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Water supply and sanitation: an agenda for research*

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Water supply and sanitation: the last 10 years

As the International Drinking Water Supply and Sanitation Decade (1981–1990) draws to a close, and the international community discusses plans to follow it with a second decade focussed on these and other issues of environmental health (Anon. 1988), the formation of the Commission on Health Research for Development provides a useful opportunity to review progress in this area over the last 10 years and to suggest measures for future action. Some idea of how far our understanding has developed may be gleaned from consideration of the principal problems of the sector as they were perceived in the late 1970s.

First, with regard to water supply, the problems were largely regarded as technical or economic. Many of the problems of urban water supplies are indeed susceptible to engineering solutions, but rural water supplies were also frequently considered from a purely engineering point of view, with no more than a passing reference to social or institutional aspects (Tschannerl 1979). With the exception of the pioneering work of White, Bradley and White (1972) water supply in developing countries had hardly ever been considered from the users' point of view.

Investment in water supplies had grown rapidly in the post-war years. In the urban areas it was necessary to keep pace with the accelerating process of urbanization, while the growth in rural water investments was propelled by demand from an increasingly vociferous peasantry, by pressure from politicians seeking to use it as an instrument of patronage, and by the growth of international aid to developing countries. This was particularly noticeable in many African countries, whose newly found independence created an alliance between local politicians and international aid agencies, both of which (for different motives) sought a tangible but innocuous intervention to benefit at least some of the rural poor (Cairncross 1988).

By the late 1970s, however, there was a developing awareness of a certain malaise in the sector. In many countries, the rate of water supply construction was hardly keeping pace with population growth, and even so it was frequently vitiated by a comparable rate of breakdown. Improvements in urban water supply capacity simply led to greater leakage from distribution systems, while even the simple hand-pumps installed in rural areas were soon out of action. Small wonder, then, that many doubted that even the modest target of 25% coverage for rural water supplies in developing countries would be reached by the end of the 1970s (Feachem 1977).

Sanitation, on the other hand, had been largely neglected. Urban sanitation was usually understood to mean sewerage, so that the low-income majority of the population of most

*This paper was originally commissioned to provide background information for the Commission on Health Research for Development, an independent international initiative established to define and promote advances in research that will improve health in developing countries. The Commission's members, experts in health and development who represent twelve different nations, most of them in the developing world, are working to set an international agenda that will help national governments, donors, and international health agencies strengthen health research for action. This paper represents the opinions of its author, not necessarily of the Commission itself.

The Commission invites submission of ideas, observations, and useful models or cases to its secretariat: Commission on Health Research for Development; Room 1-1104, International Health; Harvard School of Public Health; 665 Huntington Avenue; Boston, MA 02115, USA. The Commission will complete its investigations and publish its recommendations in 1990.

tropical cities, for whom sewerage is neither feasible nor affordable, were automatically excluded. A few pioneers had attempted unconventional approaches in cases where these were considered especially suitable, such as site and service schemes (Marais 1973), but it could fairly be said that no feasible and tested technical solution existed for the problem of excreta disposal in the great mass of overcrowded slums and shanty towns of the Third World.

Rural sanitation was faring little better. In many countries, little had been achieved since the pit latrine campaigns of colonial times, and the promotion of rural sanitation was still largely a question of enforcement rather than assistance and advice. Rural latrines, if they were used at all, were liable to be smelly and structurally unsound, serving as foci for the breeding of flies and transmission of hookworm.

In the event, rural water supply coverage reached and surpassed the target for the 1970s, boosted by the significant progress achieved in Latin America. In Africa and Asia, sophisticated technology inappropriately transplanted from the urban areas began gradually to be replaced by simpler systems with lower construction costs and fewer maintenance problems, such as hand-pumps on wells or boreholes. The more glaring deficiencies of urban systems, such as the Calcutta water supply, were also mitigated by simple autonomous sources such as wells and tubewells with hand-pumps. Some took the simplification process still farther, admitting the possibility of winch and bucket systems on wells (Visscher & Hofkes 1982) or on boreholes (Morgan 1983). However, most rural water programmes outside Latin America have focussed on hand-pumps or stand-pipes. A major study of hand-pumps, both in the laboratory and the field, was promoted by the World Bank (Arlosoroff *et al.* 1987) and greatly contributed to our understanding of the technical factors making for reliable operation of a hand-pump.

The focus on hand-pump systems has led to renewed interest in shallow well construction (Watt & Wood 1977; DHV Consulting Engineers 1978) and considerable research has been devoted in recent years to cheaper and simpler methods of borehole drilling (Metianu 1982; Blankwaardt 1984).

At the same time, it has become increasingly clear that the frequent breakdowns of rural water supplies are not primarily due to technical deficiencies but to inadequate institutional provisions for maintenance. Early evidence for this came from the discovery that, whereas 60% of the public hand-pumps in rural India were out of order, this was true of only 10% of the privately owned pumps. A start on tackling the problem has been made by training villagers as 'barefoot water engineers' in many countries, often supplying them with a basic toolkit to carry out essential maintenance and simple repairs (Chauhan *et al.* 1983). These local volunteers have in some cases been incorporated as the lowest level in a maintenance hierarchy, such as the three-tier system developed in India (Gray 1984) and the system of committees mirroring the hierarchy of distribution pipes in the large gravity-fed systems of Malawi (Glennie 1983).

The adoption of technology with lower per capita costs, together with greater efforts to resolve maintenance difficulties, should in theory permit faster progress in extending the coverage of rural water supplies. Nevertheless, increasing attention has focussed in recent years on the potential for recovering the cost of water supplies from the consumers, including hand-pump and stand-pipe users, with a view to financing an accelerated rate of investment in the sector (Van Wijk 1987). Whereas in 1980 the World Bank was ready to admit that 'Capital contributions from outside the area, as from the government, for example, can seldom be recovered fully' (World Bank 1980), one of its senior spokesmen has more recently suggested that 'country policies and investment strategies should aim for a higher level of cost recovery than has been sought in the past.' (Churchill 1985).

To some extent this is a reflection of the prevailing ideological climate, and cost recovery is often conflated with privatization (e.g. Lewis & Miller 1987). However, cost recovery measures are also being introduced for entirely pragmatic reasons by water supply agencies (Wood 1988), which face increasing and costly demands on

their maintenance capability while subject to the economic stringency and budgetary retrenchment which have been forced upon most developing countries by the state of the world economy. The implementation of cost recovery policies by water agencies, and the advocacy of them by donors, has led to some research into willingness to pay (Whittington *et al.* 1987) and the informal payments already made to water vendors in many communities (Zaroff & Okun 1984).

This concern with costs and their recovery has been counterbalanced to some extent by a more careful scrutiny of the benefits. Willingness to pay for improved water supplies is largely determined by the value of the time-saving benefit which they bestow (Churchill 1985). The importance of time savings is well known to consumers but often neglected by donors when they consider the benefits, and hence the objectives, of water supply. Water supplies offer to women a saving in time and drudgery which is a benefit in itself, but which also enables them to devote more time to other household tasks (Cairncross & Cliff 1987), particularly food preparation, with consequent nutritional benefits to their children (Popkin & Solon 1976; Tomkins *et al.* 1978).

The study of the benefits of water supplies has been furthered by an increased readiness to conduct ex-post evaluations of water supply programmes, paying attention to their effect on the consumer. Some guidance is now available on how this should be done (Cairncross *et al.* 1980; WHO 1983), but most evaluations are still conducted at the behest of external donors, rather than the initiative of local governments.

Much debate has been devoted to the health benefits of water supplies, and the certainties of the sixties have given way to dismay at the difficulty of detecting them and even to some doubts as to their existence (Anon. 1987). These health benefits have been the subject of a considerable number of epidemiological studies, frequently conducted as a means of evaluation for funding agencies. Most such studies have concentrated on diarrhoeal diseases, and many have failed to demonstrate the health benefits they sought to measure.

Scientists and policy makers have reacted to this in several different ways.

(i) Some have pointed to the very real methodological flaws in many of the studies (Blum & Feachem 1983)

(ii) Others have argued that, due to the fact that diarrhoeal diseases have many transmission routes, the interruption of water-related transmission may be a necessary but not a sufficient condition to obtain reductions in incidence (Briscoe 1984).

(iii) A third approach has been to fall back on the general trend of the studies which, taken as a whole, suggest a reduction of diarrhoeal disease incidence on average by some 30% (Esrey *et al.* 1985).

(iv) Finally, some cynics have concluded that it is not worth looking for health benefits from a water supply scheme, as there are probably none to find; rather, water supply investments can be justifed by other benefits, such as time savings (Churchill 1985).

However, none of these responses makes use of Bradley's insight (White *et al.* 1972) that water supplies do not affect all disease transmission routes in the same way. Water-borne transmission, for example, is susceptible to control by improved water *quality*, while much other transmission occurs for lack of water in sufficient *quantity* to maintain adequate standards of hygiene. Many of the negative studies were conducted in communities where water quality had been greatly improved, but water quantity and hygiene standards relatively unchanged. The implication is that the water-borne route is not necessarily the predominant mechanism of endemic disease transmission.

The advance in our understanding of water supply in recent years has raised many new questions. In the field of sanitation, on the other hand, a major question has been resolved. It is now possible to propose one or more feasible and affordable types of toilet for most low-income urban communities in the Third World. Much of the credit for this is due to staff and consultants of the World Bank, who made a detailed study of a wide range of sanitation systems installed in many different countries,

culminating in a series of publications which they then distributed very widely, free of charge, to consulting engineers, sanitation officials, academics, and anyone else who asked for them. Of course, no less credit is due to those who had implemented the systems they studied.

The two main types of system are, firstly, the pit latrine, improved where affordable by the addition of a ventilation pipe and secondly, the pour-flush toilet. The addition of a vent pipe to produce the Ventilated Improved Pit (VIP) latrine arose from research in Zimbabwe. It is an excellent example of what can happen when a trained, creative mind, based in a developing country, is tuned to a local problem and starts by analysing the current attempts to deal with it, with a view to improving them. It was the work of Peter Morgan (1977) at the Zimbabwe Ministry of Health's Blair Research Laboratory which showed how this simple refinement, if correctly executed, solved simultaneously both the smell and the fly problems of conventional pit latrines. The subsequent construction of hundreds of thousand of VIP latrines in Zimbabwe showed the importance of choosing technology which is affordable to most people, and backing it with strong political support.

Political backing was also a factor in India's pour-flush latrine construction, undertaken with Indira Gandhi's support as a measure for the emancipation of the scheduled castes, rather than as a public health intervention. With this system, flies and smells are controlled by a water siphon as in the conventional cistern-flush toilet, but the siphon is designed to work with only 2–3 l of water, poured by hand. The flushing water and excreta are discharged to a soakaway pit beneath or beside the toilet.

In urban areas, where it is often impossible to dig a replacement pit or soakaway when the old one fills, the problem of emptying the pit arises with both of these systems. Emptying can sometimes be done with vacuum trucks, but these may be unavailable, expensive or vulnerable to damage due to solid objects in the pit. A solution sometimes used with pit latrines, for instance in Southern Brazil and in Botswana, and with pour-flush toilets in India, is to provide two pits. When one pit is full, it is sealed and the other pit is used. After a year the first pit can safely be emptied by hand, and the pits are used and emptied alternately thereafter.

We now know that several other sanitation systems about which there was considerable enthusiasm a decade ago, have proved to have only very limited application, if any, in developing countries. This is particularly true of composting latrines, which by producing compost, a useful agricultural fertilizer and soil conditioner, would provide a strong motivation for the regular emptying and effective use of the pit. Of course the double pit system described above is a kind of composting latrine, but the other types, with retention times of less then a year, have been less successful. Attempts to introduce them in more than half a dozen countries have met with serious difficulties or, where successful, as in Northern Vietnam, the use of the compost appears to play an important role in *Ascaris* transmission. Biogas units, another fashionable system in the 1970s, have also lost their appeal as we have come to understand them better.

The greatest change of all, however, has been in attitudes to water-borne sewerage. Those who proclaimed its irrelevance in the 1970s (Feachem 1976) were in a minority. Now, no-one can plead ignorance of its disadvantages as a sanitation system for low-income communities. Its excessive cost, its wasteful water consumption, its unreliability in conditions of intermittent water supply, and its technical impossibility in the narrow, winding alleys of the slums and shanty towns of the Third World are only the better known of the arguments against it.

As understanding of the technical issues was becoming clearer, awareness that sanitation has a social dimension has become more widespread. It is often expressed in the form of cautionary anecdotes in which the users are seen as subject to social constraints and misconceptions. For instance, 'They won't use latrines facing Mecca' or 'They won't handle excreta'. No general way of dealing with these problems is prescribed, except to employ an anthropologist. However, it may be more important to analyse the misconceptions of planners and policy-makers (including the statements above when they are erroneous, or such ideas as, 'A latrine must have a roof'), and the constraints

Table 1. *Percentage of population in developing countries with adequate access to facilities*

Type of facility	Year		
	1970	1980	1985
Urban water supply	65	74	77
Rural water supply	13	33	41
Urban sanitation	54	50	62
Rural sanitation	9	13	18

and distortions introduced by international aid. These have tended to result in the design of sanitation systems on the basis of theoretical criteria and what is hygienically desirable, rather than on local practice and what is financially affordable, resulting in low construction or acceptance rates for the systems on offer.

Thus, none of the low-cost sanitation projects promoted in Africa by the World Bank has led to the construction of more than a couple of thousand latrines, whereas most countries' needs are of the order of hundreds of thousands. The more successful programmes have been local initiatives, often with very little outside financial support (e.g. Brandberg 1985; Hasan 1988).

Perhaps the progress so far of the International Drinking Water Supply and Sanitation Decade can best be summed up by the figures in Table 1, recently published by WHO (1987). They show an advance in coverage during the first half of the Decade, at roughly the same rate as that achieved in the previous 10 years. At present rates of progress, water supply coverage would be reasonably complete in both urban and rural areas within two to three more decades. Sanitation, on the other hand, would take far longer. Perhaps it is no coincidence that the sector in which implementation is most affected by social and cultural factors should be the one to lag behind.

Problems and responses

Much of the research in the field of water supply and sanitation in the last 10 years has focussed on technical issues such as hand-pump design and sanitation technology. A few general technical problems remain. For instance, it is likely that the next decade will see the development of cheaper techniques for locating and drilling boreholes, and of a lightweight motor-pump suitable for dewatering wells when the digging teams have reached a depth greater than 8 m. In the sanitation sector, we can hope for a clearer understanding of sludge accumulation rates and of factors affecting the capacity of tropical soils to absorb liquid wastes.

However, research into questions of this kind needs little stimulation, and a far greater effort is required in the second half of the dual activity which industry calls R & D. 'Research' in that sense may provide us with solutions to our problems; but 'development' of those solutions is required to adapt them to each specific context and bring them to a stage where they can be implemented. To illustrate, it is relatively easy to prescribe a pit latrine as a solution. It is a far greater task to design one for a setting where there is no wood or steel for the floor, to develop manufacturing processes for its components, to set up a distribution and promotional system, and so on.

The 'development' half of the R & D activity is in fact an applied form of research and requires a similar degree of creativity and acumen. In the context of this paper it will be termed 'implementation' research. An important form of implementation research is the evaluation of interventions which have been made in the past or which are in course of implementation. While the measurement of their benefits is of interest, it is often easier and more useful to evaluate the functioning of the intervention and the population's use of it. Implementation research is mainly specific to the particular context in which it is conducted, and its results can not easily be generalized. The need for it is especially great in areas of policy relating to water supply and sanitation, which include the principal issues of current concern in the sector. Unfortunately, the international response has been one of action rather than research, and the action has frequently been taken on the basis of preconceptions, in the absence of objective justification, and even of defined

policies. The problem can be illustrated by some of the current issues in water supply.

The first policy question concerns who will benefit from an improved water supply. Here the preconception that the benefits of water supply stem mainly from improved water quality has led to gross wastage of resources. Governments and aid agencies build water supplies for many thousands of people whose existing water sources are within a few hundred yards of their homes. Many of these people prefer not to use the new systems and if they do, the benefit to them is negligible, whether in terms of time saving or of improved health. Since their old and new water sources are at similar distances from their houses, there is little change in their patterns of water consumption or hygiene. Of course, water supplies are also built for some people whose sources are more distant, but many more in this group, on whom investment could have been focussed, are left unserved.

Another preconception is that water supply and sanitation should be combined in a single programme. To some extent this arises from the mental association in the administrator's mind between two interventions which, to him, both involve pipes laid beneath the street. However, in the context of low-income communities in developing countries their technology and their manner of implementation is fundamentally different. A water supply in such a setting means a tap in the street or a pump in the village square; a piece of infrastructure clearly in the public domain. Sanitation, on the other hand, means a toilet with an on-site disposal system, a part of the owner's house, built on his land, at his expense and frequently with his (or her) own hands; its use requires a change in some very intimate habits, in the privacy of the home. An agency which can implement one of these efficiently is unlikely to be suited to the other.

Donors sometimes argue that their pressure for the integration of the two is a form of advocacy for sanitation, which is often neglected in comparison with water supply; but the combination of such disparate measures under the aegis of a single implementing agency diverts resources (such as manpower) from the area where the agency can most effectively use them. It also frequently leads to duplication of activity between agencies, and exacerbates the complex problem of defining ministerial responsibility for sanitation.

The same is also true of the incorporation of hygiene education in water supply programmes. Pipe-layers and borehole drilling teams are not likely to be very competent as communicators and educators, and still less as listeners. Certainly they will be no better than nurses and midwives have proved to be hitherto. And yet the apparent failure of some water supply programmes to produce health benefits, coupled with the feeling that the benefits must be 'out there, somewhere' has led to an insistent call for hygiene education to be tacked on to water supply in the hope that both together will achieve what water alone has failed to do. How (and whether) this combination can be achieved effectively, and whether it is worth the trouble, is a question for implementation research.

One positive measure which seems to have arisen from research and evaluation in the water sector is the development of village level caretakers for hand-pumps and public taps. The need for them became apparent from the calamitous breakdown rates found in the 1970s, and their number is growing in many countries. However, their performance, and the performance of the systems set up to select, train, supervise and remunerate them, has rarely been evaluated objectively. There are many analogies with the problems of Village Health Workers here (De Zoysa & Cole-King 1983).

Moreover, the establishment of a volunteer caretaker system is only one of the institutional measures which research has suggested to improve the maintenance of rural water supplies (Feachem *et al.* 1978). The other measures tend to be more contentious, necessarily involving a certain degree of devolution of political power, and these are far less commonly put into practice (Curtis 1985). However, to avoid the study of an issue purely because it is political would be a denial of intellectual responsibility on the part of a researcher. Implementation research is inevitably a political activity, as it aims to provide a basis for policy.

When an ideological position proves to be materially advantageous to those who hold it,

its advance becomes hard to resist. So it was with the advocacy of self-help labour and cash contributions for the construction of water supplies, which became increasingly prevalent in the post-war years, especially in the newly independent nations of Africa. It fitted the language of self-reliance while suggesting 'to donors that they were not giving 'something for nothing'; it also served as a means of political mobilization, and offered the material advantage of potential savings in construction costs. Self-help construction has been widely adopted. However, the policies needed to define and circumscribe it have usually been worked out only when the pitfalls have already become painfully obvious. Implementation research would have brought them to light much sooner.

A similar development is likely in the area of cost recovery, where ideological interests are reinforced by the material advantage to the financially hard-pressed water supply agency. Already, major changes in policy have been taken in this regard, with neither preparatory research nor subsequent evaluation. For example, Ghanaian villagers willing to pay for water have been deprived of access to hand-pumps because their villages as a whole have been unable to organize cash collections (Wood 1988). Water tariffs are being introduced with very little knowledge of the likely response of the consumer, although simple research techniques to assess willingness to pay have been developed and tested (Whittington *et al.* 1987). No data have been published on how pro-rata water tariffs affect the quantity of water consumed by low-income groups, although this has a clear relevance to hygiene and hence to health.

It would be unfortunate if the sea-change in cost recovery policy were to occur without some implementation research into the various options and their consequences, because it offers a useful opportunity for reconsideration of the levels of service which a water supply should aim to provide. Collecting water payments from villagers using hand-pumps or stand-pipes poses serious institutional difficulties, as sanctions are not easily imposed on non-contributors. There may therefore be a case in many settings for restricting water supply interventions to minimal improvement of existing water sources, thus reducing the cost to be recovered (White 1983) or, at the other extreme, to providing private connections for which payment can be demanded subject to the sanction of disconnection (Cairncross 1988).

Ideology also plays an important role in the current debate regarding the role which governments should play in the sector. It is being suggested with increasing insistency, particularly by the staff and consultants of major international agencies, that governments should wherever possible avoid being a provider of services in the sector in order to concentrate on enabling communities to generate an economic demand for such services and regulating private sector activity (Churchill 1985; Lewis & Miller 1987). The supporting evidence for the notion that this will be in some way more effective or efficient proves on examination to be very flimsy (Cairncross 1987a). Those who argue in favour of the idea maintain that it will create the potential for accelerated growth in the sector.

However, a scenario with the opposite outcome is equally likely. If local communities are to be able to invest in infrastructure, this implies that they will have increased control of local resources, which would imply a shift in the balance of power from national to local government. This would be contrary to the trend observed in most developing countries in recent decades. Many national politicians have much to gain from patronage in the allocation of government services and would be reluctant to countenance such a shift. Were it to occur in spite of them, the failure of local communities to mobilize or manage the funds involved, coupled with a retrenchment by the central government, could lead to a fall rather than an increase in sector investment. Whatever the truth of the matter, the question calls for experimentation and research.

Some indication of the rewards of implementation research is offered by some of the world's successful low-cost sanitation programmes, which are in the main the result of indigenous initiatives, responding to local constraints. In these cases, locally-based researchers have

experimented with variants and refinements of the local technology, starting from the problem rather than the solution, and aiming for a system which people could afford.

However, very little effort has been devoted to developing the capacity for implementation research. It must necessarily be conducted in the environment where the water and sanitation programmes are implemented—the developing countries. This means that it should ideally be conducted by developing country nationals. However, the international agencies which, to their credit, sponsor most research of this kind tend to employ specialist consultants and academics from Europe and North America to develop sanitation technology or to evaluate water and sanitation programmes.

The most useful role played by the international agencies has probably been to synthesize and to spread information. The World Bank's Technology Advisory Group (TAG) has been a notable example of this activity, and so has the International Development Research Centre of Canada. TAG publications (Kalbermatten *et al.* 1981) are on the desks of sanitation engineers throughout the world, and they have helped to convince many doubters of the feasibility and intellectual respectability of the low-cost approach (although some doubters remain in the Bank itself!), and information gained through regional and international seminars and study tours has fired quite a few imaginations.

UNICEF has been more successful in promoting successful projects than the other large agencies, due to its readiness to support experimental, pilot and demonstration projects and its enthusiasm for evaluation. To implement and evaluate a pilot project is probably the most common and practical form of implementation research. Examples of UNICEF's success in the sector include its support for the three-tier hand-pump maintenance system in India, for the rural sanitation programme in Burma which achieved the construction of some 300 000 latrines in its first 2 years, and for the Imo State water and sanitation project in Nigeria, which was instrumental in persuading the Government that boreholes with hand-pumps were preferable to the sophisticated, expensive and vulnerable systems which it had previously preferred (Baker 1987).

A problem in both the water supply and sanitation sectors is that engineers are often left to tackle complex social and political issues, such as the organization of local institutions for the maintenance of water supplies, or the motivation of people to use latrines. They are unprepared for such tasks by their training. Moreover, they have been taught about specific technical systems, such as water treatment plant or sewerage networks, rather than how to choose between several possible systems, how to establish priorities, or how to respond to an existing practice with a view to improving it. Finally, they usually graduate with a negligible understanding of how their work will affect the transmission of water and sanitation-related diseases. Even today, only a handful of the centres training water and sanitation engineers for developing countries offer courses which cover low-cost solutions. The World Bank is now offering very welcome support to a selected few of them in this regard. Nevertheless, most of these give very little emphasis to social or institutional aspects or to the evaluation of water and sanitation prorammes.

Current research in the sector reflects this bias. The vast majority are concerned with the refinement of technology. Examples include

hand-pump design (Arlosoroff *et al.* 1987)
water filtration (Wegelin 1984)
water microbiology (Fujioka & Shizumura 1985)
waste water treatment (Pearson *et al.* 1987)
ground water pollution (Lewis *et al.* 1982)
pit latrine emptying equipment (Carroll 1985).

The interest in health impact studies has already been mentioned. However, these are of little diagnostic power for the improvement of specific water and sanitation programmes, and their methodological flaws usually limit their value in the global debates on health impact.

Research into the institutional and policy aspects of the sector has been very rare by comparison, and is mainly represented by a handful of publications by economists and a few of the more articulate practitioners (Saunders & Warford 1976; Carruthers & Browne 1977;

Glennie 1983) and some reviews of the unpublished reports known as grey literature (e.g. Van Wijk 1979). In particular, the study of local institutions is anecdotal, lacking any attempt to synthesize its lessons into a prescriptive form, however general. In part this is a weakness of anthropological method (Curtis 1985), but it is also a reflection of the paucity of implementation research in the sector.

Two other measures are allied to water supply and sanitation as basic environmental health interventions: storm water drainage and solid waste disposal. They assume a particular importance in urban areas. In fact, water supply and excreta disposal are practically impossible to implement satisfactorily in an area subject to frequent flooding or landslides, although these are common risks in the growing shanty towns of the large tropical cities (Cairncross 1986). Indeed, many of the urban poor in the developing countries would rate storm drainage more highly than water supply if they were consulted about the relative priority of these items of infrastructure. Storm drainage itself requires effective solid waste disposal for its implementation, because without it the drains rapidly become blocked with solid waste.

The World Bank and the regional development banks have lent considerable sums for urban drainage projects and financed the purchase of large numbers of expensive refuse collection vehicles. Their support for research on these subjects, however, has been minimal. The search for appropriate technology, on the lines of what has been achieved for water and sanitation in the last 10 years, has barely begun.

Research needs

Water supply and sanitation are technical interventions, but their implementation has significant social dimensions. In so far as they are considered to have public health objectives, they have epidemiological dimensions as well. These three aspects of the sector are considered in turn.

TECHNICAL ASPECTS

The principal engineering problems posed by the sector are relatively minor; most of them could be adequately covered by a few competent PhD theses. They probably will be, as departments of sanitary engineering in developed and developing countries alike cast about for new challenges. Sanitary engineering in the industrialized countries is what has been called a 'mature' profession, in which most research concentrates on the details of well established conventional solutions, and fundamental rethinking is seldom called for (Briscoe 1984).

Examples of the purely technical questions which might be studied include cheaper and easier techniques for siting and drilling boreholes, pumps for dewatering during well construction, and water meters capable of durability and accuracy when used in an intermittent water supply. In the sanitation sector, there is a need for a reliable and hygienic hand-operated pump for emptying pit latrines and de-sludging septic tanks.

However, very few questions can be considered to be purely technical, as the answers to most of them only have meaning in the context of the social use of the technology to which they refer. The best design for a hand-pump, for instance, depends on how and by whom it will be maintained, and the size of pit for a latrine depends on the materials used for anal cleansing, which are often bulky. This means they can be studied effectively only in the context of implementation research.

SOCIAL ASPECTS

This conclusion applies even more forcefully to the questions which are primarily social and institutional in nature. Reference has been made to some of the most important ones in preceding discussion:

How can local institutions best be organized for the maintenance of village water supplies?
How can sanitation best be promoted?
How can water supply and sanitation be paid for, without undermining their expected benefits?
Can water supply and sanitation programmes be implemented efficiently by a single agency?
How can private enterprise be harnessed to benefit the sector?

How can the costs of urban storm water drainage projects be reduced to make them more cost effective?
What makes for a cost-effective and hygienic solid waste collection and disposal system?

There is no single measure which the international community can take to promote research of the kind required to answer questions such as these. Rather, the search for such measures can be reduced to yet another question for implementation research:

How can implementation research into water supply and sanitation be most effectively promoted?

Nevertheless, a few suggestions can be made. The first relates to courses for the training of sanitary engineers. Any such course for engineers who will work in a developing country should include a study project to investigate or evaluate a problem or a programme of water supply or sanitation in a low-income community. Whether the project is to be carried out individually or in groups, it should require a final report with the recommendations which would be discussed with members of the community concerned. A start in this direction could be made by the World Bank, by suggesting such a policy to the institutions which belong to its Training Network.

Another measure would be for any new water supply policy or low-cost sanitation technology to be tested and monitored on a local scale for at least 1 year before its introduction in any large programme. At least one national of the country concerned would participate in the monitoring team at the most senior level. International aid donors could play a central role in ensuring the observance of such procedure.

Finally, the practice of appraisal and ex-post evaluation of externally funded water and sanitation projects by external consultants should be avoided wherever possible. Quite apart from the ease with which such consultants can be mistaken or misled, the failure to entrust local professionals with the task means that an excellent opportunity is lost. Appraisal and evaluation studies funded by external agencies may represent a small percentage of project costs, but if the sums involved were spent locally, they could transform the approach to field research in many developing countries. Of course, there are many countries where, due to a lack of local expertise, some external support and supervision would be necessary. Nevertheless, the international agencies could require a significant degree of local participation in all appraisal and evaluation studies.

The difficulty of generalizing from the results of implementation research has already been mentioned. However, experience which cannot be generalized may nevertheless be relevant and useful in other settings. The best way to ensure that others benefit from it is to promote communication between researchers and practitioners in different countries. Publications which are distributed free can contribute to this, but there is always a danger of flooding the market with an excess of paper, from which the busy professional does not have time to sift the useful information.

Best of all is the opportunity to meet face to face and to visit projects on the ground. The World Bank, WHO and UNICEF have occasionally promoted this, usually as a by-product of their support for a regional or international conference. However, there is plenty of room for more study tours, organized explicitly as such. These could be promoted fairly cheaply on a regional basis, focussing mainly on institutional and policy issues, which often vary widely between adjacent countries. Participants from several countries in a region would together visit each of the countries in turn. In each country at least one member of the group would be in his or her own country, and host the others. A smaller number of study tours could be organized between regions. For example, Africa and Latin America have much to learn from each other in the field of water and sanitation.

EPIDEMIOLOGICAL ASPECTS

Lastly, but by no means least, there is the health dimension to water and sanitation. Here the results to be gleaned from research may be of global relevance. To clarify our understanding of the relations between water supply and sanitation on the one hand, and infectious disease on

the other, is most emphatically *not* a question of 'fine tuning'. Considering the importance of diarrhoeal disease morbidity and mortality in the developing world and the large sums of money spent on water supplies as a measure to control them, it is striking that there is still no scientific consensus as to whether water supply affects endemic diarrhoeal disease at all, and if it does, whether it achieves this through improvements in water quality, or quantity, or both. The answer to the question affects the sort of water supply we should seek to provide, and to whom it should first be provided. The likelihood that water quantity and hygiene are of greater significance suggests several areas for research.

(a) Studies of the health impact of water supplies in conditions where they are known (or are likely) to have brought about an increase in water use per capita. In practice, study sites are usually chosen because of donor concerns or for circumstances favourable to the study methodology. In the words of Briscoe *et al.* (1986), the objective would be to choose study sites where health impact evaluations would be 'sensible', and not only 'useful' and 'feasible'.

(b) Studies of the factors which determine the quantities of water used for domestic purposes, particularly for hygiene. It is remarkable how few studies of this kind have been conducted, considering how easy they are to perform. Those by White *et al.* (1972), Feachem *et al.* (1978) and others have found a counter-intuitive relationship between water use and distance (Cairncross 1987b) which has important consequences for policy. If the influence of distance to the water source has been little studied, the influence of cost has been totally neglected. There are simply no published data on the elasticity of demand for water among low-income groups in developing countries, although the question is central to the issue of cost recovery.

(c) Studies of replicable interventions to promote hygiene. Of course, an increase in total water use cannot of itself bestow health benefits; rather, what is beneficial is the improvement in hygiene which it can facilitate. Of course, some hygiene improvements may require relatively little increase in water consumption, and may be promoted directly rather than by building water supplies. While the likely success of hygiene education is often boosted by wishful thinking (compare, for example, the slow effect of education on smoking), it would at least be worth more rigorous evaluation (Feachem 1984). The interventions to be evaluated should be more feasible on a broad scale than that of the pioneering study by Khan (1982). Khan found that hand-washing with soap, often reserved for laundry use by low-income families, had a dramatic impact on *Shigella* diarrhoea. The promotion of this soap use deserves more study. For example, what would be the effect of tax exemption or subsidies? Soap manufacturers might be persuaded to support such research.

Water supply can be expected to influence diseases other than diarrhoea, and yet we are largely ignorant of its impact on other infections, and hence of how water supplies can be built and operated to control them most effectively. Trachoma, for example, has been little studied in the context of water supply. Community surveys often indicate a prevalence of infection much higher than is imagined by national health authorities (e.g. Cairncross & Cliff 1987) and much still remains unclear about the transmission of the disease, particularly with regard to human behaviour (Taylor *et al.* 1985). The same applies to Guinea worm. It is astonishing that, when Guinea worm is the second disease whose eradication has officially been declared as a goal by the World Health Organization (1986), the Tropical Disease Research Programme of that body should be sponsoring only a single epidemiological study.

With regard to excreta disposal our ignorance is also very great. The health problems most closely linked to poor sanitation are the intestinal nematode infections, which number among the most widespread infections of humanity (Feachem *et al.* 1983), and yet our knowledge of the risk factors for these infections, particularly the risk factors for high worm burdens, has

advanced little since the pioneering studies of the Rockefeller Foundation 60 years ago (Cort *et al.* 1929). Since no paper on these 'forgotten diseases of forgotten people' has been commissioned by the Commission on Health Research for Development, the following discussion is not limited to the influence of sanitation.

Considerable controversy still surrounds the question of whether the risk factors for the gut nematodes, and particularly for high worm burdens, are immunological or environmental in nature (Anderson 1986). If the experience of schistosomiasis is relevant (Wilkins *et al.* 1987), they are likely to be both. However, very little research is devoted to the environmental and behavioural questions, by comparison with current efforts in parasite immunology.

The identification of such risk factors could permit the development of environmental and educational interventions which may well prove more feasible to apply in the short term than any future vaccine.

One well known risk factor for heavy burdens of *Ascaris* and *Trichuris*, as well as for frequent episodes of diarrhoea, is youth. It is well known to scientists, but not to many parents, that children's faeces are more likely to contain pathogens, possibly in greater numbers, than the faeces of adults. And yet there is little experience in practice of how to target sanitation programmes at children. The development and the health impact of facilities specifically designed for children, such as cheap locally-made chamber pots or children's latrines, is an important area for research.

Another area worthy of interest is the time typically spent in the environment by the intestinal helminths between human hosts. Although experiments have shown that they can survive for months in favourable conditions, it is likely that in practice many of them are deposited in hostile conditions which rapidly kill them. The aggregate environmental survival curve may have a much shorter half-life than laboratory studies would suggest. The shape of this curve can be studied only indirectly, for example by comparison of re-infection rates after successive rounds of chemotherapy in a reasonably self-contained community.

Nevertheless, a short half-life could indicate novel mass treatment strategies, such as chemotherapy repeated at short intervals, not only to control the population of adult worms in human hosts, but also to prevent reinfection until the vast majority of eggs and larvae in the environment have died.

The health impact of water supply and sanitation has been considered as something of a taboo subject for some time by the World Bank and the World Health Organization. The World Bank ceased to contribute actively to the debate on the subject after an expert panel had concluded that 'long-term longitudinal studies of large size and expense are probably the only means through which there is any chance of isolating a specific quantitative relationship between water supply and health' and recommended, given 'the very high cost, limited possibility of success and restricted application of results', that such studies should not be undertaken (World Bank 1976). The motives of the World Health Organization were less explicit, but may have arisen from the personal views of a few of its staff. Whatever the reasons, both bodies seem to have taken a renewed interest in the subject in recent years. This development was facilitated by the development of fresh approaches to the methodology of health impact measurement (Briscoe *et al.* 1986) and accelerated by the recent changes in structure and in the key personnel of both organizations. It is a development which the Commission on Health Research for Development should endorse.

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