)+(9)		
						(6) Vaccination	(7) Sanitation	(9) Total cost of prevention			
none [b)]	112,215	0	0	274,840	0	0	0	0	274,840	0	0
vaccination(V)[c]	2,960	9,255	76	66,604	208,236	750,000	0	750,000	816,604	81	-541,764
sanitation(S)[d]	2,552	9,663	79	57,423	217,417	0	150,000	150,000	207,423	16	+ 67,417
V + S	784	11,431	94	17,644	257,196	750,000	150,000	900,000	917,644	79	-642,804

[a] *Per capita* cost of hospital treatment: US$ 25.00 (90% of patients receive this treatment)
vaccination: US$ 0.10
sanitation: US$ 0.15

c Annual incidence rate about 12 per 10,000. The force of infection is assumed to remain unchanged. Vaccine efficacy: 70% at beginning: vaccination coverage:75%.

d 5% reduction in force of infection per annum.

Sanitation, on the otherhand, has proved to be very effective against bacillary dysentery and other diarrhoeal diseases [6,7,12,13]. It appears, therefore, that in the control of dysentery and other diarrhoeal diseases, sanitation is far more effective than immunization so that there is practically no choice but to utilize sanitary measures in control of these diseases.

3.2. Other enteric and diarrhoeal diseases

Health statistics show that most of intestinal infections and diarrhoeal diseases are not diagnosed as being typhoid, cholera, or bacillary dysentery and that there are many more undifferentiated diarrhoeal diseases caused by various microorganisms and their toxins[14]. For them there is no vaccine available but there are sanitary measures to prevent them as well as an effective treatment[15].

For the prevention of these diseases, which actually make the majority of all enteric and diarrhoeal diseases, there is no other effective control measure but environmental sanitation, food control and personal hygiene.

One can, perhaps, rightly make the general statement that for the totality of enteric and diarrhoeal diseases, sanitation is more rational, more effective and more beneficial a control measure than immunization.

4. DISCUSSION

The meaningful analysis of the advantages of immunization over sanitation and vice versa is only possible in view of actual strictly defined field conditions. If vaccination might be considered as a very rapid method of bringing a disease like cholera, or typhoid, under control and sanitation to be a rather slow acting process and costly one in one case, in another case, e.g. of a water-borne outbreak, chlorination of water supplies will act more rapidly and cost less than immunization. In certain cases, where food is shared among families, carried around and kept unprotected, provision of sanitary privies may have less effect than in areas where this is not the case. In many instances, it would be harmful to consider control of an outbreak or endemic situation in the light of a dilemma: either vaccination or sanitation. Both could be applied for good reasons. For example, in an area with endemic typhoid, vaccination can be used to start with in order to make an initial impact on the disease and in the meantime set up an intensive sanitation programme. While it is obvious that these two measures are not mutually exclusive, it is not rational either to use them always combined as often one of them does not add much to the control. For example, in a water-borne outbreak, there is no room for immunization. It is difficult to decide whether groups of people like travellers or soldiers going to an endemic area should be immunized or should instead depend entirely on sanitation to protect themselves from the infection, or should do both.

Every control programme must be set up according to the epidemiological situation. The effect of investments in sanitation greatly depends on the human factor, namely, on the proper use and maintenance of the available sanitary facilities. Therefore, health education should be considered as an important part of sanitation programmes. On the other hand, it must be made certain that a sanitation programme such as provision of water supply does not create conditions favourable for the spread of diseases, e.g. when water is provided without drainage and is spilled around creating conditions favourable for insect breeding and for contamination of food etc.

5. CONCLUSIONS

Conclusions on the relative value of sanitation and vaccination in control of enteric and diarrhoeal diseases perhaps can be best presented in a table form for brevity and easy reference. These are given in Table 2, below:

TABLE 2. Summary presentation of the effectiveness, cost, health and economic benefits, advantages and disadvantages of sanitation and vaccination in the control of enteric infections

Criteria of comparison		Vaccination	Sanitation
Effectiveness		- 50-80% protection against *specific infections** - *short* duration of protection, constantly declining	- 50% or so against *all enteric infections* - *long* lasting protection with cumulative effect
Cost		- initially relatively *cheap* - maintenance with repeated boosters with several specific vaccines *very costly*	- initially relatively *expensive* - maintenance relatively *cheap*
Benefits	Health	- decrease of *specific infections** for short period of time	- decrease of *all enteric* infections for *long* period of time
	Economic	- prevents undue losses in *trade and tourism temporarily* - has *little effect* on *economic development*	- facilitates and promotes *trade and tourism permanently* - *promotes economic development*
Advantages		- *immediate* effect - Initial cost: *low*	- *long lasting* effect - *cumulative* effect - *promotes* general and especially *economic development*
Disadvantages		- *short-lasting* effect - gives a sense of *false security* - maintenance costs *high* - strict specificity of vaccine requires surveillance and/or surveys	- initial investments *high* - if not supported by public cooperation, health education and economic development, is likely to become ineffective

The general conclusion that can be drawn is that sanitation is to be considered always as a method of choice for control of enteric and diarrhoeal disease unless there is evidence that immunization for some reason would prove more effective, e.g. in travellers and other special high risk groups. Sanitation acts upon many more enteric diseases than immunization and it brings various other health and economic benefits besides control of these diseases.

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THE SURVIVAL AND TRANSMISSION OF *V. CHOLERAE* IN AN ARTIFICIAL TROPICAL ENVIRONMENT

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Abstract
An outbreak of cholera on a South African gold mine involved individuals who were associated, either as trainees or as staff members, with the acclimatization centre. This centre generated a tropical microclimate for the purpose of acclimatizing new underground workers to high environmental temperatures. The hypothesis that *V. cholerae* could be seeded into the environment of the climatic chamber by the sweat of healthy faecal carriers, and recirculated by steam droplets and water of condensation, was confirmed by the experimental demonstration that *V. cholerae* not only survives for considerable periods of time but also multiplies readily in human sweat, tap water and other fluids found in this particular environment. It is believed that these findings are of potential importance in cholera epidemiology in the tropics as 'low dose excretors' may be 'high dose disseminators' and water supplies may be contaminated by healthy carriers other then via direct faecal contamination. Further studies are in progress to define more clearly the role of sweat from heat-acclimatized versus non-acclimatized individuals, as the sweat samples in the present series were uniformly alkaline. The high pH, together with high Na and Cl values, provided excellent conditions for *V. cholerae* survival and multiplication.

INTRODUCTION

Cholera, as predicted, was introduced into South Africa in 1974 by mine labourers recruited in the cholera affected areas of Mozambique and Malawi. The course of the epidemic which resulted on a group of western Transvaal gold mines, and the methods and techniques employed in surveillance, have been published earlier (1,2). It was shown that exposure to infection was associated with the process of acclimatization which new mining recruits are required to undergo before they are permitted to work underground. Three liters of water are consumed by each trainee during a four hour acclimatization session. This water, which had been filtered and chlorinated, was found to be faecally contaminated after having been drawn from the tap. Trainees sweat profusely and it was postulated that a healthy carrier may under prevailing conditions of acclimatization disseminate *Vibrio cholerae* from the perianal area to the floor by means of sweat flowing down the lower limbs. This belief was strengthened when *V.cholerae* was subsequently isolated from perspiration fluid which had been collected from the climatic chamber floor during a training session. The floor had been swabbed, hosed down and treated with a quaternary ammonium compound before training had commenced two hours earlier.

A water reservoir, the only purpose of which was to supply water to the air humidifying sprays serving the climatic chamber, was found to be faecally contaminated and it was shown that fluid from the floor of the chamber and from a sump could gain access to the humidifying system. The reservoir was emptied and refilled every two weeks from the chlorinated, piped domestic water supply. From time to time a labourer in overalls and boots would enter the reservoir for various purposes, for example collection of watersamples. *V. cholerae* could be introduced mechanically into the reservoir by such a labourer if his boots had been contaminated by floor or sump fluid.

Vibrio Cholera

It was believed that the combination of circumstances as observed may have provided a mechanism for the dissemination and perpetuation of *V. cholerae* in this particular environment. Such a mechanism would include the following stages:

1. the dissemination of *V. cholerae* in sweat from the perianal region of healthy carriers to the floor;
2. the dissemination of *V. cholerae* from the floor via droplets into the air conduits to the reservoir and humidifying system, or mechanically introduced by staff members servicing the reservoir;
3. the dissemination of *V. cholerae* by the humidifying system back into the chamber where various surfaces and utensils could be contaminated by water of condensation containing the cholera agent;
4. the ability of *V. cholerae* to survive in the relevant components of the climatic chamber environment.

An experimental study was designed and carried out to gain additional information necessary to evaluate the probability of a cholera epidemiological cycle as outlined above being operative. The study involved quantitative *V. cholerae* viability studies in various water samples and in secretions. Routine microbiological and chemical tests were also carried out on these samples.

MATERIALS AND METHODS

The climatic centre situated on a gold mine close to Johannesburg was made available for the duration of the study. It was served by a climatic control system identical to that on the cholera affected mine. The size of the chamber and the number of trainees per acclimatization session were similar to those on the other mine, as were training procedures, cleaning techniques, administration of replacement fluid and evaluation of acclimatization (3).

The heating apparatus remains constantly in operation but the water sprays which humidify the atmosphere are switched off when the chamber is not in use in order to minimize fungal growth. Although the heaters remain on, the inactivation of the sprays and the fan result in a drop in temperature of the air in the chamber and the water in the reservoir.

It was established by means of a minimum and maximum thermometer that the reservoir water temperature ranged from approximately 32°C when the chamber was in use (from 4 to 12 hours daily), to an approximate minimum of 20°C when not in use. This temperature range was fairly constant for each 24 hour period. These conditions were closely simulated in the laboratory in a thermostatically controlled waterbath by setting the temperature at 32°C and thereafter switching the bath on at 0800 hours and switching if off at 1700 hours. A maximum and minimum thermometer showed that the temperature in the bath fell from 32°C to 22°C on most nights and occasionally slightly lower.

Water samples, collected in 100 ml sterile glass containers, were obtained daily from Monday to Friday from each of the following sources:

1. Domestic water supply. This is surface water, collected and processed by the Rand Water Board for domestic use on a metropolitan scale. It is chlorinated to a final free chlorine level of ± 0.3 parts per million. At point of delivery in the area in question the free available chlorine was not measured but estimated to be less than 0.1 ppm.

2. Large polystyrene water dispensors. These were filled from the tap (see 1. above) and used to replenish the small individual drinking water containers used by the trainees. Water stood in the large containers for periods not exceeding 1 hour as they were periodically emptied and refilled during acclimatization sessions. Remnants of water could remain in the containers overnight.

3. An individual trainee's plastic drinking water bottle. The same bottle was sampled daily throughout this study. On the cholera affected mine enamelled mugs had been in use.

4. Floor. Fluid was aspirated from the floor by means of sterile disposable syringes. The time of collection was midway through an acclimatization session, i.e. two hours after it had commenced, at which time most of the disinfectant could reasonably be expected to have been washed away.

5. The humidifying water reservoir.

6. The overflow sump serving the acclimatization chamber.

Twenty-eight samples were collected from each of these six sources during the period 11 July - 30 August, 1975.

The samples were conveyed to the laboratory in cool boxes and were processed immediately on arrival. The following basic investigations were carried out on receipt of each water sample:

1. pH determination;
2. total bacterial colony forming units (C.F.U.);
3. presumptive *E. coli* count;
4. faecal *E. coli* count;
5. presence of sucrose fermenting vibrios before and after enrichment in alkaline peptone water;
6. sodium, potassium and chloride content. This was done by means of an autoanalyser by courtesy of the SAIMR biochemistry department.

All the samples obtained from the domestic water supply, the humidifying water reservoir and the sump were inoculated with *V. cholerae* (grown in alkaline peptone water and diluted with distilled water) and incubated in the waterbath subject to the fluctuating temperatures described above. The first twelve samples from each of these three sources were inoculated to a final concentration of 10^4-10^5 *V. cholerae* per millilitre of fluid and the next sixteen samples from each source received the same organism to a final concentration of 10^6-10^7 cells per millilitre. The calculation of each inoculum was controlled by a simultaneous viable plate count on blood agar. The cholera strain used for the experiments was C14918/74 *V. cholerae* eltor Inaba, phage type 4, which was the first isolate obtained from a healthy carrier on the cholera affected gold mine.

The inoculated water samples were kept in the waterbath throughout the experiment. From the bottles containing inoculated domestic water and reservoir water 0.2 ml aliquots were removed daily and diluted tenfold with distilled water to a final dilution of 10^{-8}. Of each dilution 0.25 ml was planted on each of two blood agar plates, incubated overnight at 37°C and the cholera colonies were counted the following morning. After a little practice it was possible to distinguish *V. cholerae* morphologically from other bacteria but, for confirmation, all suspected *V. cholerae* colonies on the plates representing one dilution were tested by slide agglutination with Inaba typing serum. The water samples from the sump contained too many non-cholera bacteria to make quantitative determinations on the presence of *V. cholerae* practicable. For this reason 0.5 ml of the inoculated sump water was removed daily from the waterbath, enriched overnight in 5 ml alkaline peptone water and the mere presence or absence of *V. cholerae* recorded after subculturing from peptone water onto TCBS medium.

The daily cholera tests on the inoculated samples were continued until *V. cholerae* was no longer demonstrable by the methods employed in this study.

Samples of sweat were obtained from six male staffmembers of the climatic centre each of whom was fully acclimatized to high environmental temperatures. Each of the samples was tested to determine pH, Na, Cl and K levels, and examined to establish the presence or absence of vibrios and total viable bacterial counts.

Two lots of 5 ml each was taken from every sample and inoculated to a final concentration (established by viable plate counts) of 1.45×10^6 and 1.45×10^4 *V. cholerae* respectively. The dilution factors of the *V. cholerae* peptone water culture were 1:200 and 1:20000 respectively, sufficient to dilute out growth promoting agents in the culture. The twelve inoculated sweat samples were incubated for 48 hours in a 32°C waterbath and then left at 20°C for a further 3 days. Aliquots were removed from each at 24,48 and 120 hours respectively in order to quantitate *V. cholerae* survival, if any, by plate counts on blood agar. Two samples were also tested after 5 hours incubation.

RESULTS

Sucrose fermenting vibrios were absent in all the samples tested prior to inoculation with *V. cholerae*. Table 1 shows the results of the routine bacterial and biochemical analyses of the various fluids before inoculation with *V. cholerae*.

TABLE 1. Results of bacteriological and chemical analyses of various waters before their inoculation with *V. cholerae*

Source of water	Tap	Dispensing bottle	Drinking bottle	Reservoir	Floor	Sump
No. of samples tested	28	28	28	28	28	28
Total CFU/100 ml						
Range	1-289	1-600	2-*	*	*	*
Mean	39	77	*	*	*	*
Presumptive *E. coli*/ml						
Range	0-5	0-1800	0-1800	4-1800	20-1800	40-1800
Mean	0	66	484	740	1729	1618
Faecal *E. coli*/ml						
Range	0	0-2	0-600	0-900	8-1800	6-1800
Mean	0	0	31	107	1303	1226
pH						
Range	7.5-8.2	7.6-8.0	7.5-8.0	7.8-8.3	7.7-8.7	7.7-8.4
Mean	7.7	7.8	7.7	8.1	8.2	8.1
Sodium mmol/l						
Range	0-2	0-3	0-3	0-4	6-87	22-110
Mean	1.3	1.4	1.2	1.9	45	50
Chloride mmol/l						
Range	0-5	0-5	0-5	0-5	7-89	25-107
Mean	2	2.0	1.8	2.5	43	45
Potassium mmol/l						
Range	0-1	0.1-0.2	0.04-1	0.03-03	1-10	4.9-10
Mean	0.2	0.1	0.2	0.1	5.8	6.9

*: The counts exceeded 1000 colony forming units/100 ml by undetermined values. Ranges and means could therefore not be calculated.

CFU: Colony Forming Units

The progression of the water from the tap through the dispensing bottle to the consumer's drinking bottle is shown to be associated with increasing contamination. The water/fluid from the reservoir, floor and sump were grossly contaminated with faecal *E. coli* and had a comparatively high pH. High sodium and chloride values were present in fluid from floor and sump; this probably reflected the admixture of sweat.

Figure 1 presents the *V. cholerae* survival time in the inoculated water samples as a graph charting the daily percentage of samples yielding *V. cholerae*.

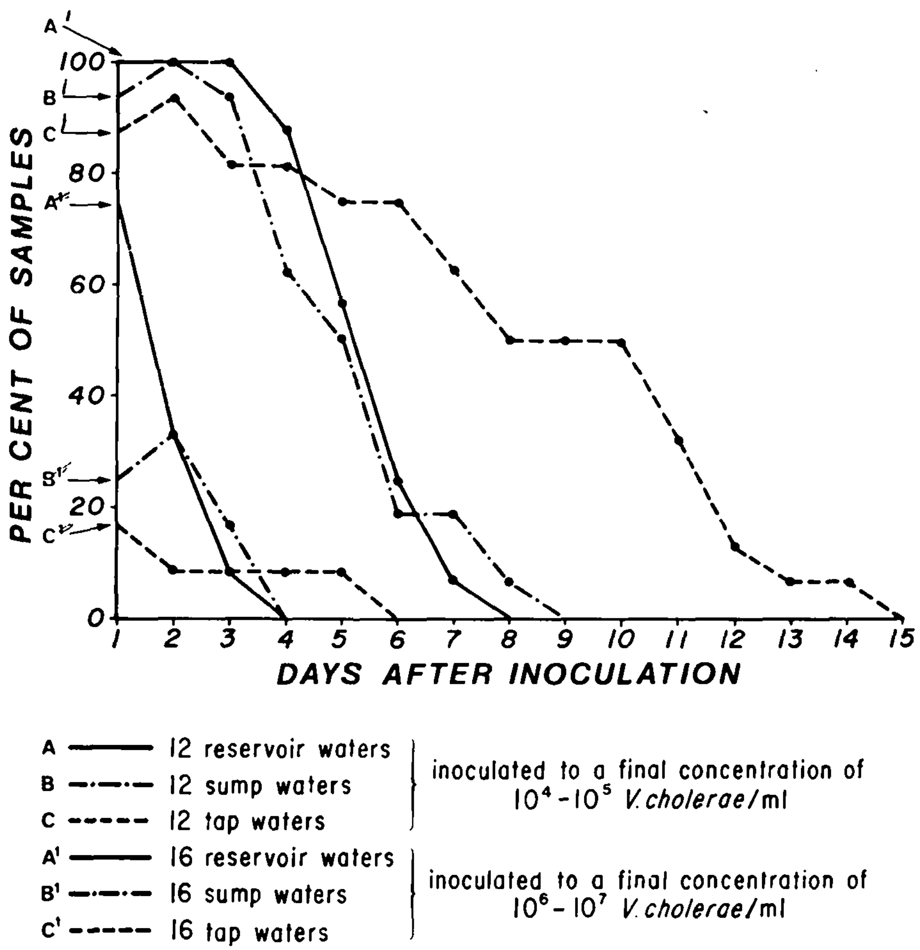

FIG. 1. *V. cholerae* survival in various waters as a daily percentage of samples yielding *V. cholerae* after a single inoculation of each sample.

Figure 2 gives additional information on viability in the form of mean daily counts of *V. cholerae* in tap and reservoir water.

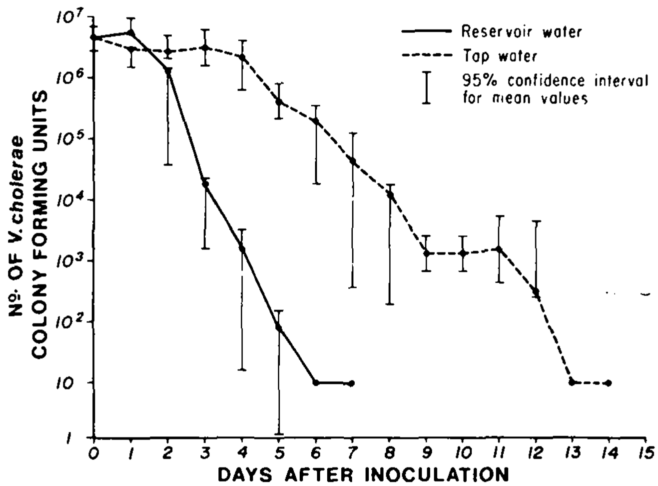

FIG. 2. Quantitative daily survival of *V. cholerae*.

Table 2 shows the basic chemical and bacteriological results of the sweat samples before inoculation with *V. cholerae*.

TABLE 2. Basic chemical and bacteriological data on sweat obtained from 6 heat acclimatized staff members of a climatic centre.

Sample no.	pH	Na mmol/l	Cl mmol/l	K mmol/l	Co_2 mmol/l	Total CFU/100 ml
1	8.1	136	122	9.4	18	> 1000
2	7.9	66	59	16.1	18	> 1000
3	8.1	53	45	16.1	22	> 1000
4	8.2	96	89	16.2	30	> 1000
5	7.8	63	44	16.1	18	> 1000
6	7.5	88	80	13.4	9	> 1000
Range	7.5-8.2	53-136	44-122	9.4-16.2	9-22	
Mean	7.9	84	73	15	19	

Table 3 presents the highest dilution in which *V. cholerae* was present in sweat samples 5, 24,48,120 hours after incubation at 32°C.

TABLE 3. Highest dilution of 6 sweat samples in which *V. cholerae* was present 5,24,48 and 120 hours after inoculation with ElTor *V. cholerae*.

Sample no.	5 hours		24 hours		48 hours		120 hours	
	LD[a]	HD[b]	LD	HD	LD	HD	LD	HD
1	10^{-7}	$> 10^{-9}$	$> 10^{-9}$	$> 10^{-9}$	10^{-3}	10^{-8}	10^{-3}	10^{-6}
2	10^{-6}	$> 10^{-9}$	$> 10^{-9}$	$> 10^{-9}$	10^{-5}	10^{-6}	10^{-5}	10^{-6}
3	ND[c]	ND	$> 10^{-9}$	$> 10^{-9}$	10^{-3}	10^{-8}	10^{-4}	10^{-6}
4	ND	ND	10^{-8}	$> 10^{-9}$	10^{-3}	10^{-8}	10^{-4}	10^{-7}
5	ND	ND	10^{-8}	$> 10^{-9}$	10^{-5}	10^{-8}	10^{-5}	10^{-6}
6	ND	ND	10^{-8}	$> 10^{-9}$	10^{-5}	10^{-8}	10^{-5}	10^{-7}

[a]LD : Sample inoculated to a final concentration of 1.45×10^4 *V. cholerae*/ml
[b]HD : Sample inoculated to a final concentration of 1.45×10^6 *V. cholerae*/ml
[c]ND : Not done

The presence of numerous other bacteria made actual counts difficult and *V. cholerae* presence after the 24 hour count was established by tenfold dilution of the sweat with sterile distilled water, the inoculation of 0.5 ml of each dilution in 5 ml alkaline peptone water and 6 hours incubation at 37°C, followed by subculture onto TCBS agar.

DISCUSSION

Numerous studies have been conducted by others on survival of *V. cholerae* in waters of various origins and composition and under varying conditions. As a result the following phenomena have been observed:

1. *V. cholerae* survival time is reduced in water samples which are exposed to sunlight (4).
2. The eltor biotype survives better than the classical biotype in water under comparable conditions (5).
3. The pH of the water is important and the optimum pH for *V. cholerae* survival is in the alkaline range.
4. The presence of other bacteria, especially enterococci, may inhibit growth of *V. cholerae* (6).
5. The presence of NaCl promotes survival and multiplication of *V. cholerae*.

No reference to the role of sweat was found.

In the present study none of the waters and fluids used were exposed to sunlight and all had an alkaline pH, the overall range being 7.5 - 8.7. The following observations were made:

1. The domestic drinking water which is supplied not only to the mines but also to the metropolitan areas on the densely populated Witwatersrand is derived from surface water collected in rivers and dams, and then treated by filtration and chlorination according to internationally accepted standards. The routine bacteriological tests which were carried out on the daily samples in this study confirmed that this water is of a satisfactory standard for domestic purposes (see Table 1). However, although filtration and chlorination have rendered the water safe for consumption the residual free chlorine level is insufficient to prevent survival and multiplication of *V. cholerae* when inoculated into the water after it has been treated. Thus *V. cholerae* eltor remained demonstrable in tap water for up to 14 days (Fig. 1) and was present in relatively high concentrations for up to 7 days. These observations indicate that the provision of safe water supplies and adequate sewage disposal are not sufficient in themselves for the control of cholera. In rural communities the initial introduction of a treated domestic water supply frequently takes the form of one or a few taps centrally situated. Water is collected at these points by the consumers in various receptacles such as buckets, jerry cans, paraffin cans or barrels. Subsequent contamination of the stored water constitutes a serious danger, particularly if the consumer fails to boil the water prior to use in the belief that the safe central supply makes this unnecessary. It must therefore be emphasized that even treated water, unless piped to each dwelling, may become a source of cholera infection. The health education programme, which should form an integral part of any cholera control campaign, must therefore stress the importance of avoiding contamination of stored drinking water. The demonstration of domestic animals such as cows, dogs and chickens as carriers of cholera introduces a new aspect to this problem (7).

2. The good survival of *V. cholerae* in the water samples from the sump and the humidifier reservoir was unexpected in view of the gross bacterial contamination prevailing in these sources (Figs. 1 and 2). Factors in favour of *V. cholerae* survival in the sump were the high pH (greater than 8 in almost all samples), the high NaCl content, (see Table 1) favourable temperature for growth and the absence of sunlight.

Entirely unexpected was the prolonged survival of *V. cholerae* in sweat and its rapid multiplication to very high levels (see Table 3). However, the alkalinity and high NaCl values of all six samples (Table 2) are growth promoting factors for *V. cholerae*.

Sweat is usually acid with a pH range of 4.0-6.8 but alkaline values have also been reported (8). It is probable that acclimatization to heat may affect the pH.

These preliminary findings on the survival and multiplication of *V. cholerae* in sweat indicate a need for further work in this direction. The implications for the epidemiology of cholera are several:

1. The healthy carrier who excretes but few cholera vibrios in faeces may become an important source in the tropics when vibrios in the anal region gain access to sweat where they may multiply to high numbers on the skin.

2. The healthy carrier may contaminate communal water sources at all times while fishing, swimming, bathing or laundering, even when no defaecation takes place and when personal hygiene is of a high standard.

3. Person-to-person transmission is facilitated, especially in crowded and warm regions where little clothing is worn. This mechanism could be of importance in those regions (e.g. certain areas in India and West Africa) where an increase in incidence has been noted during the dry season. The high rate of infection in households may be explained on this basis.

The findings on the survival of *V. cholerae* in sweat were obtained at the time of writing. It is planned to repeat and expand this study. Some of the questions which need to be answered concern the pH of sweat and the fate of

V. cholerae in acid versus alkaline sweat. The effect of heat acclimatization on its pH and chemical composition requires further study with special reference to its suitability as a vehicle for *V. cholerae*. Further investigation will also be done concerning the ability of *V.cholerae* to survive on skin and on fomites with and without the presence of dried sweat.

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THE NEED FOR INTEGRATED PLANNING IN RURAL HEALTH SERVICES

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Abstract—Development schemes to improve the health of the rural populace through prevention of the transmission of communicable diseases should be considered in the context of some kind of Sanitation Package to ensure effectiveness. The general practice of concentrating resources on limited objectives, like water quality improvement, is shown to be less effective than allocating the same resources to multi-objectives defined in a Sanitation Package. System Dynamics Modelling based on the DYNAMO II language, is presented as a capable tool for sanitation systems planning.

INTRODUCTION

The World Health Organization reported that in 1970, only 15% of world's rural population have reasonable access to safe water and estimated that US$ 3 billion would be required to provide safe water for 70% based on 1970 price levels.(14) Similarly, the "Habitat Forum" puts the required investment for providing pathogen-free water to villagers at US$ 30 billion annually for a period of 14 years beginning in 1976.(8) Justification of this huge expenditure is primarily based on the importance of clean and safe water in improving the health and well-being of the human race, particularly in the prevention of waterborne diseases.

The scheme of concentrating resources solely on safe water provision, is however doubtful insofar as disease prevention is concerned. Studies conducted by Azurin and Alvero (1974) in the Philippines revealed that provision of sanitary facilities alone reduced the incidence of cholera by as much as 68% while the provision of safe water effected a reduction by 73%. Where safe water and toilets were provided, a 76% reduction was observed.(1) Also, based on their studies on cholera-clean water relationship in Bangladesh, Levine et al. (1976) reported that better water quality did not significantly reduce morbidity and mortality rates attributed to cholera. They, however, positively correlated education of inhabitants and quantity of water available to them to reduction in cholera and dysentery levels.(6) Saunders and Warford's (1976) findings, dovetailed with Levine's (1976). They reported that the highest incidence of diarrheal cases was found in household away from the water source, those which consumed a lesser quantity of water.(10) Furthermore, studies conducted here in Thailand indicated that the distribution of bacterial density is normally negligible after treatment and chlorination, but usually increases during transportation and storage due to recontamination to a level sometimes even higher than that of the pre-treated water. In European as well as in Oriental countries, several cases have been reported in which the establishment of a water supply system in rural areas failed to check the spread of communicable water borne and food borne diseases.

McGarry (1977) observed that the importance of a clean water supply in rural areas should be considered together with other equally important factors; and that these must be viewed as some kind of "sanitation package", each component of which cannot be implemented separately without losing the total health benefit it intends to generate.(8).

RURAL SANITATION SYSTEM

Rural Sanitation depends on a wide range of variables as shown in Fig. 1. It is apparent that the rural water supply is just one of the factors responsible for the improvement of health standards of the community when the level of bacteria is taken as the criterion. It may also be noted that the contamination mostly comes from poorly designed excreta and waste disposal subsystem whcih includes the spent water from bathing and washing, and animal, human and industrial wastes. The transport of these contaminants could be attributed primarily to the poor sanitary habits of the villagers.

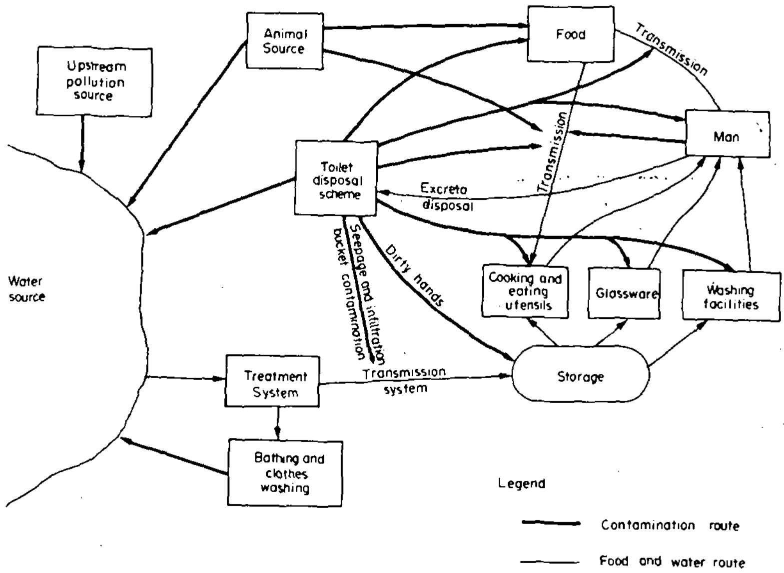

Fig. 1. Schèmatic diagram of contamination routes.

Water supply subsystem

The water supply subsystem is broken down into five components: the raw water source, the treatment plant, on site storage, transmission, and household storage.

The water quality of the water source is influenced by contaminating factors such as industrial and domestic wastes. Supply from a well-protected water source might be consumed without the necessity of treatment. For a contaminated source, contaminants could come from upstream pollution, animal excrements, spent water from washing and bathing, and human excreta and waste disposal subsystems. All these lower the water quality, encourage the growth of algae which cause undesirable taste and bacteria, the disease-causing agents.

The type of treatment is dependent upon the water quality desired and the initial quality of raw water. For a heavily turbid and contaminated water, a pre-filtration or sedimentation process coupled with chemical treatment to remove undesirable chemicals may be required before rapid or slow sand filtration, followed by chlorination.

To regulate the water demand and treatment rates, on-site storage is often used. From storage, water is either piped directly to the users or they take their water supply from supply pipes using cans or bcukets which are often dirty and heavily infested with coliform bacteria. The latter type of transmission system is usually used in the villages on account of the lower investment cost.

Where water transmission is inadequate or direct pipe connections are not provided, the villagers store their water supplies in containers which are not free from pathogens. Moreover, water is drawn out from the household storage with a dip can or glasses, a process that often results in wetting the user's hand and consequently transferring contaminants (faecal matter) into the water.

Excreta and waste disposal subsystem

Almost all contaminants and pathogens come from the excreta and waste disposal subsystem, and are either transmitted to human beings directly through the faecal-oral route or indirectly through six major transmission routes:

Route 1 Contaminants→water source→treatment system→on site storage→transmission system→household storage→kitchen utensils→man. The contaminants enter the water source through agricultural runoff or seepages, or through direct disposal of waste to the water course. These contaminants are, however, removed in the treatment process; the degree of removal is dependent upon the extent and efficiency of the treatment.

Route 2 Contaminants→transmission system→household storage→kitchen utensils→man: with pipes used for transmission, water supply is contaminated through infiltration or seepages from a poorly designed excreta and waste disposal system. With containers (usually buckets or cans), water may be contaminated in one or more of the following ways:

(a) containers may contain pathogens in large numbers if poorly cleaned;

(b) during its carriage from the supply pipes to the household storage, the containers may be contaminated with air dust and the resident microbes, both pathogenic and non-pathogenic;

(c) the container may be contaminated by man himself when dirty hands are dipped into the container during the process of transfer.

Route 3 Contaminants→household storage→kitchen utensils→man: coliform concentration of random water samples collected from storage jars near the Danish farm in Northeastern Thailand varied from 43 to more than 2,400 MPN (Most Probable Number) per 100 ml. The microbial concentration built up in the household storage was from the first two routes, the bacteria originally present in the storage jar, and the pathogens directly introduced by man himself or by animal vectors.

Route 4 Contaminants→kitchen utensils→man: the microbes may be transmitted from the excreta and waste disposal system through various vectors or media. These include insects and animal vectors, contaminated water used in washing utensils, handling with contaminated hands, and microbes from air.

Route 5 Contaminants→food→kitchen utensils→man: the bacterial concentration is practically nil after the cooking process except when food is half-cooked resulting in only the partial killing or inactivation of the microbes. Contamination may also take place when the food is cooled prior to serving or when served with contaminated kitchen utensils.

Route 6 Contaminants→food→man: this takes place when food like fruits, which do not need cooking, are eaten without thorough cleaning or with dirty hands or utensils.

Man and his habits

Man's sanitary habits are influenced primarily by his beliefs, traditions, customs and education. Of all the subsystems, this is the hardest to quantify.

DEVELOPMENT OF SYSTEMS DYNAMIC MODEL

A Systems Dynamic Model illustrating the interactions of different parameters involved in rural sanitation was developed to serve as a guide for policy planners in setting forth development plans.

Figure 2 shows the skeletal structure of the model in signed digraph. It identifies the interrelationship of the different variables in rural sanitation. The arrows in the diagram indicates the direction of influence and the sign (plus or minus) signifies the type of influence. A positive sign denotes that the change in one variable generates a change in the same direction in the second variable relative to its prior value; a negative sign suggests a negative relation which means that a change in one variable produces a change in opposite direction in the second varibale. Applying this concept, the diagram could be interpreted as follows:

Starting from the left of Fig. 2, it is shown that the coliform origin of the water source is the excreta and waste disposal subsystem. Bacterial transfer could be minimized through good practice of hygiene and sanitation.

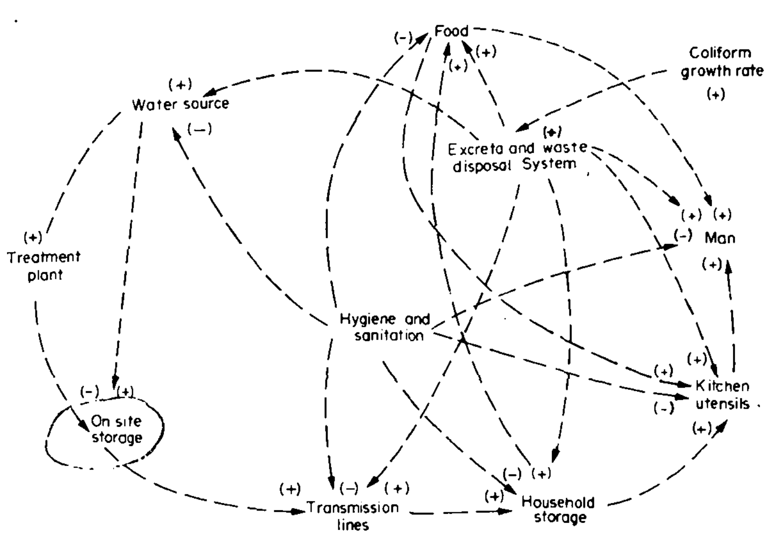

Fig. 2. Causal - loop diagram of rural water supply and sanitation.

Coliform density in water from the source decreases through water treatment, then increases through accumulation in the storage tank and increases further through contamination in the transmission line from poorly designed excreta and waste disposal subsystem and poor sanitary practices.

Similarly, the MPN index in the household storage increases in the same direction. This concept of parallel increase of coliform density is based on the analysis of random water sample collected for 32 weeks from six Central Thai Villages (5), and from a village near the Danish Farm in Northeastern Thailand.

In small Thai communities (Charnvit, 1971), excreta is used in fertilizing vegetables (2). Thus, the excreta and waste disposal subsystem is shown to have a positive influence on the build-up of coliform in vegetables. This build-up, however, is inhibited by the environment (especially by the ultraviolet rays of the sun, and desiccation), and is further reduced by proper washing and cooking prior to eating.

The skeletal structure also shows three primary sources of coliform transfer to man: direct faecal-oral route with dirty hands as the vector of transfer, and indirectly, through various media like food and water. It also indicates that the excreta and waste disposal system is the main source of contaminants and pathogens. Raw water source and pipelines may be contaminated excreta and disposal systems. In villages where the inhabitants collect their water supplies from supply pipes, pathogens may be reintroduced by dirty containers used for collection and by dirty hands of the fetcher.

Furthermore, hygiene and sanitation have an immeasurable influence in cutting off the coliform flow lines. Hygiene and sanitation of a certain locality is however a function of the villager's beliefs, traditions, customs and education. These factors are the decelerators of progress of the villages, in cases where these parameters create reluctance among the villagers to accept the advantages of good health and sanitation. For instance, Charnvit reported that the villagers in Northeastern Thailand used treated water for bathing and washing purpose, but preferred raw water for drinking(2). Education, on the other hand plays a positive role in rural health and sanitation.

DEVELOPMENT OF THE DYNAMO MODEL

The Systems Dynamic Model of rural sanitation is shown in Figs. 3(a)-3(c). The flow diagram portrays the interrelationship of different subsystems shown in Fig. 2 in terms of the symbols developed by Forester(4).

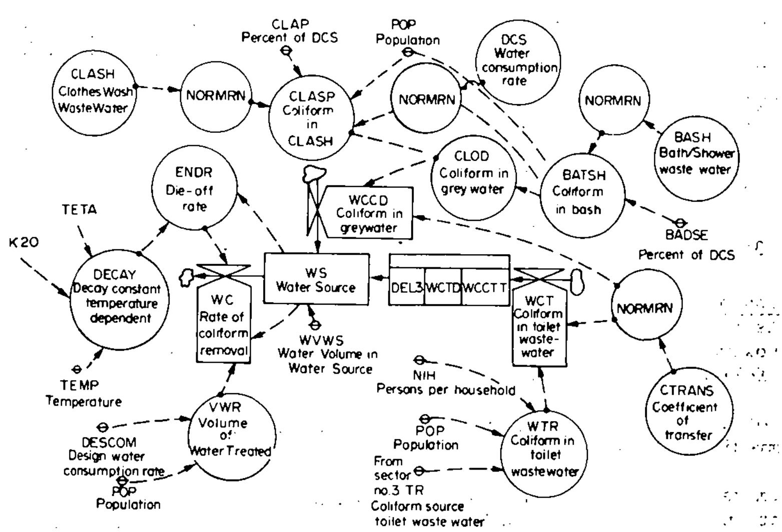

Fig. 3(a). Sector 1: Water source.

The rectangles as shown in Fig. 3 represent the level variables which integrate or accumulate the results of action in the system, and create systems continuity between points in time. The rate variables symbolized by a valve (as in the hydraulic system) are policy statements that define the flow streams in a system. The rate equations received only information as its input and controls the rate of accumulation of the level variables. The auxiliary variables, represented by a circle, lie in the information channels between the level variables and the rates. They are parts of the rate equation, subdivided and separated because they express concepts that have independent meanings. Constants are shown by an underline or overline having an information take-off. Information take-off are lines that indicate information transfer. Shown in Fig. 4 are the details of the DYNAMO symbols and notations. A list of DYNAMO equations is given in Degoma (1978) (3).

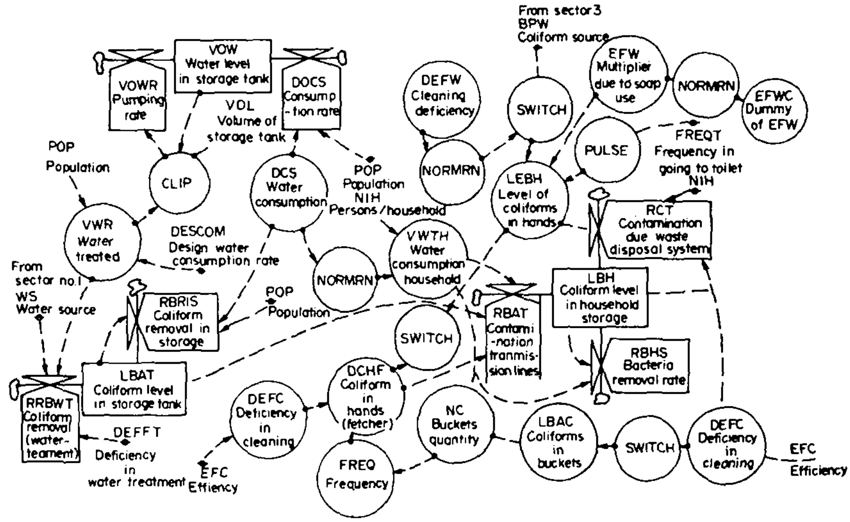

Fig. 3(b). Sector 2: Water supply.

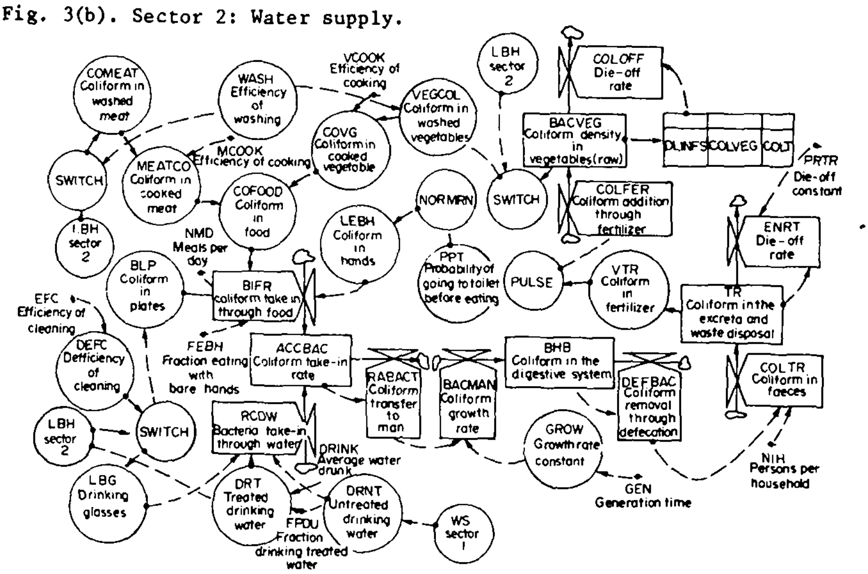

Fig. 3(c). Sector 3: Coliform take in, food and sanitation.

General assumption of the model

The model depicts the daily life and activities of the villagers in Central Thailand. Some input data are however based on studies in Bangladesh, Philippines, Northeastern Thailand and U.S.A. The following general assumptions were made.

(1) The volume of water source (Chao Phya River) is constant; that is, whatever volume is taken out, is immediately replaced.

(2) The coliform density level in the upstream area of the water source has almost the same magnitude as that in the study area making the contribution from upstream almost negligible. This is possible when the upstream village has the same sanitary characteristics as in the study area.

(3) The villagers collect their water supplies from standpipes using buckets and containers.

(4) The bacterial die-off rate in the river follows the first order differential equation according to Chick's Law, and the constants used by Marais (1974) is applicable (7).

(5) The excreta and waste disposal subsystem is the only source of coliform bacteria.

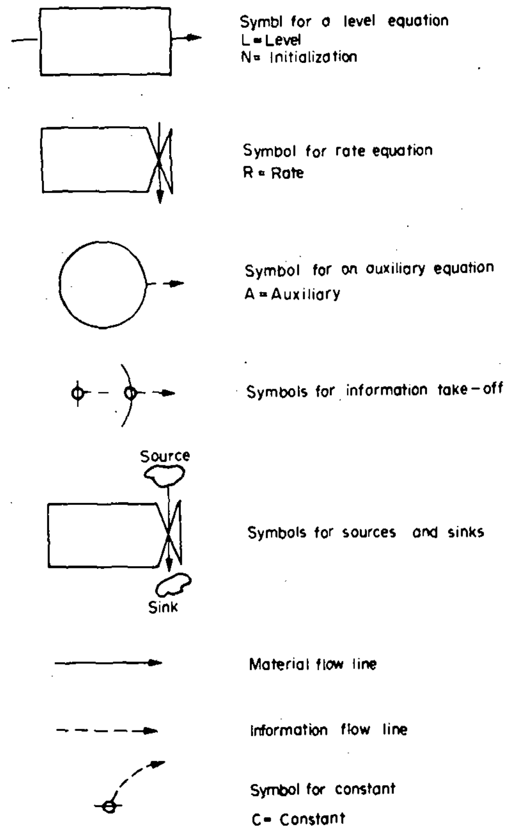

Fig. 4. Dynamo flow diagram symbols and notations.

SIMULATION OF STRATEGIES AND OPTIONS

The model was run batchwise on an IBM 370/145 computer using the DYNAMO II language. The model serves as a planning laboratory where alternative development schemes for a particular village can be examined. In this paper, consequences of alternative strategies for the Central Thai Villages were investigated.

Experiment No. 1 No treatment of water supply, poor excreta and waste dispostal system, and poor hygiene and sanitation.

This run uses the assumption and parameter values shown in the lists of equations of the model given by Degoma (1978) (3). The assumptions and parameters generally depict the characteristics of the villages under study, namely: Villages 2 to 4 of Tambon Khlonchik, and Villages 8 to 10 of Tambon Bangrasan, both in Central Thailand.

The results of this run is shown in Figs. 5(a) and 5(b), and is summarized in Table 1. Figure 5(a) shows the variation of coliform density level per unit time in water source(WS), on site storage(LBAT), and household storage(LBH), and coliform take-in rate per person per unit amount of food take-in per unit volume of water consumed(BIFR). It may be noted in this run that the coliform density in water source (klong or canal) ranges from 847 to 44,733 MPN per 100 ml and this increases in the succeeding levels under conditions of no water treatment of any kind. The water quality is at the worst level during rainy days when runoff is rather high; the best quality is obtained when runoff is at its minimum. That the coliform density level did not decrease ot zero, even if there is no runoff, cna be attributed to the fact that most villagers have no toilet, hence they defecate either in the field or along the klongs, causing direct transport of excreta and consequently, effecting a high MPN index on the water supply source.

Figure 5(b) shows the coliform take-in rate(ACCBAC) of the inhabitants. The coliform transfer through water per unit time(RCDW) is higher than coliform transmission per unit time through food(BIFR) due to a high MPN index of drinking water. The coliform take-in due to food is highly variable, although it revolves around a constant value. This variability is due to the assumed varying nature of the inhabitants' handling of their food.

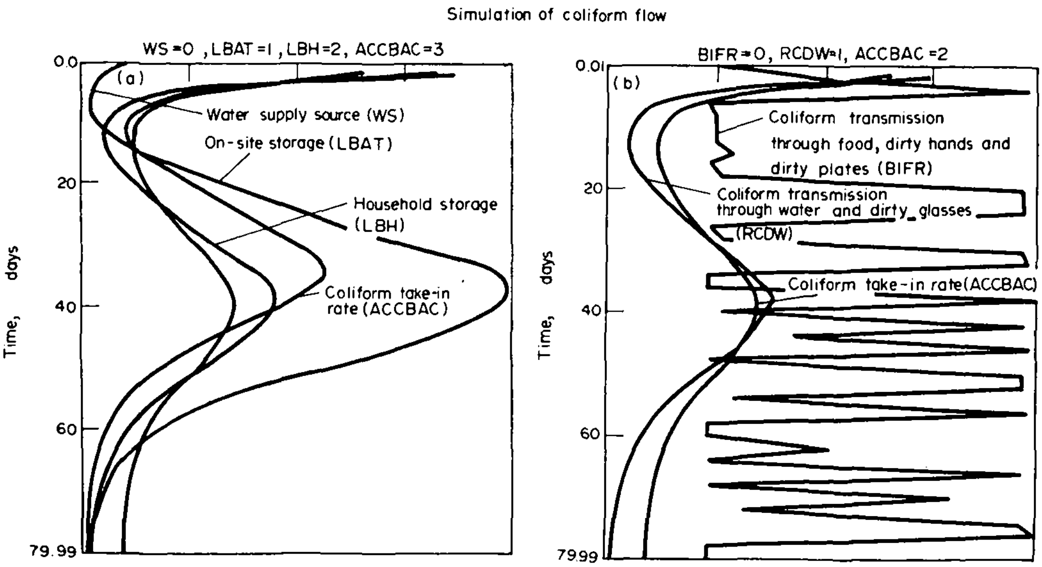

Fig. 5. Dynamo output for Experiment no. 1.

TABLE 1. Summary of the results of the experiments

Parameters	Experiment no 1	Experiment no 2	Experiment no 3	Experiment no4	Experiment no 5
1. WS, MPN/ml	9-447	9-555	0-14	0-14	0-14
2. LBAT, MPN per ml	19-790	0.007-0.2	0-237	0-0.05	
3. LBH, MPN/ml	37-890	12-15	15-592	12-15	0-0.3
4. BIFR, MPN/ person-day, 10^4	40-55	40-55	39-40	39-40	0-.00001
5. RCDW, MPN/ person-day, 10^4	1-797	1-4	3-100	1-4	0-0.2
6. ACCBAC, MPN/ person-day, 10^4	53-730	45-53	43-210	37-43	0-0.04

LEGEND: WS = Coliform Density in Water Source, MPN/ml
LBAT = Coliform Density in On-site Storage, MPN/ml
LBH = Coliform Density in Household Storage, MPN/ml
BIFR = Coliform take-in Rate through Food, MPN/person-day
RCDW = Coliform take-in Rate through Water, MPN/person-day
ACCBAC = Coliform take-in Rate, MPN/person-day

Experiment no. 2. Slow filtration was used for water treatment, poor excreta and disposal system, and poor hygiene and sanitation.

This experiment investigates primarily the effect of improved water supply quality on coliform intake rate among the inhabitants. In this run, slow sand filtration is assumed to be the water treatment schmeme employed, and the findings of Sirisak (1978) on the coliform removal capability of slow sand filters (99.98%) was used as input data to the model(24).

Results are shown in Figs. 6(a) and (b), and summarized in Table 1. Figure 6(a) shows that the MPN index initially ranged from 0.76 to 167 MPN per 100 ml at the onsite storage (LBAT), was increased to 1200-1500 MPN per 100 ml showing the extent of recontamination that had taken place in the transmission line and household storage. Figure 7(b) shows that the coliform take-in rate (ACCBAC) decreased by 20-60% as a result of water treatment. Consequently, the coliform transmission through food (BIFR) dominates that over water.

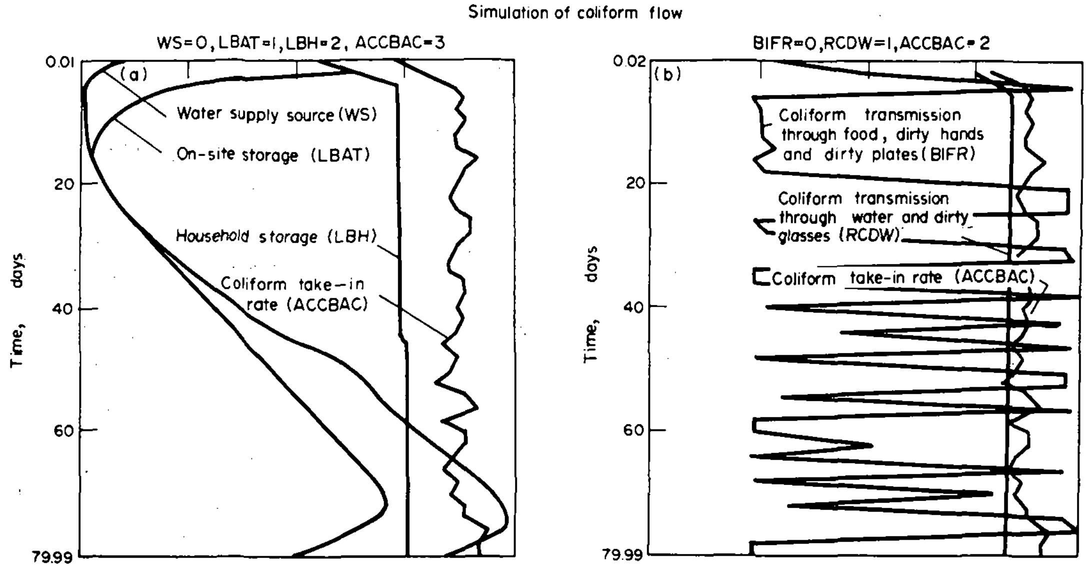

Fig. 6. Dynamo output for Experiment no. 2.

Experiment no. 3. No treatment of water supply, improved excreta and waste disposal system, and poor hygiene and sanitation.

Experiment no. 3 verifies the effect of mass construction of excreta and waste disposal system. Shown in Figs. 7(a) and (b), and summarized in Table 1 are the effects of the above strategy.

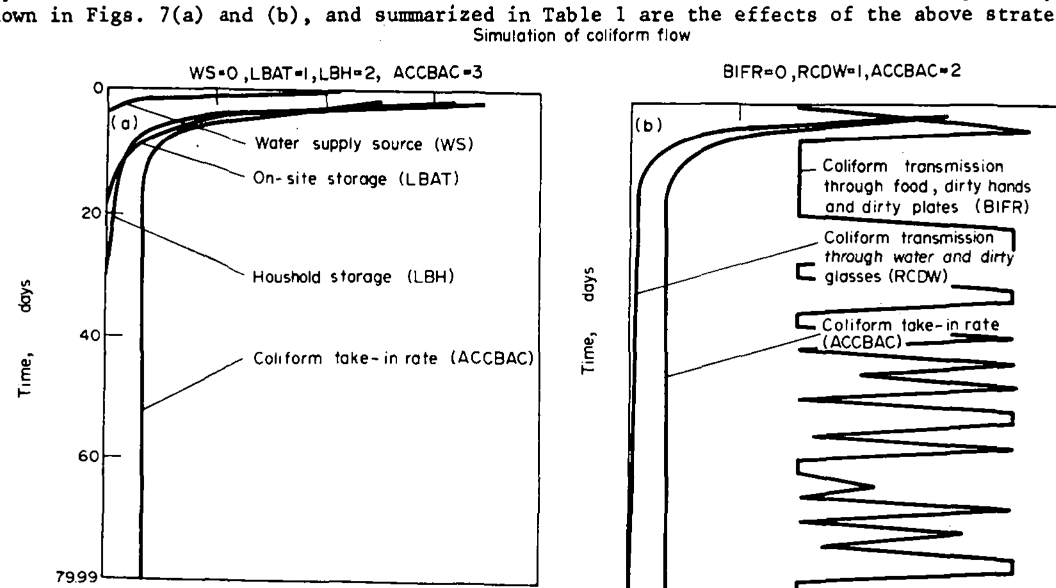

Fig. 7. Dynamo output for Experiment no. 3.

As reflected in Fig. 7(a), the scheme partially cuts off the coliform transmission line, resulting in a lower coliform density level of the water source to the extent that no further water treatment is necessary. However, the MPN index increased and it is at its worst level at the household storage. Contamination has taken place at the transmission lines and at the household storage due to poor sanitary habits of the villagers. Figure 7(b) show the effect of this scheme on the coliform take-in rate of the inhabitants. This policy decreased the coliform intake rate to a level 0-5% of that achieved by the construction of a slow sand filtration system.

Experiment no. 4. Slow sand filtration used for water treatment, improved excreta and waste disposal system, and poor hygiene and sanitation.

This experiment verifies the effect of joint construction of a slow sand filtration system and improvement of excreta and waste disposal system. Shown in Figs. 8(a) and (b) are the results of the experiment. It is noted that this scheme has almost the same effect as that of Experiments 2 and 3.

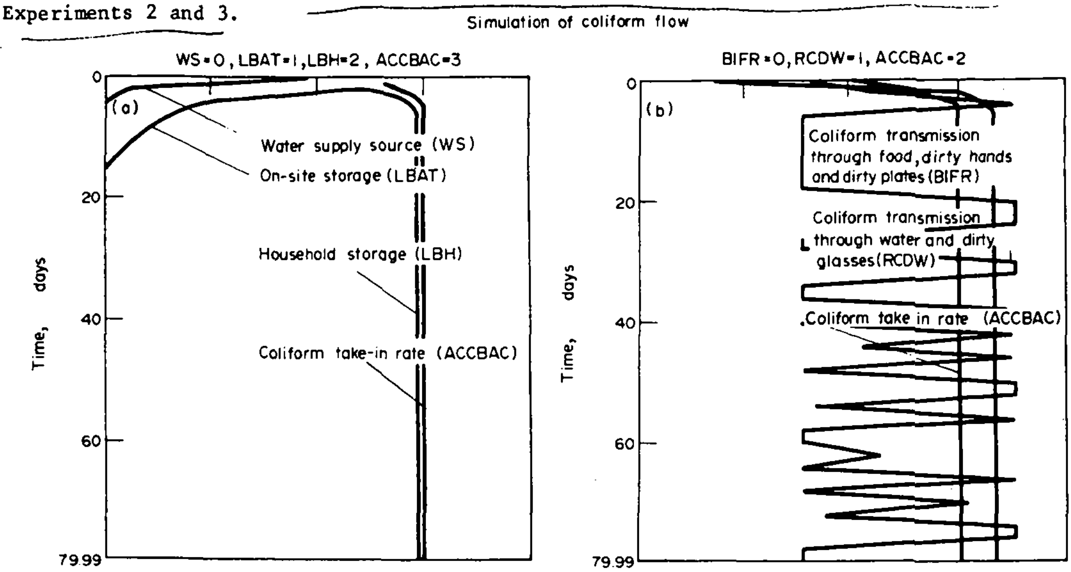

Fig. 8. Dynamo output for Experiment no. 4.

Experiment no. 5. Slow sand filtration used for water treatment, improved excreta and waste disposal system, and improved hygiene and sanitation.

This experiment illustrates the effect of joint implementation of the sanitation package. Shown in Figs. 9(a) and (b) are the outcomes of the experiment.

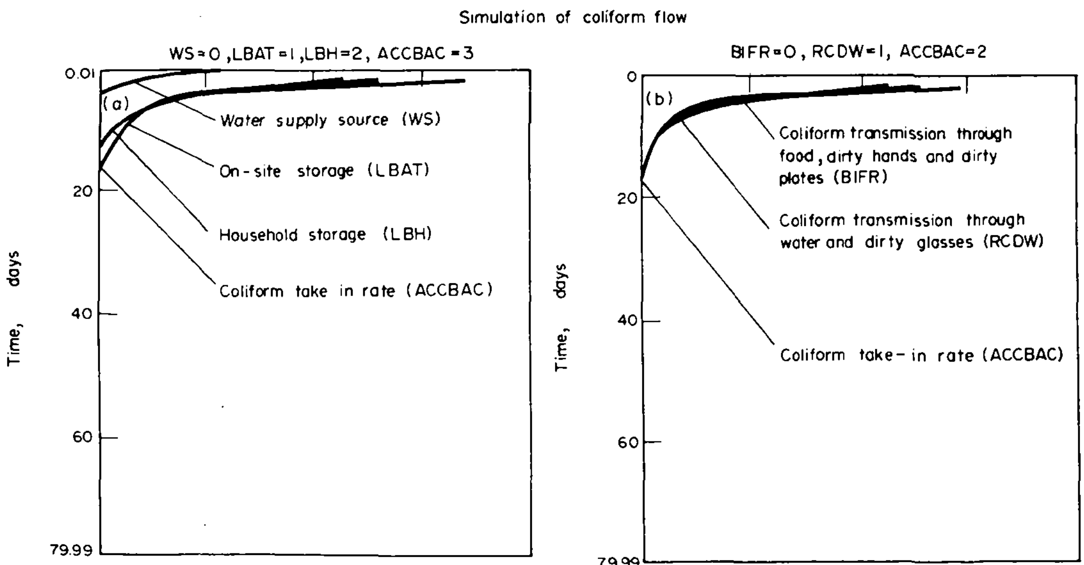

Fig. 9. Dynamo output for Experiment no. 5.

Figure 9(a) shows that the coliform density level at the water source is at minimum several days after the implementation of the sanitation program and that the water quality did not change from level to level indicating a total cutoff of the coliform transmission lines. Figure 9(b) indicates that the coliform take-in rate reduced to zero.

CONCLUSION

The simulation experiments using the Systems Dynamics Laboratory have shown that the development of one particular subsystem like water supply does not necessarily ensure a solution to the problem of rural sanitation as the failure of one subsystem, such as the disposal system even with a success in the water supply scheme, can cause the failure of the total system. It is, therefore, proper that the development of water supply a scheme propounded by World Health Organization, must be reconsidered to include parallel schemes like the sociological development of the villagers through education on hygiene and sanitation, establishment of proper waste disposal system, and other related developments if it is to be a success.

A Systems Dynamics Model based on the DYNAMO II language can be very helpful in evaluating parallel and interacting schemes for rural sanitation. Given a certain amount of resources, the System Dynamics Laboratory (the model) may be used to simulate various combinations of schemes which can bring about the best health benefit to a rural village.

Acknowledgements
A review of this manuscript by Dr Peter Edwards is gratefully acknowledged.

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A COMMUNITY ORGANISATION APPROACH TO CLEAN WATER AND WASTE DISPOSAL IN CAMEROONIAN VILLAGES

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Abstract

Whether the problem of water is one of available quantity or of quality, constraints of money, time, and technical know-how still limit efforts to improve water supply and the disposal of waste materials. At an even more basic level, rural populations are often constrained by lack of organisation, secondary to a multiplicity of social, economic, and cultural factors. In 43 villages of the South Central Cameroon between 1973-76, health committees were organised which assessed local health problems and devised programmes for meeting those problems with the exclusive use of local materials and labor. In most cases the problem addressed was enteric disease, and latrine construction and spring protection constituted the programme. When springs were tested, the water was found to have significantly less fecal coliforms than water in unprotected springs. While only a first attempt at evaluating the effects of these local efforts, the results are nonetheless encouraging to those interested in this approach to community water supply.

INTRODUCTION

How can rural populations assure themselves of improved health through their own efforts? Given the penury of funds at their disposition, the size of their scattered rural populations, and the shortage of skilled manpower, most developing countries must depend upon the population itself to shoulder a large share of the responsibility for health status improvement. The provision of water of sufficient quantity and quality and of adequate disposal of waste have been suggested as appropriate ways for populations to involve themselves in this endeavor (Ref. 1). Several factors, however, impinge upon the ability of a population to so involve itself, among them the availability of local finances, local materials, and local manpower with needed technical skills, the size of the population, and the nature of the environment in terms of geography and climate. Another factor of paramount importance is the organisation of the population for community choice (Ref. 2) and for community maintenance of facilities over the long term.

The impediments to community organisation have been reviewed elsewhere (Ref. 3). In brief, they include the effect of centralised economies and political structures on depleting rural communities of needed talent, the inappropriate elitist educational systems, and the incursion of religious values which elevate individual worth over the common good. These factors combine to reduce, frequently severely, the ability of a community to become engaged in any form of self-help without extended efforts at transferring organisational and technical skills. The Project described in this presentation incorporated such efforts in its programme.

PROJECT SETTING

The zone selected for initiating community organisation activities was the Mefou department of the South Central Cameroon. This area serves also as a demonstration zone for training programmes at OCEAC (Organisation de Coordination pour la Lutte contre les Endémies en Afrique Centrale) and the University Center for the Health Sciences.

The Mefou, with a population of about 200,000, surrounds the capital city of Yaounde like a C reversed. Almost no point in the department is more than two to three hours' driving time from the capital. Most towns and villages lie along one of the major arteries radiating out from the city. An estimated 20 to 30 percent of the population, however, may dwell in hamlets lying several kilometers off the main roads. Villages as currently conceived, in fact, are frequently made up of hamlets joined together. Many were created during the colonial eras, first German, then French, by forcing entire hamlets to move from the forest onto the roads for purposes of census-taking, taxation, sanitary control, and forced labor. This history needs to be borne in mind in the organisation of rural people. An organised effort occasionally disintegrates because the village itself is not a unity.

In the Mefou there are over 400 villages and countless hamlets. Village populations range between 50 and 1,500 or from five to over 100 households. The average village has 200-300 inhabitants with 30-40 households. The population density is one of the greatest in all of rural Cameroon, there being about 40 persons per square kilometer. Most are of the Fang ethnic grouping, the majority Ewondo. Other subgroupings include the Evouzok, the Mvele, the Ntoumou, and more than a dozen others. Ewondo is the principal language and a certain number of people speak French as a second language.

The terrain is gently rolling at an elevation of 800 to 1,500 meters. It is covered with dense tropical rain forest. Rainfall is abundant at about 125 days per year or about 170 centimeters. Most hamlets and villages are situated on the crests of hills. At the foot of these hills are multiple springs, usually 0.5 to 1.0 kilometer (Ref. 4) away, where the villagers draw water (Fig. 1). Alternative sources of water include occasional ponds, streams, or rivers. Water-drawing is the exclusive chore of women and children, the usual container being a large bucket or a kerosene can. Because the average trip may take 45 minutes (Ref. 4), the total time expenditure is about 90 minutes a day, since the average household makes two trips daily.

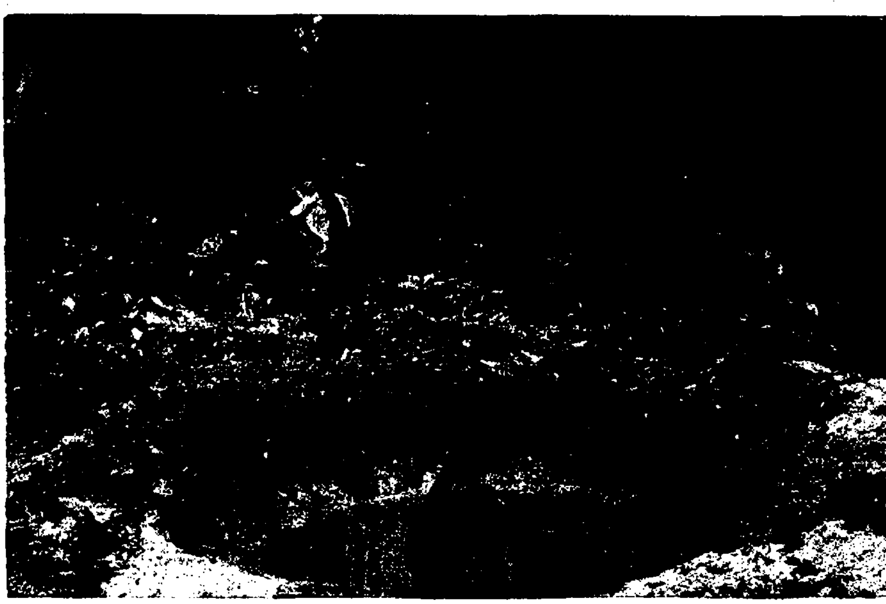

FIG. 1. A typical unprotected spring

The nature of the terrain and the abundant rainfall create ideal conditions for cultivating cocoa and coffee as cash crops. This activity is the preoccupation of the men of the village and produces the major source of income for clothing, tools, fertilizer, insecticide, school fees, medical care, and village improvements. The average household income is about 51,000 CFA per year or $237.00 (Ref. 4).

Food crops, mostly cultivated by women, include ground nuts, maize, plaintain, bananas, cassava, yams, taro root, and macabo.

The cultivated plots are the usual site of defecation. Some latrines of an older type (Fig. 2) where the floor is a mound of packed clay with a hole maintained by a wood frame in the center are still in existence, but there is little evidence of their use.

Families in the Mefou are patrilineal and virilocal. There is a sharp separation of tasks as indicated above. Women are responsible for most basic life support tasks: bearing and rearing children, cultivating, harvesting, and preparing food, drawing water, gathering wood for the fire, and tending the house. Men raise cash crops, clear fields, build houses, and make major decisions.

Organisations already existing in the villages of the Mefou include the national political party through its representative, the chairman of the local cell, youth and women's auxiliary branches of the party, men's and women's savings associations, youth associations, and village development or "animation" committees.

FIG. 2. Old type "mound" latrine

PROJECT STRATEGY

Into this setting the University of Pittsburgh/OCEAC Regional Public Health Training Project launched several activities in early 1973 including the organisation of village health committees in four pilot villages, followed by training auxiliary level nurses as itinerant health workers, through whom the number of health committees multiplied with succeeding classes of itinerant workers until the number reached 43 in total by June 30, 1976.

Phases of development of a health committee

Each committee (Fig. 3) progressed through basically two phases: an *organisational phase* in which the committee was formed, health problems were identified, priorities were set, resources were assessed, and a programme of work was devised and implemented. At a point in the process the initiative seemed to pass from the agent to the committee itself and a second phase was entered, the *maintenance phase,* in which meetings and work sessions could take place without the presence of the agent; the committee initiated, planned, and executed new projects; and the committee learned to make rational use of outside help.

The formal stages in the development of each committee consisted of an initial demographic and sanitation survey and a series of meetings leading from problem identification to definition of a programme of work.

A first meeting at which the survey was reported on and the committee asked to name priority health problems.

A second meeting at which the committee announced its priorities. The problems usually named were dysentery and intestinal worms, the unavailability of therapeutic drugs, and the perceived widespread infertility of couples. The impression of enteric disease as a priority problem was confirmed in the baseline survey performed in four villages. Stool examinations performed on a total of 987 persons revealed a mean percentage carrying *Ascaris* ova of 78.6, whipworm 44.7, and hookworm 15.5. When asked about recent symptoms, 1,081 respondents indicated the following (Table 1):

FIG. 3. Village health committee meeting

TABLE 1. Symptoms by age group (mean percentages and ranges per village) four villages.

Symptom	Children (0-14 Years) Mean	Children (0-14 Years) Range	Adults (15 + Years) Mean	Adults (15 + Years) Range
Abdominal pain	80.2	71.6-89.2	77.6	56.5-93.0
Vomiting	68.6	49.3-90.0	46.5	13.9-60.8
Diarrhea	69.7	46.6-90.8	65.0	40.2-90.2
Bloody diarrhea	2.3	1.5- 5.2	4.9	1.4-12.6
Visible worms	65.6	36.2-80.5	56.5	23.9-81.0

Subsequent meetings in which a problem is chosen as the first to work on, and the agent supplies the committee with technical information about the problem, the approaches to the problem, and helps the committee choose from among several options. For example, several committees wanted to protect their springs using cement or metal piping, but lacking funds decided to use local materials first and replace them later with more durable materials.

Work sessions (Fig. 4) in which the approach to the problem was implemented by committee members and other interested villagers. The number of participants varied from village to village. It might be only a handful or more than 30 or 40 at a session.

The usual projects undertaken by the committees were spring protection and latrine construction. A few committees undertook the organisation of village pharmacies (Ref. 5) or a village maternity.

RESULTS

Evaluation of the results of this project is beset by several difficulties. Among them are the impossibility of controlling the many variables which influence the achievement of objectives, the shortness of the project with respect to health status outcomes, and the uncertainty of relationship between the improvements in water supply and waste disposal and health status indicators (Refs. 6 and 7).

FIG. 4. A health committee at work

FIG. 5. Typical latrine construction

Several preliminary approaches to evaluation do, however, yield results of interest.

The number of committees

From 4 original committees in early 1973, the number grew to 11 in mid-1974, 26 in mid-1975, and 43 in 1976. As of 1977, 36 of the 43 were still active to some degree.

Latrine construction

With 27 of 43 committees reporting in mid-1974, 26 indicated latrine construction at some stage of development with an average of 15.6 latrines per village, or about half the households, in an average village of 200-300 inhabitants. The range was from 2 to 44 latrines per village. Inspection of these latrines by an impartial jury from the Ministry of Health in early 1977 affirmed that the majority were in use. Figure 5 illustrates the average type of construction used.

Spring protection

Results were evaluated in two ways: the number of springs protected in an acceptable manner and the quality of water resulting from the protection. Figure 6 illustrates the type of spring protection undertaken. The spring was excavated back into the hillside then deep gutters were dug around both sides and earthen barriers erected between the gutters and the spring proper. Stones were hauled in for reinforcement as necessary. A barrier built across the front of the spring was pierced with a bamboo tube and a raphia mat was placed over the top. A fence built atop the barrier served to keep out animals and children.

In the 26 villages reporting, 82 springs were protected or an average of 3.4 per village. The number per village ranged between one and seven.

In 11 of those 26 villages, the springs were tested in 1974. Samples were drawn from 15 protected springs and from 33 unprotected springs in the same villages serving as controls. Testing took place at the Pasteur Institut in Yaoundé. Tests run included the number of bacteria per liter, the number of fecal coliforms per liter, and the number of aerobic and anaerobic streptococci per liter. The determination of potability depended on finding no coliforms. Partial results are displayed in Table 2.

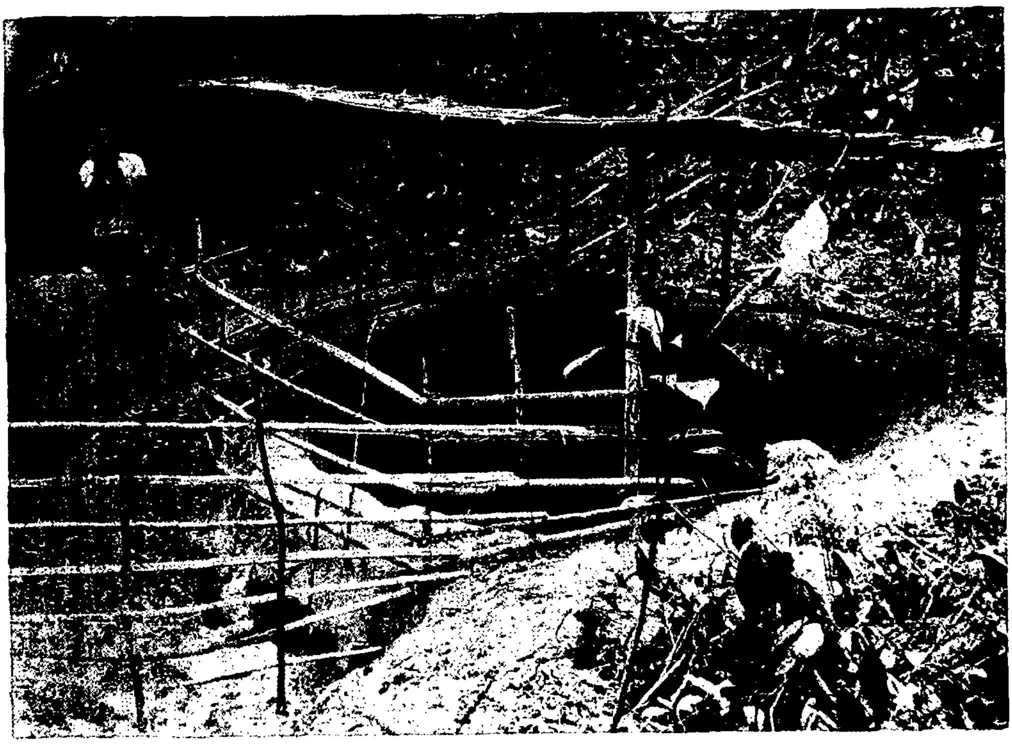

FIG. 6. Typical spring protection

TABLE 2. Potability testing of Springs, 11 villages

	Protected springs	Unprotected springs
Number	15	33
Number with potable water (i.e., no coliforms)	7	3
Proportion potable (%)	49	7
Mean coliforms/liter	259	6,847
Mean bacteria/liter	91	221

Comparing protected and unprotected springs statistically (Chi-square and normal testing), p values of 0.05 for the number with no coliforms, and 0.001 for the mean number of coliforms and the mean number of bacteria are obtained. Of note is the fact that all three unprotected springs with potable water were in one village which had sufficient warning in advance to clean out their springs. Okun (Ref. 1) reminds us that even the most polluted spring may yield potable water under proper conditions.

DISCUSSION

What importance can be attached to these results? Are there implications for further community level planning? What of national planning?

Community level implications

Potable water at the source in and of itself is no assurance of improved health of a population. A series of factors (Ref. 8) intervene between the potability of the water at its source and the quality of water finally consumed by individuals and families. Among these factors are the appeal of the water (taste, color, odor) and the convenience of the source, which determine first of all whether or not a population will use it (Ref. 6). Another factor is the level of technical skill required to draw water from the source. In the case of the springs protected in the present study, it is unlikely a spring would have been protected had the village not considered it a source of good quality and convenient enough for use. As for the water-drawing techniques, the level required for a spring is obviously minimal.

If a certain source of high potability is selected, then other factors enter in to determine what finally passes between the cup and the lip: (1) the quantity of water delivered at the source, probably more important than quality because of the impact on the water-washed diseases of White, et al. (Ref. 6); (2) the method of drawing the water--is the container dipped into the water or filled at a spout? The problem was obviated in this study by the use of the bamboo tube; (3) the cleanliness of the container, a factor obviously not controlled for here; (4) the cleanliness of the containers used for storage and for drinking and these in turn upon how many people use them, whether they are kept covered and washed frequently, and whether the persons using them wash their hands after defecation.

Even if potable water is drunk, is there assurance of better health? There is little evidence to support the notion. The incidence of typhoid fever cholera, infectious hepatitis, and perhaps leptospirosis, some of the clearly waterborne diseases (Ref. 8), will probably be reduced, but the evidence stems from only single source epidemics in large systems, not from multiple source systems in small communities.

The health-related implications of the results are therefore only assumed. The importance of the results depends more upon the social and economic appropriateness of how they were obtained, and upon the efficacy of employing local labor and local materials in a programme of organised community effort. The simple technology used is easily taught to itinerant health workers and thence to villagers. There is also the potential in time of covering entire populations with essential sanitation services through the multiplier effect of the itinerant worker training programme. Evidence also exists (Ref. 9) that there is horizontal spread of technical know-how from village to village.

The first implication of the results, therefore, is for community-level planning. Insofar as possible, local labor and local materials can and should be used in water source protection. The results, while not spectacular in health-related terms, could be so in time, but the approach is presently commendable because of its economic and social appropriateness (Ref. 10).

National implications

The results are more difficult to interpret when applied to the problems of national planning.

Not all communities obviously are at the same level of technical proficiency nor cultural amenability to change. Not all have geographic and climatic conditions as favorable as the communities studied. Not all have the same economic advantages. Even with these differences in mind, however, policy should based on the community organisation approach because of its social and economic advantages. Communities having clearly deficient resources or greater problems should be given increased technical and/or financial assistance.

The first task, obviously, is to assess the needs and potential of the country region by region including both rural and urban areas. Planning for manpower training and deployment resource allocation and technical assistance can then be rationalized according to varying degrees of need. Until such data are available, however, national planning will continue to be ineffective or worse, lopsided in favor of urban areas where data are available.

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NITRATE LEVELS IN GROUNDWATER FROM THE FLEUVE, SENEGAL

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INTRODUCTION

Nitrate concentrations in drinking water in the Sudan have been found by Burden (1) to be higher than usual. The likelihood of heavy fertilization as the Senegal River Basin is developed may add to the already high concentrations of nitrate of arid and semiarid soils (2). The extensive use of these waters to reconstitute powdered milk is likely to add to the total body burden of the nitrate anion in infants. In addition, the reduction of nitrates to nitrates by sporulating microbes present in all non-acidified dried milk, e.g. *Bacillus subtilis* (3) may result in high concentrations of its more toxic (4) nitrite ion's being ingested. Thus, an infant fed dried milk diluted with nitrate-bearing water is at high risk for developing methemoglobinemia. He is at further risk if the water has been boiled, concentrating the nitrates. Illnesses common to infants in the Sahel, such as diarrhea (5,6), and those endemic to Senegal, such as malaria (7,8), behave synergistically with methemoglobinemia. Furthermore, nitrate concentrations in drinking water are of particular interest in Africa where G-6-PD deficiency is more prevalent than in the rest of the world (9). This anemia limits one's ability to reduce methemoglobin. These factors deserve some attention due to the extremely high infant mortality rate in Senegal; it has been reported to be as high as 300 per 1,000 live births (10).

MATERIALS AND METHODS

Water samples were collected from a number of sources within a 100 km radius of St. Louis, Senegal (Table 1). All samples (approximately 50 ml) were placed in nalgene bottles which were capped and taped to prevent seepage. The samples were not filtered or otherwise treated prior to shipment. During transit the bottled waters were kept on ice and were then refrigerated until analysis. Water samples were analysed for nitrate and chloride contents and in some instances we also determined the total iron concentrations.

Briefly, we determined the nitrate content of water using the Brucine colormetric analysis (11). Water samples (10 ml) were mixed with sodium chloride (2 ml of 30 percent W/V) and sulphuric acid (10 ml of 30N). After cooling, brucine-sulfanilic acid reagent (0.5 ml) was added to each tube. The samples were heated in a boiling water bath for 20 minutes and subsequently cooled. The optical density of the samples was determined in a spectrophotometer (Bausch & Lomb Spectronic 100) at 410 nm. The brucine sulfanilic acid reagent was prepared by dissolving 1 g. of brucine sulfate and 0.1 g. of sulfanilic acid in 70 ml hot distilled water. After 3 ml concentrated hydrochloric acid was added, the solution was made up to 100 ml. Reagent blanks were run using distilled water. In addition, to serve as positive controls, local raw and heated water was analysed. Data were quantified from a standard curve prepared using anhydrous potassium nitrates as the source of nitrate ion. The nitrate ion concentrations ranged from 0.0/to 1 mg/l. Reagents used were obtained from Mallinckcodt Chemical Co., St. Louis, Mo.

RESULTS

TABLE 1. Nitrate content of nine water samples from the Fleuve, Senegal, 1977.

Sample	Salinity mg/l Cl.	Fe mg/l	pH*	NO_3 mg/l
Blank (distilled water)				----
Raw water Lake Saltonstall Connecticut			7.2	2.8
Plant effluent Lake Saltonstall Water Treatment Plant, Connecticut				2.6
#1 - Rosso, Mauritania tap water	12			0.3
#2 - Richard Toll tap water	28			0.3
#3 - St. Louis tap water	148			0.4
#4 - Lampsar well water (1:5 dilution)	40	.02	6.6-7.0	35.4
#5 - Savoigne well water (1:10 dilution)	2660	.03	6.9-7.4	226
#6 - Dagana well water (1:5 dilution)	16	0.95		15
#7 - Rong river water	420			1.02
#8 - Kassac Sud river water	20		7.4	1.0
#9 - Kassac Nord river water	8			0.6

*collected from river overflow

The results are summarized in Table 1. Our analysis of raw water and plant effluent from local sources (New Haven) gave nitrate concentrations which were in good agreement with previously established levels for this water source. The samples from Senegal were examined prior to analysis and some samples were noted to have a residue, but the supernatant fluid was macroscopically clear. This clear fluid was decanted and used in the analyses. The well water samples showed higher concentrations of nitrate, with sample #6 from Savoigne, well in excess of acceptable levels. The World Health Organization finds concentrations of nitrate greater than 45 mg/l unsafe in drinking water. Iron and chloride were measured and found not to interfere with the measurement of nitrate. There was no correlation seen between salinity and level of nitrates, nor iron content.

DISCUSSION

The potential for further increases in nitrification could pose a continued problem in the Fleuve, Senegal, as irrigation and fertilization increase. The conditions which favor nitrification would appear to be present in the three areas sampled which used well water. The cultivated areas are highly fertilized, a factor which greatly increases the potential for leachate containing nitrates (2). The pH of the river water in the area is 6.6-7.4 (6.5-8.0 is the optimal range); ammonia salts are likely present as a result of fecal contamination; and the mean annual temperature is 85°F, the optimal being between 50° and 100° F (12).

Occurrence of nitrates in the drinking water in the Fleuve region is of vital interest because infants, adults and animals require more water in the tropics than in the temperate zone, four to five times what they need in temperate zones (1), a fact which greatly decreases the safe limit of nitrate-nitrogen ingestion. Children drinking water from the Dagana well may well have significant levels of methemoglobin even though the 15 mg/l nitrate content of that sample was within the W.H.O. safety limits, because they doubtless ingest more water than children in temperate zones.

Infants and ruminants are at particular risk for developing methemoglobinemia from the presence of nitrates in drinking water. The lethal dose of nitrates for humans is 20 mg/kg. Older children (13,14,15) and fetuses may also be at risk. Methemoglobin is formed by the presence of nitrite ions which cause oxidation of the iron of hemoglobin from the ferrous to the ferric form with fetal hemoglobin oxidized twice as fast as adult hemoglobin. Normally one percent or less hemoglobin binds reversibly with methemoglobin. Such symptoms as cyanosis occur at levels of ten percent methemoglobin and death at 50-75 percent, or at 20 mg/kg (16,17).

As stated earlier, an infant fed dried milk diluted with nitrate-bearing water is at high risk for developing methemoglobinemia. Savoigne, the village with the highest levels of nitrate sampled (226 mg/l) was the recipient of shipments of powdered milk through Catholic Relief Services. Infants drinking powdered milk diluted with water from this well are at high risk for methemoglobinemia. In California 11.3 percent of infants drinking water with levels of nitrate between 5-9 mg/l had elevated methemoglobin levels (18).

The infant in ill-health is especially vulnerable, particularly if he has diarrhea or a respiratory illness (5,6,18), is under three months of age (13), or has a mucosal abnormality in the upper G-I tract which might raise his stomach pH above 4.0 (19). Methemoglobinemia reacts synergistically with other diseases, particularly the anemias, such as G-6-PD deficiency.

Malaria, which causes anemia and is endemic in Senegal, is a two-edged sword, as some common antimalarials, the 8-animoquinolines (7), actually induce methemoglobinemia. The common prophylaxis used in Senegal is chloroquine, a 4-aminoquinoline. However, chloroquine resistance is being reported in Southeast Asia and the Americas (20). Still, substituting 8-aminoquinolines should be avoided in areas with high nitrate concentrations in drinking water.

Further health risks may occur because the water from the three sampled wells is stored in large metal containers. Waters high in nitrates left standing in metal troughs and waterers can be sources of excessive nitrites; reduction can occur by bacteria or chemical reactions with the metal in the troughs (14). Ruminants, as well as infants and children, are susceptible to methemoglobinemia, and since cattle are a form of capital and social prestige to the pastoral Peuls in the Fleuve, they should be considered in assessing the effects of nitrates in ground water.

CONCLUSIONS

With the high probability of the development of irrigation in the Fleuve and attendant fertilization of cash crops, it seems important to monitor ground water supplies for nitrates even though the testing procedure is neither simple nor quick. This monitoring process is particularly important as nitrates are not cost-effective to remove from drinking water, so that the effects of a nitrate build-up are virtually irreversible. With clear health risks to infants and ruminants, unstudied chronic effects on older humans, the problem of nitrates in the ground water of Senegal deserves immediate attention.

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THE HEALTH HAZARDS OF OPEN DRAINS IN DEVELOPING COUNTRIES

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Abstract

Samples of waste water were taken from open drains in four different types of residential neighbourhoods in Ibadan, Nigeria. The results of the physical, chemical and biological analysis of the samples taken from both the traditional areas and the private layout areas show that the open drains contain waste water with characteristics varying between those of fresh and septic domestic sewage. The BOD varies between 35 and 450 mg/litre, depending on the water consumption rate in the locality. Many types of pathogenic organisms, which normally cause morbidity and mortality in Ibadan, were identified in their infective forms in the samples. Even though the people dislike the open drains, all those who live in the areas, especially the children, have either occassional or regular contact with the drains' content. Therefore, the drains are the foci of infection. The drains in the government reserved areas and estates, which are low density residential areas, are normally for surface run off from the rain, although some of them contain other components of sewage.

Some theoretical suggestions have been offered for urgent modification and elimination of the drains from the communities which have them.

INTRODUCTION

One important and indisputable difference between communities in the developing countries and those of the developed countries is the existence of the open drains in the former. In the developed countries, normally all the different components of sewage are eliminated from the human premises through sewers. Unfortunately in most of the communities in the developing countries, at least one component of sewage finds itself in the open drains where mosquitoes breed. Other pathogens could be present, depending on the source of the component of sewage present in the open drains. In the urban centres of the developing countries, it is usual to have pipe borne water supply without sanitary provisions for elimination of waste water from the human premises. This is confirmed by the WHO findings (1) when it was reported that about 77% of people in the urban areas of the developing countries have access to pipe borne water while only about 25% of the people were connected to public sewers. In Africa only about 13% of the urban dwellers were estimated to have been connected to public sewers. The waste water in the urban areas of the developing countries is commonly discharged into open drains.

There are different types of open drains. Some are constructed and well lined while many are neither constructed nor lined. Those which are not constructed are often formed by the waste water, especially the rain run off. In some areas, the lined surface drains are well maintained, including regular spraying with insecticides, while in many areas, the drains are very unsightly with refuse and foul smelling septic sewage. Those areas which employ properly designed, well constructed and regularly maintained septic tanks have open drains for only the surface run off from rain, waste water from car washing or other waste water without much pollution. While those areas with faulty septic tank systems or those without any ready access to any form of excreta disposal facility have open drains which serve as open sewers. Poor refuse collection programmes worsen the characteristics of the open drains in all areas. Such refuse is often deposited at places where they have access to the open drains where it obstructs flow and causes flooding during rain. In Ibadan the regular flooding of many areas in the city is due mainly to the blocking of the main drainage channels and streams with refuse (2). From these characteristics of the open drains, it is not difficult to imagine that all types of organisms, both pathogenic and otherwise, will one time or the other have access to the drains. The important point is the persistence or the latency of the pathogens in the drains (3).

Numerous studies and reports have been carried out and are being carried out on the physical, chemical and the biological characteristics of domestic sewage in sewers. Mills (4) discussed the physical and chemical analysis with emphasis on the presence of colloids in sewage; Painter and Viney (5) described the general composition of domestic sewage; Oluwande "et al" (6) discussed the biochemical oxygen demand characteristics of sewage of people on Nigerian diets. Others like Mom and Schaeffer (7) Allen "et al", (8): Hensen, (9) Kelly "et al", (10) Dunlop, (11) McCoy (12) and Wang, "et al", (13) discussed various aspects of the survival of different common pathogens in sewage. Nearly all these workers had reported on the sewage in conventional sewers and not open drains. Also, only few research workers had reported on the physical, chemical and biological characteristics of effluents from the septic tanks and the soakaway pits. Majumder "et al" (14) and Phadke "et al", (15) discussed the characteristics of the effluents from the septic tanks in India. While Raman and Chakladar (16) and Ranade and Subba Rao, (17) discussed how the effluents from the septic tanks can be cheaply polished. These workers had not been specific on the survival of the pathogens in the septic tanks.

This paper discusses the physical, chemical and biological characteristics of the waste water in the open drains and those of the septic tanks effluents. It will also discuss how hazardous the open drains are to those people who live very close to them. Some suggestions are also made as to how the open drains may be eliminated from the communities of the developing countries.

THE FIELD SURVEY AND LABORATORY ANALYSES

For the purpose of sampling of the waste water in the open drains, Ibadan City was divided into four types of residential neighbourhoods: (i) the government reserved areas which are low density areas mainly for the senior civil servants: (ii) the government housing estates, which are also low density areas established since the late fifties for those who can afford either to rent or build in the areas (iii) the private layout areas which had been developed by individuals who bought plots from families. These areas are often high density areas because those who bought the land are often too eager to have maximum living units which they can let to tenants. The planning authority is often unable to control the qualities of development in the areas. In many places, such areas had developed into slums. (iv) The traditional old core areas are the oldest parts of the city. These are the areas where most of the indigenous people of the city live. The houses are arranged close together without order. It is impossible to ride ordinary bicycles along the alleys between the houses. Initially, samples for physical, chemical and biological analysis were obtained from the drains in the four types of areas. Later, the survey was restricted to only the private layout areas and the traditional areas with occasional sampling in the other two areas because most of the drains in the areas have waste water only during rains. Samples of effluents from the septic tanks, soakaway pits and aqua privies were also analysed. In order to find how much self-purification goes on in the open drains, some drains were sampled from the points where no branch drain enters them downstream until they enter bigger drains or streams. The typical results are given in tables 1, 2 and 3. The survey is being carried out in such a manner as to be able to determine the contribution which different types of domestic waste water are making to the characteristics of the contents of the open drains.

DISCUSSION

The studies on the open drains in Ibadan have revealed that there is no difference in the general characteristics of the waste water in the drains found in the traditional old core and the private layout, high density areas. On the other hand, only few drains in both the government reserved areas and the government estates contain any other component of sewage apart from the surface run off from rain. The few drains found in the areas with other components often produce samples with better physical, chemical and biological characteristics (see table 1). It is pertinent to note that in the government reserved areas, the government estates and most of the private layout areas, all the houses employ the septic tank systems for sewage disposal. While in the traditional areas, all sorts of methods are employed for excreta disposal. The open drains in the private layout areas contain waste water with characteristics similar to those of the drains in the traditional areas because the septic tanks in the private layout areas are often badly designed, poorly constructed and poorly maintained. Often the tanks and the soakaway pits overflow into the open drains. Also, many septic tanks in the areas are designed to admit only flushed faeces from the water closets.

TABLE 1 Typical Results of Worst and Best Areas

Areas / Characteristics	Mokola (II)	Oremeji (II)	Foko (I)	Yemetu (I)	Adeyi Rd. Bodija (III)
p^H	7.2	7.5	7.3	7.5	7.0
Turbidity	115	100	50	40	15
Total Solids mg/l	9,420	2,630	412	286	142
Suspended Solids mg/l	70	40	20	20	3
Permanganate value (4 - hr.)	26	26	38	19	8
Dissolved oxygen mg/l	0	0	0	0	4.6
BOD_5 (20°C) mg/l	120	98	95	83	26
Ammonia (N) mg/l	25	107	110	107	67
Protozoa	(a) Trichomonas species (b) Giardia Intestinalis (c) Balantidium coli	Trichomonas species	Trichomonas G. intestinalis B. Coli	Nil	Nil
Total Coliforms per 100m.	1.4×10^8	1.4×10^7	1.8×10^8	1.8×10^7	1.8×10^7
Faecal Coliforms per 100 ml.	1.8×10^4	1.4×10^2	1.6×10^4	1.6×10^3	1.6×10^4
Pathogens	Staphylococcus aureus	Staphylococcus aureus	Staphylococcus aureus Candida albicans	Staphlococcus aureus	Staphylococcus aureus
Helminths	(a) Schistosoma haematobium Miracidia (b) Ascaris ova (c) Hookworm larvae	Nil	S. haematobium Miracidia	Nil	Nil
Cysts	Giardia sp. B. Coli	Nil	(a) Giardia (b) B. Coli (c) Entamoeba histolytica	Nil	Nil

NOTE (i) Traditional core areas
(ii) Private Lay Out Areas
(iii) Govt. Estate.

TABLE 2 Variations in characteristics along the drains

Location / Characteristics	Origin	After 30m	After 1000 m	Yemetu stream before drain	Yemetu stream after drain joins
p^H	7.2	7.1	7.1	6.9	6.9
Turbidity mg/l	290	145	120	50	60
Total solids mg/l	688	68	50	34	120
Suspended solids mg/l	140	60	40	10	12
4 - hr. P.V. mg/l	61	30	23	7	13
DO mg/1	Nil	Nil	Nil	2.8	2.6
$BOD_5 20^oC$ mg/1	980	200	80	30	60
Ammonia (N) mg/1	499	273	233	93	7.3
Protozoa	Trichomonas species	Trichomonas species Balantidium coli	-	Nil	Nil
Total Coliforms per 100 ml.	8×10^7	1.8×10^7	1.8×10^7	1.8×10^7	1.8×10^7
Faecal coliforms per 100 ml.	2.0×10^3	4.0×10^3	1.0×10^3	4.0×10^3	4.0×10^3
Pathogens	Staphylococcus aureus	Staphylococcus aureus	Staphylococcus aureus	Staph. aureus Strep. faecalis Candida albicans	Staph. aureus Strep. faecalis Candida albicans
Helminths	Hookworm Larvae	Ascaris ova Larvae	nil	Ascaris ova Hookworm Larvae	Nil
Cysts	Nil	Nil	Nil	Nil	Nil

Note: - indicates not done

TABLE 3 Effluents from Septic Tank and Aqua Privy Systems

Characteristics	Septic tank Effluent	Soakaway pit effluent	Aqua Privy Effluent
p^H	8.0	7.8	7.1
Turbidity	-	30	-
Suspended solids mg/l	150	50	180
Total Solids mg/l	355	320	511
Dissolved oxygen mg/l	8.0	7.0	2.5
BOD(5) 20°C mg/l	180	39	250
(4hrs.) P.V. mg/l	-	8	-
Ammonia N mg/l	-	206	-
Protozoa	Nil	Nil	Nil
Total Coliforms	1.8×10^5/100 ml	1.8×10^3/100 ml	1.8×10^7/100 ml
Faecal Coliforms	1.8×100^2/100 ml	300/100 ml	1.8×10^4/100 ml
Pathogens	Nil	Nil	Nil
Helminths	Ascaris ova Hookworm larvae	Ascaris ova 100/litre Hookworm larvae 100/ l	Ascaris ova Hookworm larvae
Cysts	Nil	Nil	-

Note - indicates not done

Figure 1 showing everite pipes arrangements for discharging waste water into open drains

The remaining components of domestic sewage are discharged directly into the open drains (see figure 1). The standard of refuse collection in both private layout areas and the traditional areas is the same - very poor. In both areas, many people defaecate or urinate either straight into the open drains or into the bathrooms which are subsequently washed into the open drains.

It is therefore not surprising to find, as shown in table 1, that the physical, chemical and the biological characteristics of the waste water in the drains of the two high density areas are similar to, and in certain respects worse than those of the domestic sewage. The open drains are therefore very hazardous to health because the few types of pathogens, which were identified by the limited laboratory facilities, are present either in active and infective forms or as cysts. The pathogenic organisms which have been identified in the drains are those which are recognised as causing high mortality and morbidity among the people in the areas. There is no doubt that viruses and other species of fungi can be found in the drains since the drains contain domestic sewage. The snails which are intermediate hosts for schistosoma haematob um are found in some big drains. From table 2 it can be observed that self-purification takes place along the drains due to sedimentation, aeration, photosynthesis and other biological activities. These are responsible for the improvement in the characteristics as the waste water flows down the drains. This is an important difference between the sewage in the conventional sewers and the open drains.

In table 3, the typical results obtained for physical, chemical and the biological characteristics of the best functioning septic tanks, soakaway pits and aqua privy effluents are given. The characteristics of effluents from soakaway pits of septic tanks are better than those from either aqua privy or ordinary septic tanks. Only hookworm larvae and the ova of ascaris were identified from the three types of effluent. The high counts for both total and faecal coliforms indicate that other pathogens may be present.

PROXIMITY OF THE DRAINS TO THE PEOPLE

Fig. 2 Proximity of open drains to the houses.

Figure 2 shows how close the open drains are to the houses. It is customary to find traders siting along the drains selling articles, some of which could be food items which are exposed and are never processed further before consumption. Children are often found playing along the sides of the drains. They often have regular contacts with the contents. Water pipes are often found in the drains (see figure 3)

Fig. 3 water pipes inside open drain

Since many areas where the open drains exist often have intermittent water supply, it is obvious that the water in such pipes can easily be contaminated. It had been found that the water tends to have little or no residual chlorine, so there is no safeguard against accidental pollution. The incidence of ascaris, hookworm and schistosoma haematobium infections in the areas are very high.

IMPROVING OR ELIMINATING THE OPEN DRAINS

The open drains are evidence of poor sanitary conditions in most of the residential areas of the developing countries. As this study has shown, open drains contain all types of pathogenic organisms in different stages of development. The drains are also aesthetically unacceptable even to those who live with them. Environmental sanitation cannot improve in the areas without modification or elimination of the drains.

The drains take different forms in different areas (see figs. 4, 5 and 6).

Fig. 4. An unlined drain receiving effluent from a septic tank

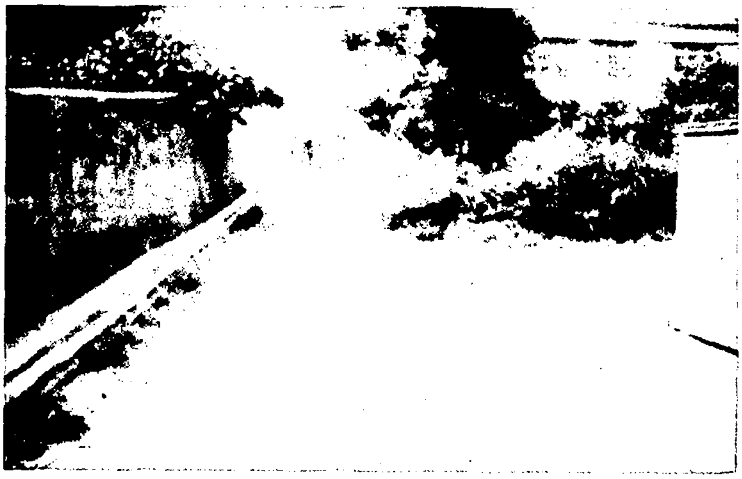

Fig. 5 Open drains constructed by landlords

Fig. 6. Junction of a drain with another

Figure 4 illustrates a big and unlined drain into which a septic tank effluent is being discharged. This type of drains is common in the traditional built up areas. The only way to modernise environmental sanitation in such areas is through slum clearance. The various governments of the developing countries cannot effect the slum clearance as speedily as the horror and misery in the slum areas justify. In order to remove the slums from the urban centres of the developing countries, the government efforts must be supplemented massively by the private sectors. (Ref.18). All private industrialists, and property developers must be made to acquire land in the slum areas. Also most of the development schemes of the governments like new hospitals, industries and other institutions can be sited in the slum areas instead of siting in the undeveloped areas. The people displaced from the slums will then be resettled in well planned areas.

In the other areas, the drains can either be re-constructed and covered up or be replaced with sewers at the landlords' expense. Many of the drains are often found near expensive buildings. As can be observed in figures 5 and 6, the owners of the houses near the drains often make efforts to line the drains. All that is required is for the municipal authorities to standardise and supervise the construction of the open drains. If the open drains are to be replaced with sewers, the landlords can be made to pay for the portions of sewers in front or around their own houses. This aided self-help approach will go a long way to remove the constraint which inavailability of funds places on the efforts of the governments to provide sewers. In figure 7, drawings of typical precast reinforced concrete units which may be used to line the open drains are given.

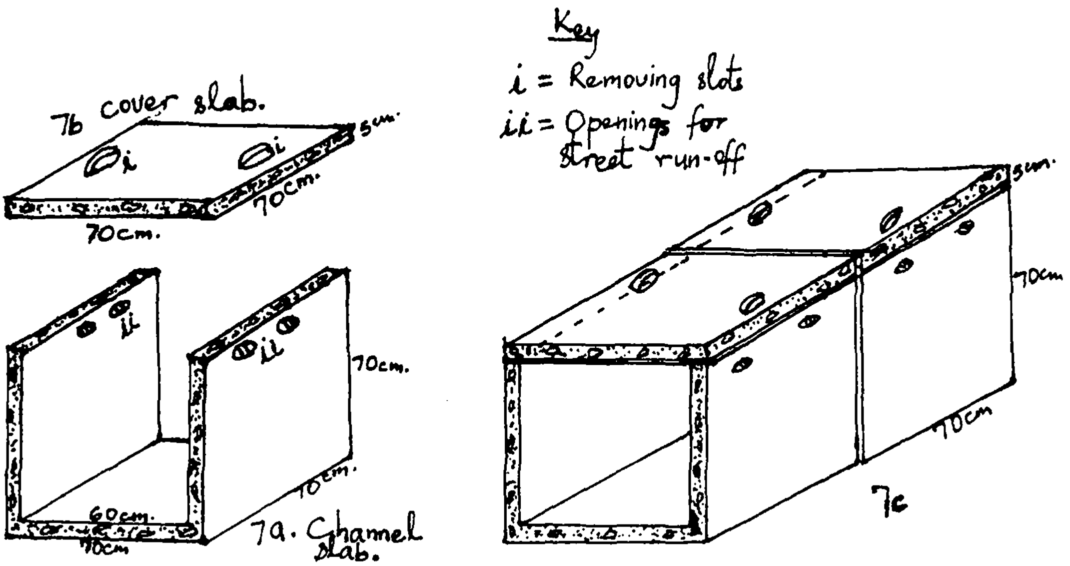

Fig. 7. Typical precast reinforced concrete units for drain improvement

The dimensions and the shape of the channel slab shown in figure 7a may vary according to the quantity of flow expected. However, to prevent frequent blocking, the dimensions given should be regarded as minimum. In some cases circular or v - sections may be adopted. The cover slab shown in figure 7b should be provided with removing slots to facilitate lifting of the slabs during channel maintenance. If the units are assembled as shown in figure 7c to form the drains, access of refuse to the drains will be minimised and frequency of maintenance can be reduced to once a year. Drains of the shape shown are common in many road sides of the developing countries. In such places, the channels are generally cast "in situ". Thus the quality control of construction is poor except for those drains which had been closely supervised during construction. The approach being suggested in this paper will ensure that both the channel and the cover slab units are precast preferably at central places where better quality control can be effected. It will also ensure standardisation of the drains cross-sections.

In those areas where the open drains are to be replaced with conventional sewers, it is suggested that separate sewerage systems be adopted in all tropical developing countries. In order to reduce the amount of disruption to traffic and general living activities during the construction period, it is suggested that the sewers are either located on either side of the roads just like the drains for those places where the roads are narrow, or at the centre of the roads in those areas where the roads are wide enough for traffic to use half of them during construction.

Since shortage of funds is the major constraint which prevents the municipal authorities in developing countries from providing modern and efficient environmental health services, it is necessary that revenue collecting methods be overhauled completely. From the experiences of the authors in many developing countries, it has been concluded that the efficiency and the effectiveness of the local authorities on environmental health programmes are directly proportional to the calibre of staff and the financial resources. In countries like Kenya, Uganda and others where towns with population as small as 30,000 have city engineers, medical officers of health, qualified town clerks and other personnel, the standard of environmental health services is comprable to what is found in the developed countries. In such places modern tenement rating systems are adopted and the rates collected are judiciously spent. On the other hand, in a country like Nigeria where many towns with populations over 500,000 do not have town engineers and medical officers of health, the environmental health services and facilities are very poor indeed.

It is the view of the authors of this paper that tenement rating systems based on fixed percentage of values of property should be adopted by all developing countries. This will ensure that landlords pay rates commensurate with the values of their property and the services which their tenants deserve. Thus a situation now in Nigeria, where landlords who derive more than N50,000 (£42,000) annually from houses contribute nothing towards the costs of bringing environmental health services into the streets where such houses are located, must be changed before the quality of the environment can improve. Some people often express the view as to whether it is politically wise to ask landloards whose houses are valued atN50,000 (£42,000) to pay 1% as general rate when such landlords are not adequately aware of the importance of modern environmental health services. This doubt is unfounded, because the landlords will be willing and happy to pay if the necessary services are adequately provided and efficiently maintained.

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