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Engineering, Science and Medicine in the Prevention of Tropical Water-Related Disease

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

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INTRODUCTION BY A. M. MUIR WOOD

First it is my pleasant duty to welcome to this Institution the delegates from many different disciplines and from 32 different countries. We are probably concerned on an occasion such as this less with new fundamental knowledge than with its application, particularly with the special problems of the developing world. Apart from malnutrition, probably more disease is caused in the developing world at the present time from good but misguided intentions in development than from englect. It is our main purpose on an occasion like this to become more aware of the hidden dangers so that these may be combated.

In this type of activity we cannot look to statesmen and politicians to guide development in the right direction. Even in the U.K. — potentially possible the easiest country in the world to govern — politicians seem unable to get priorities right and here, in public health terms, there is already an investment, at the present day replacement costs, of at least £2000 per inhabitant. Such a figure helps us to comprehend the magnitude of public health problems in countries where such a figure represents the total income of an individual over many years. Against the competition of the prestigious and meretricious project, what can be done to tackle a problem of such magnitude?

There is a present tendency to suppose that courses in the broad area of environmental health could equip people to work in this field; this is an appropriate occasion to state that expertise acquired by training and experience must be based upon a fundamental understanding of medicine, engineering or an appropriate science.

I wish to express thanks to those who have organised this occasion on behalf of the Royal Society for Tropical Medicine and Hygiene, the International Association on Water Pollution Research and on behalf of the Institution of Civil Engineers.

Finally, it is my pleasure to invite Mr J. Tomlinson M.P., Minister of State of the Ministry of Overseas Development, to open this conference.

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OPENING ADDRESS BY MR. JOHN TOMLINSON, PARLIAMENTARY UNDER-SECRETARY FOR OVERSEAS DEVELOPMENT

In vast areas of the developing world one of the universally-recognised essentials of life is still lacking: potable water allied with adequate sanitation. The burden of disease that contaminated water and inadequate sanitation imposes, becomes increasingly unacceptable as both rural and urban populations grow. One consequence of this is, of course, greater recognition by international organisations, governments, voluntary bodies and professional societies that only an integrated approach to these difficult problems is capable of providing solutions. This Symposium can, I believe, make a significant contribution to my Ministry's aims of helping the poorest. I find it heartening to see present here today so many people directly concerned with the provision of adequate and safe water to communities, be they large or small, throughout the developing world. I am sure it augurs well for the future.

It is the prevention of tropical disease that is the main concern of this meeting. We in ODM know only too well the enormous toll taken, in lives and lost human resources, by water-related tropical diseases. The position is particularly tragic when we remember that it is the children who are most vulnerable. Thus, anything that can be done, any new method or technique that can be developed for dealing with this problem will be wholeheartedly welcomed and, I hope, tested.

Consciousness of the need for adequate safe water supply as one of the weapons in our battle against these, all too prevalent, diseases is becoming greater as we gather our forces for the assault upon the peak the World Health Organisation has set us: health for all by the year 2000. This is a tremendous task. And those agencies concerned, including the WHO itself, the World Bank, UNDP, FAO, governments both of developed and developing countries, voluntary agencies and professional people like yourselves, are increasingly involved in seeking ways and means to bring under control those widespread tropical diseases which are major obstacles to successful action in providing health care (and a healthy environment) for the developing world.

The United Kingdom is involved bilaterally in a wide range of projects designed to further this aim. And we support the UN system's intention, propounded at the UN Water Conference and endorsed by the General Assembly, that a major effort should be made to provide safe water supplies in developing countries. This is in complete harmony with the aims of the Symposium and, as I mentioned earlier, I am particularly pleased that the Symposium has among its objectives the bringing together of those professional disciplines which are working towards the same goal but who have, in the past, not talked to each other perhaps as frequently or as fully as they might have done.

As a Minister concerned with development in the broadest terms, I recognise that much needs to be done; and also that the difficulties of doing it are, if not insuperable, then certainly daunting. Safe water supply and good water resource management are inextricably linked with local conditions and customs, agricultural demands, climate and other factors which make it important in deciding on an overall approach to take into account local variations and special difficulties. That is why the expert views, opinions and ideas elaborated at this Symposium will, I am sure, have the most wide-ranging effects. Those of you from developing countries will be able to lend us your valuable experiences and knowledge of your particular problems. Those of you from the developed world will, I hope, learn from this interchange and contribute through your hard-won skills and insights.

We see the provision of safe and adequate water supply and sanitation as a major weapon in the fight against certain tropical diseases. My Ministry, and its Medical, Engineering and Environmental Advisers have taken up the challenge by giving increasing emphasis to water supply and sanitation as part of projects designed to raise the overall health level of the communities they serve, particularly those in the most impoverished and remote rural areas. But we need your help. Without the professional skills and insights you can provide, we are without a focus. Your knowledge is vital to our most basic concerns for deprived populations throughout the world. I am therefore delighted that this Symposium has been arranged and wholeheartedly wish it every success.

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ADDRESS BY S. G. BROWNE, PRESIDENT, ROYAL SOCIETY OF TROPICAL MEDICINE AND HYGIENE

On behalf of the Royal Society of Tropical Medicine and Hygiene, I welcome our Distinguished Guest, Mr. John Tomlinson, MP, Parliamentary Under Secretary to the Ministry of Overseas Development, and the participants in this Joint Symposium, which brings together diverse interests impinging on the relation of water to tropical disease. I need hardly assure you that the Society I have the honour to represent has been identified with this Symposium since its beginnings as a small trickle, a rill or runnel; it has watched it broadening out as major streams of national and international dimensions have flowed in, until we have here today a powerful surge of expertise and experience unparalleled in the history of water-related disease in the tropics.

Although doctors in the West are popularly supposed to be curative technicians, yet from the very foundations of our Society, medical men working in the tropics have been forced to take cognizance of water in the whole economy of health and disease. They have seen water as a vehicle of disease pathogens, as a culture medium, as a necessity for personal bodily hygiene, as an indispensible entity for the multiplication of disease vectors or as providing an essential milieu for parasites and vectors at some stage of a surprisingly varied series of life cycles.

Not only so. Doctors working in the tropics have over many years been forced to recognize the importance of water in food production and nutrition, and all too frequently they see the sad results of starvation – politely and euphemistically hidden under such terms as undernutrition and protein-energy malnutrition. And they have more recently perceived the overriding importance of water in the whole process of rural – and urban – development in the tropics.

It has been said that bringing good water to, and taking soiled water from, households in the tropics is the greatest single benefit that Western science and technology could confer on the peoples of developing countries. This modern rephrasing of the ancient adage that "cleanliness is next to godliness" has much to commend it.

But the provision of pure water supplies, even in adequate quantity is – like patriotism – not enough. It will not by itself abolish infantile diarrhoea or typhoid, or polio or hepatitis; nor will it eradicate trachoma or scabies. You can take a horse to water, but you can't *make* it drink. You can provide pure water, but unless ordinary people use it hygienically, the prevalence of water-related disease will remain undiminished. I found that some villagers preferred the taste of contaminated water to the pure piped water we supplied, just as the soldiers and their horses in the desert during the first World War refused the pure water brought to them at considerable trouble, and replenished their salt levels by drinking the brackish local water.

And so we need the engineer and the physician, the psychologist and the anthropologist – as well as the water experts. It is my hope that this Symposium will be a continuing catalyst in making avilable to the urban as well as the rural populations of the burgeoning Third World countries, the expertise and the resources that will conserve and utilize this priceless commodity entrusted to the peoples of the world.

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WELCOMING ADDRESS BY PROFESSOR POUL HARREMOËS, VICE-PRESIDENT, IAWPR

Mr. Secretary, President, Ladies and Gentlemen,

First of all I want to forward to everybody sincere greetings and best wishes for the Conference from the President of IAWPR, Mr. Hawerman. I was with him as lately as Saturday in Africa, but urgent business at home prevented him from coming here and thus it is my privilege to address you on this occasion.

This symposium on tropical water-related diseases comes very timely. In June at the Stockholm Conference, the Governing Board of IAWPR was presented with a request from WHO to contribute to the coming programme for the Decade for Water Supply and Sanitation, 1980 - 1990. The general consensus of the Governing Board was that IAWPR should make the best of its capabilities available for the programme of the decade and we are now examining the possibilities. This may sound trivial, but in my assessment the content of the discussion was important. First, because all countries participating in IAWPR were concerned that the Association should devote more activity to the problems of developing countries. Secondly, because there was expressed intent to deal with the more day to day problems of water pollution. The fact is that IAWPR to some has an image, according to which it is concerned mostly with the academic, remote-from-reality kind of research. This is not correct, but it is correct that there has been a tendency to deal mostly with the problems of the industrialised world - with a number of exceptions. In my interpretation, this results from a misunderstanding of the word "research". Many relate research to the most recent, technological developments in the industrialised world and natural sciences related thereto. Controversially one may speculate to what extent the measures of prestige in the academic world may be responsible for this. Research in <u>not</u> only related to technological developments in the industrialised world. It is as intimately related to the industrially developing world where the needs may call for very sophisticated research and technological development, akin to but still different from that of the industrialised world. This Conference is ideal for a demonstration of this fact. Forty-three papers will be presented on engineering, science and medicine applied to water related diseases in the tropics - where after all, most of the developing countries are situated. I have of course not read all the papers, which we have received in advance. (Here I most remember to congratulate the organisers with the expedient transfer of advance material). I have read enough to realise that very advanced principles of science and engineering have been applied to the problems in the tropics; problems of great conern to everyone there, rich or poor, but especially poor, in their daily life.

I have often said to my students that water pollution combines the thrill of dealing with a multi-disciplinary field which brings you in contact with the whole range of scientific and engineering disciplines <u>with</u> the frustration of ever confronting with now little any individual can encompass. I have often seen that the frustration dominates over the thrill with the effect that people retreat to the easier position of looking at the problem with the eyes of their own discipline only. Joint efforts of different disciplines are required. This is borne out clearly in many of the papers to be presented. In particular the introductory paper by Dr. Bradley, as you will hear shortly. I want to congratulate the organisers of this conference with their initiative to bring the Royal Society of Tropical Medicine and Hygiene and the Instituteion of Civil Engineers together in joint sponsorship of this conference. The IAWPR is very happy to support such joint ventures. In fact, it is my strong belief that the future of the International Association rests heavily with initiatives of this type and with our own ability to act efficiently with respect to communication on such events.

I know of no problem within my engineering profession that calls for multi-disciplinary approaches more than the problems of developing countries. At this conference we concentrate on water-related diseases from a medical and engineering point of view. But, as pointed out in several papers, when dealing with communicable diseases you have to relate also to other routes of communication, for example, food hygiene, and before you know of it, you are concerned with the general behaviour of the population. Thus, the social sciences become important. In this regard, education of not only local professionals, but the population in general comes into focus. Following this path, you end up discussing the whole social and economic structure of the society in question. This is a sound exercise because it makes you humble in regard to your otherwise sophisticated scientific achievements.

We are dealing with a fraction of a world-wide problem to which we, as individuals, can endeavour to contribute our token. By getting together on an occasion like this we can jointly make this token significant and thus contribute through other joints to an overall development for the better.

When we, after a few days together, have taught each other the most recent gains in knowledge and development in technology, we shall disperse; but we must keep in mind that we are then left with the important task of bringing the information to the local professional on a wide scale. During this Conference, I shall look into the role that IAWPR might play in this regard. To me it is a must if such needs fit our capabilities.

I want to thank the organisers for the initiative and for efforts put into the preparations of this Conference. I wish you a continued success in your implementation of the programme and on behalf of IAWPR I welcome everybody and wish you a rewarding participation in this Conference.

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

D.J. Bradley

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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.

[illegible] was to [illegible] 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,