the WEDC GROUP

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collaboration for appropriate technology

INTRODUCTION

All technology should be appropriate (1). Highly advanced, sophisticated and extravagent equipment may be most appropriate for a space-ship. For developing countries appropriate technology is that which maximises the use of plentiful resourses and minimises the use of scarce resources (2) or 'technology which provides the most socially and environmentally acceptable, economically efficient services to the consumer at least social cost'(3). 'Technology must take into account such factors as economics, social structure, the availability of skilled manpower, climate, energy sources and materials'(4).

The WEDC Group in the Department of Civil Engineering at Loughborough University of Technology exists to study and disseminate knowledge and ideas about water and waste engineering for developing countries. It is therefore concerned with the whole of the water cycle and with solid waste and atmospheric wastes. Because the Group is wholly concerned with developing countries it places particular emphasis on aspects of technology which are peculiar to developing countries, and on the factors which determine what is most appropriate. In the past 'too much emphasis has been placed on the direct transfer of technology . . . and not enough on the creation of local conditions which enable technologies to be absorbed'(4). The local conditions for absorption of appropriate technology depend upon individuals and organizations, and it is essential that individuals and organizations should collaborate if there is to be a beneficial application of technology.

The need for improved provision of water and sanitation has been postulated in numerous documents and there is abundant statistical evidence of the deficiences (eg, 5). Figures are merely indications of the magnitude of developing countries' problems - the solution to the problems involves an understanding of a whole range of activities, of which we have selected a few for detailed consideration.

DEVELOPMENT OF WATER SOURCES

Assessment of yield from a reservoir, stream or river requires information on flows. This information comes from gauges (stream or rain) that have been sited by accident or by advanced planning, if any gauge exists at all, In many cases the data are inaccurate and/or incomplete. Yield estimates made from data obtained from stream gauges giving totally inaccurate estimates of low flow are not uncommon in developing countries. Designers/consultants often have little or no control over setting up the network of gauges or over the accuracy of data. When they do become involved in design it is too late to do anything. Better collaboration could improve this by

1. advanced planning to gauge potential future surface water sources -
2. use of suitable gauges that are simple, reliable and easily maintained -
3. a system for collecting and storing the data, and for maintaining gauges - and
4. a system for partial analysis of data to check accuracy and also for identifying the need for other gauges.

Many water supply schemes are designed from short records of flow, which leads to a rough estimate of yield. It would be better if the designer/consultant could reappraise his design after a few years when more data are available.

Surface water supply schemes rarely remain static as population expands and ways are investigated of fully utilizing many water sources. This requires a reappraisal of existing schemes at regular intervals. There are many advantages of allowing the designer and the operator of the reservoir etc to take the original design and investigate ways of increasing the yield possibly by conjunctive use as in India where the total yield from a number of reservoirs supplying a city was reconsidered.

GROUNDWATER LOCATION BY GEOPHYSICS IN A DEVELOPING COUNTRY

Groundwater surveys are frequently recommended as a preliminary to groundwater development. Much time and money can be wasted if the correct methods are not applied from the onset of the survey, or if geophysics is used when it is not cost-effective.

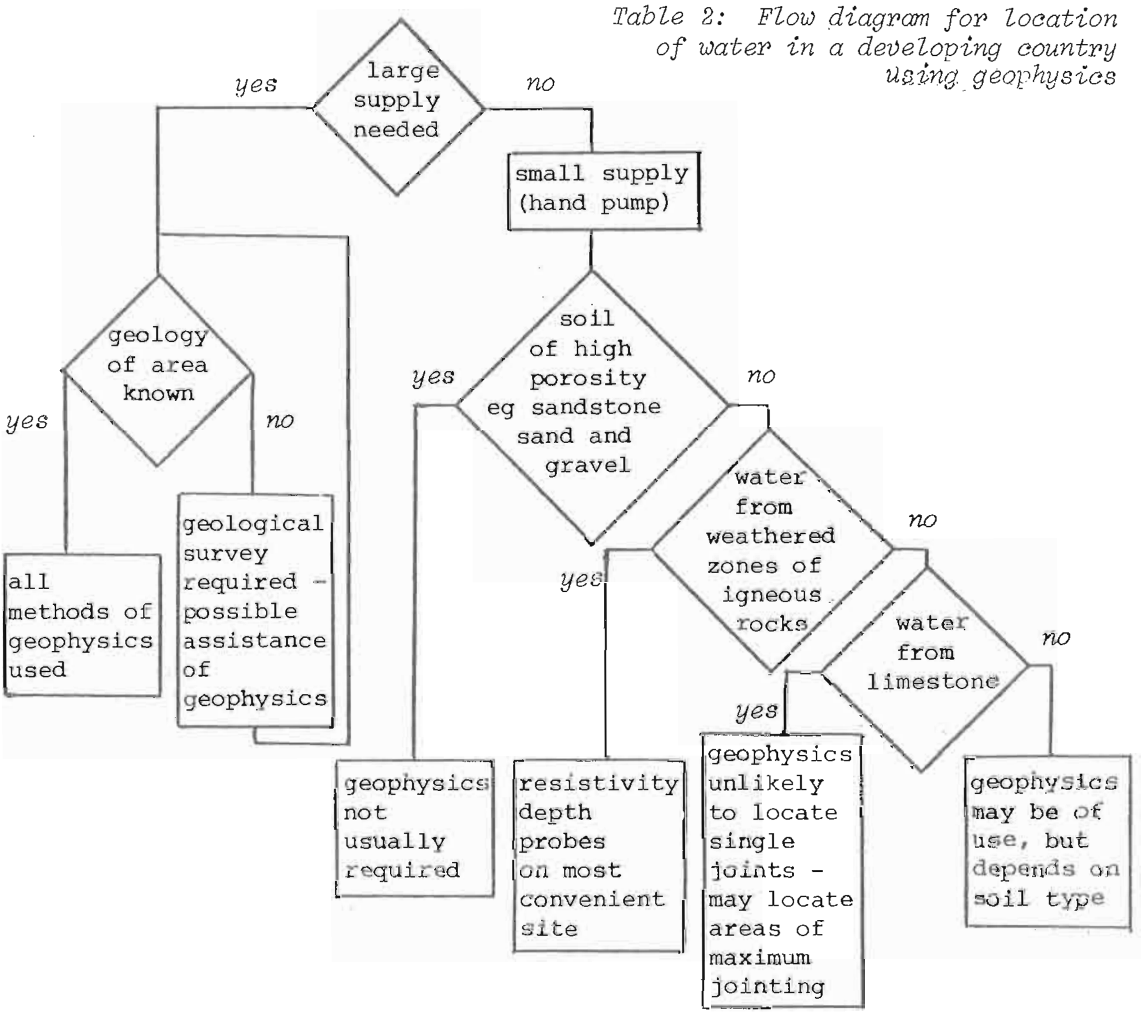
There is little published guidance on the selection of geophysical techniques for groundwater surveys in a developing country. In this situation the search for groundwater supplies can be divided into two simple classes: those which are to be exploited by hand pump and those which are to have an electric or diesel driven pump, header tanks and distribution. In the first case the volume of supply is much less important than its convenience to the demand, whilst in the latter the volume of water available is obviously important. The four geophysical methods commonly considered are set out in Table 1. Of these resistivity is by far the most commonly used, since it is the only method which actually detects water.

Table 1 Geophysical methods available

Method	Application
Resistivity	Most commonly applied method. In favourable conditions will define: a. presence/absence of water b. level of water table c. dissolved content of water
Seismic	In favourable conditions will define: a. water table b. large scale structures which may contain water Only of use for large supplies
Magnetic	Suitable if igneous dykes control the occurrence of groundwater
Borehole logging	Defines water and rock properties inside boreholes

Table 2 is a flow diagram showing the problems in which resistivity can best be applied. The essence of this is that for a hand pump supply geophysics is frequently not an economic search method especially if geological knowledge is available.

Table 2: Flow diagram for location of water in a developing country using geophysics



Interpretation of geophysical field work is the most difficult part of any survey. With modern equipment the field operation of the instruments is simple and can be learnt in a few days. Thus a field geologist can supervise a number of teams in charge of less qualified people operating instruments. For small supplies, once the 'feel' of an area has been obtained, field interpretation of the geophysics is often adequate. More sophisticated methods, frequently using computer techniques, are necessary when the meximum yield is required.

GROUNDWATER POLLUTION : THE NITRATE PROBLEM

Although groundwater provides the most satisfactory source of drinking water for the majority in developing countries, shallow wells are easily contaminated. Study of the nitrate concentration in groundwater can be used to gauge the extent of pollution.

In developing countries a common trouble is poor well construction or maintenance which allows polluted surface water to infiltrate down the sides of wells and boreholes. This can be cured by appropriate engineering techniques, but it is often necessary to obtain the collaboration of health personnel to convince users of the dangers. Where there are sewers, leaks result in groundwater pollution; but there are few sewers (leaking or otherwise) in developing countries. Where rainfall is abundant, leachate from refuse tips may increase the nitrate concentration; but scarcity of rainfall rather than its abundance is most common. Agriculture contributes to the nitrate load: the use of fertilizers is increasing and intensive stock rearing can be a problem in developing countries. Stock need water and the area around wells is often overgrazed and bare so that wastes are not decomposed before infiltrating to the water table.

Inappropriate sanitation is a cause of groundwater pollution. For example in some Botswana villages there is a rapid movement of nitrates and bacteria through weathered granite from pit latrines. Analysis of several borehole water samples showed deficiences in anions when anions and cations were balanced. Nitrate was suspected as the missing anion. Nitrate had not been determined regularly up to that time (1974) because no easy accurate methods were known.

Subsequent studies by the Geological Survey Department showed high nitrate values in the groundwater supply in many villages of eastern Botswana. Gross fecal bacterial pollution of groundwater occurs from pit latrines. A transit time of less than four hours was recorded between a pit latrine and a water supply borehole 25 metres apart, using a lithium chloride tracer. The static water rest level was six metres below surface and pumped water level about 15 metres below surface. The steep hydraulic gradient is thought to have induced the rapid movement of the tracer through the weathered basement rocks.

The high nitrate content of these boreholes is the end product of the breakdown of nitrogenous wastes from human or animal sources since fertilizers are not used extensively in Botswana. The nitrate is an indicator of pollution. The presence of nitrite is another indicator of very recent active pollution. The pit latrines in Mochudi village were shown to cause a massive build up of nitrogenous material in the surrounding soil and weathered rock; nitrate leached from this contaminated soil is postulated to be the cause of the high concentration in the local groundwater. It is unlikely that the pit latrines will be moved or replaced so the contaminated boreholes should be abandoned and new contamination-free groundwater sources provided for the village.

A new development in the field testing of water supplies enables on-the-spot determinations of nitrate, nitrite and ammonia to be made.. Merck of Darmstadt, West Germany, have recently developed test strips for the semi-quantitative analysis of nitrate, nitrite and ammonia. The strip is dipped into the water and if nitrate is present a red-violet colour is produced on the sensitised part of the strip. After two minutes the colour developed is compared to a colour scale printed on the side of the container and the amount of nitrate is read off.

The test strips enable simple and rapid semi-quantitive determination on site and can be used by relatively untrained staff. An on-site assessment of the likely sources of pollution can be made immediately and demonstrated visually to local officials and health workers. The use of test strips allows the field worker to screen water samples and indicates whether special samples need to be taken for more accurate laboratory analysis. The approximate cost is £4 for 100 strips contained in an aluminium can. At 4p per determination the cost is negligible compared to the field worker's transportation costs. The strips have a field life of about one year.

Other field test kits available for nitrate determinations are produced by Lovibond (UK) and Hach (US). Several colorimetric procedures for nitrate determinations have been tentatively approved in the United States, but in developing countries some of the recommended chemicals are often difficult to obtain and operation of the methods requires trained staff, glassware, waterbaths and a spectrophotometer. The use of nitrate ion specific electrodes is increasing and electrode methods are in common use in UK and US, but they must be used in the field with great care by technically competent staff.

More and more women in developing countries are being persuaded by advertising and by contact with other cultures to abandon breast feeding and to feed their infants with dried milk products. There is a greatly increased risk of methemoglobinaemia in infants where the milk feed is mixed with high nitrate waters. The WHO working group on health hazards from drinking water recommended that for infants below six months of age nitrate levels in excess of 5o mg/l should be considered unacceptable.

WATER AND WASTEWATER TREATMENT

The level of technology installed in water and wastewater treatment plants should be appropriate to the situation and the society involved. This does not necessarily imply the installation of the simplest and cheapest techniques. Although it is of importance that treatment works should be both low-cost and simple the criterion of reliability must always be paramount. It is as ethically wrong for designers to install cheap systems that do not work as it is to install expensive systems that cannot be worked.

There is no simple method for deciding which processes are appropriate in any given situation and which are inappropriate. The selection of the appropriate water or wastewater technology depends upon the quality of the source water or the strength of the wastewater. It depends upon the quality of the required potable water or the standard of the effluent. It depends very largely upon the money available. It depends even more on the availability or otherwise of trained technicians and skilled labour. Power supply, pay, level of management, cost of land and many other factors influence the selection of treatment processes.

It is however possible to compile a list of factors which most influence the choice of processes if they are to be truly appropriate in a particular locality. These factors will certainly include -

1. the money available for works construction -
2. the availability of a reliable power supply -
3. the level of competence of local skilled or semi-skilled labour - if any available -
4. the standard of the local technician training establishment (if any) and the standard of its product -
5. the level of pay available to technicians (and others) in the public sector as opposed to private employment -
6. the possibility of direct oversight of the operating plant by an experienced professional -
7. the competence of the local administrative organization -
8. the future availability of spares and chemicals -
9. land costs and land availability - and
10. the quality of the water or wastewater to be treated and that of the potable water supplied or of the effluent.

All too rarely are all these factors adequately considered before water and wastewater treatment plants are designed. Often in developing countries there are sophisticated water treatment facilities, usually incorporating chemical pre-treatment and rapid sand filtration and necessitating a constant and appreciable dosage with chlorine. In these situations slow sand filters could so frequently not only be more effective and reliable, but be more compatible with the local level of technical and administrative ability.

Chemical treatment is, at the least, a waste of money when the dosage rate is decided by an unskilled operative relying on experience and intuition. Rapid sand filtration of polluted source water is inappropriate if a continual supply of chlorine for final disinfection cannot be guaranteed. It is unfortunately common to find a water treatment plant which, for one reason or another, has run out of chlorine. This is not such a danger in those situations in which slow sand filtration is employed. It can be a disaster if the all-too-common rapid sand filter is used. Consideration must be given to the competence of the local administration set-up when a selection of water treatment processes is being made. It is pointless to operate a chemical pre-treatment unit if a continual supply of chemicals cannot be assured. It is pointless to incorporate pumping machinery for which spares may not be available in the future; and if a continuous supply of chlorine is not guaranteed then the provision of slow sand filters must be considered as an alternative to rapid filtration.

The conventional progression of coagulation flocculation, rapid sand filtration and final chlorination can possibly be as appropriate to a developing country as to a developed country, if only there is a simple laboratory provided with a technician capable of determining both the coagulant dose and the chlorine residual. On occasions neither of these is available. On other occasions there will be a laboratory provided and this will be supplied with the latest analytical apparatus, but without technicians either to operate the equipment or maintain it. It is also by no means unusual to discover sophisticated items such as sludge level indicators and automatic flow recorders installed in such works, although these will usually not be working for lack of maintenance.

The inappropriateness of provided treatment units may be the result of the lack of experience of the designer in local conditions. It is suspected that it is fairly common practice to transfer directly a successful design from a moderate climate to a hot climate situation without consideration, in detail, of how it may operate in the different environment. Particularly the effect of increased temperature must be considered. This will increase both the rate of the biological and chemical reactions. It is thought that this direct transfer of designs can result in a particular and peculiar weakness in rapid sand filtration installations. It is suspected that the backwash regime can be 'lifted' directly to the hot climate scene without regard for the effect of different water temperatures. With the rise in temperature the viscosity of the water is lowered and the result is a reduced hydraulic shear and consequently a decrease in washing efficiency. This can, it is considered, be a factor in the creation of deep cracks in some sand media that represents a danger of floc breakthrough.

On the wastewater side there is often resistance to the installation of stabilization ponds. While stabilization ponds must remain the obvious first choice for wastewater treatment over much of the developing world it must also be appreciated that there are situations in which they are not appropriate. Ponds are not appropriate if there is not sufficient land available. They are not appropriate if an effluent free of algal burden is required. They may not be appropriate if a moderate level of technical competence is available. However, not always is a decision for or against stabilization ponds taken for rational or, at least, rational technical reasons. Frequently municipal pride will demand a more sophisticated approach to water pollution control. There is a known situation in which the existing percolating filter works is not operated beyond the primary settlement stage due to the lack of technical ability of the operatives. Yet in this situation despite the obvious appropriateness of stablization ponds the involved government department and the consulting engineer are cooperating in the construction of a far larger filter works -- and this without provision for the adequate training of staff.

The ultimate in inappropriate design must be in a large city in Africa where municipal pride and credulity together with the designer's ignorance and/or cupidity has resulted in the construction of a sophisticated activated sludge treatment plant incorporating pre-aeration, massive pumping, aerobic sludge digestion, centrifugal sludge thickening and sludge sterilization using quick-lime. Not surprisingly the plant is beyond the control of the local work force, the power costs are staggering, the sludge accumulation cannot adequately dealt with and the works can be detected by smell at the distance of more than a mile. (The consultant was not UK!)

The selection of the incorrect technology in any situation may be for a complexity of reasons. It may be, as already suggested, the result of municipal pride in modern, sophisticated processes. It may be the result of inappropriate conditions linked to the grant of foreign aid. It may be due to lack of experience, but perhaps the following list summarises the factors that can so frequently lead to the incorrect choice of technology.

1. The conservative nature of both municipal or national authorities and of some consulting engineers -
2. the lack of experience of some consulting engineers in developing countries -
3. the ease with which designs appropriate to moderate climatic situations can be translated, inappropriately, to a hot country situation -
4. municipal pride in the installation of sophisticated treatment works -
5. the frequency with which external aid is 'tied', and results in the employment of a design firm on account of its nationality rather than for its experience - and unfortunately
6. the unethical practice of a small minority of firms of consulting engineers which appears to place capital cost and hence income above the suitability of the plant designed.

The provision of the appropriate technology for the water industry in developing countries is far more common than one often appreciates. The appropriate does not advertise itself. The inappropriate is obvious to all. Yet inappropriate designs are not rare and can be the result of ignorance on the part of the expatriate designer as of the local authority. The design of water and wastewater projects for a developing country is a most specialised subject and the need for this specialisation arises as much from the social and physical environment as from the complexity of water treatment. Education of professional engineers, both from the third world and from the developed world, in the very special demands of hot developing countries is the only true answer to this problem.

Beyond the need for education is the need for collaboration between all those associated with the demand for, the operation of, and the payment for any water or wastewater treatment works. This will mean collaboration between those designing and those designed for, as to the type of plant required, but also collaboration with the organization responsible for the training of personnel and with the organization that will administer the completed project.

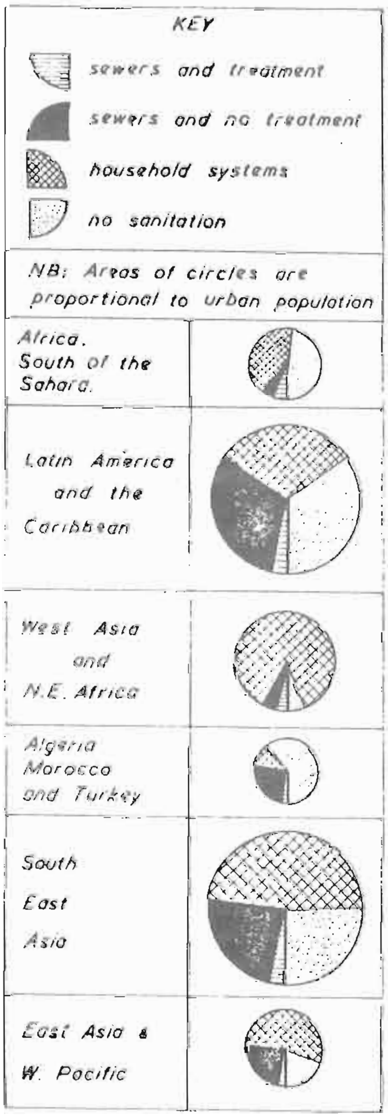
It is pointless designing in the need for spares or for a continuing supply of chemicals unless those ordering them fully appreciate the necessity for a continual supply, and possess the ability to organise it. Collaboration is essential between the design organization and the national, or local, technician training school to ensure that the correct skills are taught to the required level to those who will be operating and maintaining the plant. Frequently technicians of a sort are available but without adequate knowledge of essential processes. The collaboration, if possible, of the employing authority is further required to ensure that suitable wage levels are maintained for skilled amd semi-skilled labour so that it is not immediately lured away to work in private industry. Should there be no local training scheme then it is of importance that the consulting engineers should provide, or arrange to have provided, training of an appropriate level for the technicians to be employed. Finally collaboration between client and consultant is essential to ensure that with the one or the other, or preferably with both, there are professional engineers experienced in the demands of a developing country situation. By all these means it is possible to apply that level of technology which is most appropriate for the local situation.

WATER AND SANITATION FOR THE POOR MAJORITY

There has been an amazing change in the outlook of the World Bank, WHO and many national governments in a very short time. A few years ago conventional 'western' views of water and waste were transferred with little modification to developing countries: only first-class water should be supplied and this water should be used to remove human excreta and sullage in sewerage systems to treatment works or long sea outfalls. These views were supported by international bodies, governments of aid-giving countries, governments of developing countries, and by professional advisers trained in a western way. And so there are 'water and sewerage boards' for countries and regions with no sewers; for several cities aid paid for sewerage master plans, superceded by another a few years later - but no sewers; where sewers have been constructed they often only benefit a small fortunate minority; and in cities where the well-off sprinkle their lawns with potable water throughout the dry season the majority of the population struggles to get a daily tinfull of doubtful quality each.

Now, as far as most developing countries are concerned, it is recognized that this technology is completely inappropriate for the poor. The poor are the majority - the majority of countries and the majority of people. Most poor people in developing countries live in rural areas without reasonable access to safe drinking water or adequate sanitation, and in the towns and cities the present provision of water and sanitation is insufficient. For example, in south-east Asia in 1970 less than 5% of the urban population had a continuous piped water supply. The diagram shows how few urban people have sewers and sewage treatment, represented by horizontal hatching. The aim of the Water Decade is to give adequate water and sanitation for everybody, and this can only have the slightest chance of fulfilment if 'adequate' is interpreted in terms of 'something is better than nothing'. The main theses of the 'new' policy are that access to and quantity of water are at least as important as quality; appropriate sanitation should be provided rather than universal sewerage and treatment; and improvement should be incremental - or capable of implementation in stages.

An early step in the new direction was the publication of "Drawers of water'(6), which examined in detail the water situation in a mainly rural area in East Africa. The change in outlook for both water supply and sanitation has been supported by people in a variety of professions, including engineers, geographers, economists, planners, sociologists and administrators (for example 7 - 10), reinforced by the investigations of geologists, biologists and chemists.



Concurrently two wider changes have influenced the provision of water and sanitation. Aid is now directed specifically to poorer communities instead of assuming that the benefits of industrial development would trickle down and there is a world-wide interest in appropriate or intermediate technology.

The popular conception of appropriate technology is hardware - bullock carts with greased bearings and the like. There have been a number of attempts to devise simple equipment for water and sanitation, such as NEERI's porous pot chlorinator and nightsoil wheelbarrow. However, whether or not gadgets like these are used has little effect on the overall provision of water and sanitation for the hundreds of millions who need it. Improvements to hand-pumps, standpipes and pit latrines have received more attention and have greater potential benefit, but they do not tackle the root causes of the existing deficiencies.

Dealing with rural water supplies Pacey(11) sets out criteria for appropriateness under the following headings.

TECHNICAL APPROPRIATENESS
functional - fitness for purpose
environmental - hydrological conditions: avoidance of environmental damage
health and sanitary - disease date: water quality, quantity and availability

SOCIAL APPROPRIATENESS
community - felt needs and stated preferences: scale in relation to community size and organization
work - organization of labour force (whether self-help or paid)
consumer - changes in water carrying and water use patterns
education - interest in health, hygiene and other development
maintenance - organization, administration, village/government responsibilities, spare parts supply, training, record-keeping

ECONOMIC APPROPRIATENESS
resource - utilization - capital and labour intensity - imports, fuel consumption - scale economies
production - time/energy saving and volume of water available for productive purposes

For excreta disposal Winblad (12) suggested a similar set of criteria: *ecological, health, nuisance, cultural, operational* and *cost.*

These lists alone do not cover all that should be considered for appropriate schemes. For example, for functional appropriateness the purpose of a project has to be defined, and this is likely to involve other criteria. Mention of education and training indicates that change in the external conditions is possible. Appropriate solutions may include the provision of education/training and allow for the improved inputs resulting therefrom.

Examination of the lists of criteria indicates differences between industrial and developing countries in the level of technology and particularly in the factors to be considered in devising technical solutions. The groups of people who collaborate are different. In industrial countries civil engineers work with mechanical, electrical and chemical engineers, chemists, biologists, geologists, and financial, legal and administrative experts. Planning of appropriate sanitation or rural water supply schemes in developing countries depends on appreciation of the behaviour of people who are to use the water and sanitation, and familiarity with local endemic diseases and of the institutions which can or could support the schemes.

People in developing countries are much more varied than in industrial countries. In Britain the health, diet, water use and personal habits of the vast majority of the population are pretty much the same - everyone has a bath or shower with running hot and cold water and everyone sits on a water-flushed loo. Contrast this with most poor developing countries. Alongside people with flushing wc's and bidets in tiled bathrooms are those who defaecate on the roadside. Some people squat and others sit. Some use water for anal cleaning; others use corn-cobs, leaves, stones or cement bags. Some women regard defaecation as a social activity, getting away from the kids to chat before sunrise - for others even obtaining water from a public standpipe breaks rules of religious privacy.

Emphasis on the cultural/sociological appropriateness of water and sanitation is sometimes talked about as if it were new - a feature of the 1970s. Perhaps this is due to the specialization of recent education and professional practice - knowing more and more about less and less. The good practical and non-specialist civil engineer of former generations knew the local situation and realized that failures were often due to lack of appropriateness. A nineteenth century book (13) notes that "the history of sanitary experiments on a large scale in India has already furnished several striking instances of schemes 'that ought to have worked but wouldn't', and in each case it has turned out that something, or several things, had been taken for granted, without any warranty whatever". In this book there are many examples of ways in which local conditions influenced technology, such as in the municipality of Cawnpore (now Kanpur) where a meeting was held to discuss decoration for cast-iron standpipes. It was decided to use dog's heads for European and Mohommedan quarters, and horse's heads for the Hindus.

Coming up-to-date, a successful rural water supply operation is reported from Latin America, where a lady anthropologist was put in charge of the national programme. A survey of all villages with over 2500 population indicated which communities already participate in self-help ventures, have the greatest enthusiasm for water and show greatest promise of effective maintenance. These villages are the first to be provided with a water supply.

An example of community participation in sanitary improvement can be seen at Patna in Bihar, India, where a voluntary association operates a number of public latrines and organizes the conversion of scores of thousands of dry latrines to pour-flush units. The public latrines include washing facilities and have paid attendants who charge the equivalent of 0.25p to users. The latrines are clean and well-maintained. The basis of construction, operation and maintenance is a voluntary association whose success depends on the enthusiasm of individuals. An important factor in both the household latrine conversions and the public latrines is control of financial aspects.

Lack of money was cited as the greatest constraint to provision of water and sanitation in the 1970 WHO survey(5). Low budget allocations for recurrent costs are often given as the reason for the breakdown of projects, especially where the construction was paid for by aid or borrowed money. There is need for collaboration between engineers and economists. Costs are just as related to the local situation as any other aspect of appropriateness. However, figure-fiddling alone may lead to conclusions which need review by a practical engineer.

A ten-word summary of the essential requirements for successful provision of water and sanitation for the poor in developing countries might be ALLOW FOR LOCAL CONDITIONS AND FOR THE NEXT TWENTY YEARS.

Looking ahead implies consideration of operation and maintenance, and examples abound of schemes which have failed to achieve their design performance because they were not operated and maintained properly. The designer did not allow for local conditions in the next year, let alone twenty years ahead. There is no such thing as a simple and easily maintained water treatment plant (11), so the best water supply for the future is one which needs no treatment, or only storage. Hundreds of thousands of hand-pumps have been provided for rural water supply schemes, and there are innumerable reports of failure. An effective professional maintenance programme has been organized in some places - like the northern Ghana project reported by Robert Bannerman. Elsewhere more reliance has been placed on the local people, as in Tamil Nadu, India, where a villager appointed 'caretaker' attends a short training course and is issued with a certificate to prove it.

Nearly everywhere in the Third World there are complaints about a shortage of trained technicians. Perhaps this is partly because in the past too much attention has been devoted to the transfer of technology from industrial countries, and this has influenced ideas about the role and training of sub-professionals. 'Bare-foot technicians' may be the answer. Forget about City & Guilds and ONC or equivalent, with their insistence on an adequate mathematical background and a proper scientific understanding of the work. Perhaps the whole grading system needs revision. At one level very short courses or on-the-job training can prepare the bare-foot technician to work with the local community on a limited range of jobs - or even just one job. This in turn requires standardization. (Incidentally, one of the greatest obstacles to standardization in many developing countries is donors' practice of only giving their own products.) The bare-foot technician requires simple instruction sheets or manuals in which diagrams are preferred to words and nomograms and tables replace calculations. At the next level (bare-foot engineers ?) whose primary function should be to provide the conditions under which the technician can operate: to train them, prepare instructional material, and to be at hand to deal with situations where the standard solution does not work.

Higher up the scale the requirements of the professional (the engineer with shoes ?) are much wider in scope than those provided by present training and education, even of the kind outlined by Professor Diamant. The professional should be a collaborator, a selector, a leader and a doer.

a. He (or she) needs to collaborate with doctors, engineers, community workers, sociologists, geologists, administrators and the rest, and therefore must be familiar with their work and jargon and must sympathize with their aims.
b. An important part of his/her work is making choices - selecting which alternatives are the most appropriate - and so he must know about the alternatives, know their advantages and disadvantages from every point of view, and know the local people, their resources and their limitations.
c. He must lead a team, all the time realizing that the contribution of others, barefoot or not, is important.
d. Perhaps most important is a determination and ability to do - to provide water and sanitation, and keep systems working, in spite of all difficulties and opposition.

The old-fashioned PWD district engineer often did all these things in a wider sphere, being involved in a range of activities from building dams to providing bungalow curtains. Public works can provide the most appropriate training for water and sanitation professionals, where the objective is clearly to provide and maintain public services. Unfortunately civil engineering, like other disciplines, has been influenced by two changes which need to be reversed to get the right emphasis - increased specialization and increased sophistication.

If the world's poor are to be provided with water and sanitation there must be a collaborative input from many fields and a realization that providing the most appropriate schemes requires as much, or greater, intelligence and ability as using computers to analyse intricate details of high technology. Lord Rutherford said, "We have no money; therefore we must think." This often sums up the appropriate approach to water and sanitation.

DISCHARGE OF WASTEWATER

Where sewers exist or can be appropriately provided there is inevitably a problem of disposal of the wastewater. In coastal regions and towns situated on tidal rivers it is possible to make use of the large supply of oxygen and minerals contained in tidal waters, which can dilute and oxidize untreated effluent discharged directly to the receiving water. Much care is required in suitably sizing a discharge point, and collaboration and exchange of information between engineers and fishery resource workers is essential.

Discharge to the sea is wasteful of two valuable resources, the water itself and its organic load. In water-scarce areas (coastal or otherwise) consideration should always be given to the reuse of wastewater - usually for irrigation but possibly for industrial or even domestic supply. Exceptionally the cost of sewerage may be justified by the utilization of sewage.

Public health dangers must receive the greatest attention whether sewage is discharged to a river or for irrigation, and whether it is treated, partially treated or untreated. Collaboration between sewage works designer, the local medical staff and agricultural experts is obviously important. The greatest advantage of waste stabilization ponds over conventional treatment of sewage is the ponds' much higher removal of faecal micro-organisms including pathogens. When river water which receives sewage effluent is consumed untreated downstream the most appropriate parameter for design might well be *E.Coli* removal rather than BOD, suspended solids or nitrogen.

CONCLUSIONS AND QUESTIONS

We have dealt with a few aspects of water and waste engineering to indicate what is appropriate. We could have discussed other topics such as water distribution or refuse collection, with similar conclusions. Compared with the UK or other industrial countries, the third world uses a wide range of technologies, most of which can be appropriate in certain circumstances. Determination of what is most appropriate for particular local conditions at a particular time demands an input from a variety of specializations and therefore calls for collaboration greater than that required in industrial countries. However, as part of the limitation of resources in developing countries there is in most places a shortage of specialists and a shortage of skilled people at all levels. Two consequences are suggested. One is that in order to provide appropriate water supplies and sanitation the third world professional requires more training, more ability, more understanding of others and more dedication than in developed countries, and must be willing to consider a range of options. The second consequence is that the technology must be capable of being put in effect in the particular local conditions, which requires it to be simple and acceptable by the local people.

Some questions for discussion

1. In listing factors to be considered in deciding what is most appropriate have we omitted important ones?
2. Are there situations where the appropriate solutions are so clear-cut that there is no need to consider alternatives?
3. What types of organization are appropriate for ensuring continuing service (keeping rainfall and streamflow records, providing chemicals and spares, repairing broken pumps, desludging aqua-privies etc)?
4. In what ways can the widely-reported shortage of trained technicians be overcome? Is too much attention given to teaching technicians *why*, when all they need to know is *how*?
5. How can information about appropriate techniques (like nitrate testing paper) be widely disseminated?
6. Is practical civil engineering the best training for the team leaders?
7. How can professionals learn to consider a wide range of options rather than slavishly following text-book rules?

We suggest that one appropriate answer to question 7 is *by attending WEDC courses!*

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