Technology for water supply and sanitation in developing countries

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Geneva, 14–19 April 1986

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TECHNOLOGY FOR WATER SUPPLY AND SANITATION IN DEVELOPING COUNTRIES

Report of a WHO Study Group

1. INTRODUCTION

A WHO Study Group on Technology for Water Supply and Sanitation in Developing Countries met in Geneva from 14 to 19 April 1986. Dr B. Dieterich, Director of the Division of Environmental Health, opened the meeting and welcomed the participants on behalf of the Director-General. He drew attention to the mounting pressure to improve and expand services and to the rising interest in technological developments, especially those considered appropriate for the socioeconomic conditions at community level. He attributed these developments to an increase in the number of international, multilateral, and bilateral agencies that had become interested in the water supply and sanitation sector, and to an increased understanding of the sociocultural factors influencing the selection of suitable technologies. He stressed that the purpose of this Study Group was not to discuss new inventions but to consider whether advances in technology had been useful in relation to community needs and local resources.

The Study Group was the first to be convened by WHO specifically to consider the status and role of water supply and sanitation technologies in relation to the International Drinking Water Supply and Sanitation Decade. The objectives of the Study Group were: to review advances in technologies related to urban and rural water supplies and sanitation; to appraise these developments in the light of community needs and of the conditions in, and resources available to, Member States; to identify the constraints that limit the application of any appropriate technology; to identify gaps in knowledge and suggest further research and development; and to make recommendations for strengthening the exchange of information concerning various technologies.

2. BACKGROUND

In the early years of the World Health Organization's concern for environmental sanitation, a substantial effort was directed to the installation of water supply and excreta disposal facilities. At the same time, efforts were directed to the publication of guidelines for the planning and construction of facilities and documents for the training of technical personnel. Examples of these are the WHO publications, "*Excreta disposal for rural areas and small communities*" and "*Water supply for rural areas and small communities*" that were published in 1958 and 1959, respectively.

More recently, in the mid-1970s, the work was oriented more towards the development of suitable infrastructures to support the installed facilities. This included guidance on institutional structures, the development of human resources, and advocacy of various approaches, such as community involvement and health education, to be included as integral components of water supply and sanitation projects. This reorientation resulted from the recognition that, in many cases, old systems were failing almost as rapidly as new ones were being built, and that systems, even when operating, did not meet expectations in terms of improvements in health.

In October 1974, a technical panel convened by the *Ad Hoc* Working Group on Rural Potable Water Supply and Sanitation met to study the situation.[1] The panel made major recommendations concerning identified problems and proposed that an internationally supported programme should include a greater emphasis on manpower development, information and education for health, and a system for the transfer of technical information. The panel concluded, that technological difficulties could not truly be considered as a serious constraint to progress and suggested that the main impact on environmental health and welfare would come from the application of known methods.

The general need to develop support systems was re-emphasized by the United Nations Water Conference (Mar del Plata, 1977) and by the International Conference on Primary Health Care (Alma Ata, 1978). The World Health Organization has, therefore, concentrated its efforts and resources on the development of human resources, institutional structures, information systems, and community

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[1] The report of the technical panel was issued in 1974 as an unpublished WHO document CWS/RD/74.14.

involvement, while other agencies—international, multinational, and national—have been concentrating on technological matters.

WHO recognized certain biases and shortcomings in national plans and programmes, and in the support provided by the international community, and in 1981 recommended new approaches to be adopted in the International Drinking Water and Sanitation Decade.[1] At the national level, the recommended approach comprised:

— complementary development of sanitation and water supply;
— strategies that would give precedence to underserved populations, both rural and urban;
— programmes that would serve as models for self-reliant, self-sustaining action;
— socially relevant systems that people could afford;
— participation of communities in all stages of projects;
— coordination of water-supply and sanitation programmes with those in other sectors; and
— association between water supply and sanitation programmes and other projects for health improvement.

To guide international initiatives, the above-mentioned publication suggested that emphasis should be placed on:

— promoting and supporting national programmes for the Decade through technical cooperation;
— concentrating technical cooperation on building up national capacities and generating dynamic, self-sustaining programmes;
— promoting technical cooperation among developing countries; and
— encouraging the external financing of the national Decade activities.

The publication stressed the WHO objective of linking Decade activities in water supply and sanitation with primary health care as critical components of community and rural development.

[1] WHO. *Drinking-water and sanitation 1981–1990: a way to health,* Geneva, World Health Organization, 1981.

Table 1. Some characteristics of rural and urban areas in relation to factors affecting water supply and sanitation in developing countries

Factors affecting water supply and sanitation	Rural		Urban		
	Scattered population	Nucleated communities	Squatters (unauthorized)	Slums (authorized)	Urban developments
Political pressure	very low	low	medium-to-low	medium-high	high
Political awareness	very low	medium	medium-low	medium	high
Manpower availability:					
– high-level staff	unlikely	very limited	limited	limited	available (limited)
– medium-level staff	unlikely	very limited	limited	limited	limited available
– voluntary labour	possibly available	often available	usually not free	usually not free	not free
Maintenance arrangements:	extremely difficult	very difficult	very difficult	difficult	reasonably difficult
– repair skills	low level	low/medium	medium	medium/high	medium/high
– spare parts	–	generally absent	–	sometimes available	sometimes available
– back-up support	not available	very limited	–	sometimes available	sometimes available
Income:					
– potential for revenue collection	very low	difficult but existing	low and difficult	possible	existing and often applied
Non-public options available:					
– for water supply	unprotected surface impoundments and shallow wells	unprotected surface impoundments and shallow wells	water vendors	water vendors	water vendors and private wells
– for sanitation	open field defecation	open field defecation	street/open areas	limited/street	limited
Public land utility:					
– availability	available	often available	not available	very limited	limited
– quality	–	–	low	low	–

Requires user-involvement in decision making and implementation	high	high	high	moderate	limited
Required government input	back-up support and advice	back-up support advice and coordination	back-up support advice and coordination	coordination/ organization	coordination
Power supply	not available	limited available	limited available	usually available	usually available
Road and communication	difficult	possible with major time lag	possible but difficult	relatively manageable	relatively easy
Legislation and control	very difficult	difficult	very difficult	difficult	possible
Industrial developments	none	very limited	very limited	considerable	substantial
Literacy level	low	low	low	low	medium/high

3. EXPLANATIONS OF TERMS USED IN THIS REPORT

3.1 Urban and rural areas

It is not possible to provide standard definitions for "urban areas" and "rural areas" that would be universally applicable. Each country makes its own decisions on whether an area should be considered urban, as opposed to rural, such decisions being based on nationally recognized criteria. There are, however, a number of factors that affect the choice of technologies for water supply and sanitation that have different characteristics depending on the nature of the area in which the technologies are to be applied. These factors and their associated characteristics in different settings are identified in Table 1. Reference to this table will help to explain the way in which the words "urban" and "rural" are used in subsequent sections of this report.

3.2 Safe and adequate water supply and sanitation

Safe water is water that does not contain harmful chemical substances or microorganisms in concentrations that could cause illness in any form.

An *adequate water supply* is one that provides safe water in quantities sufficient for drinking, and for culinary, domestic, and other household purposes so as to make possible the personal hygiene of members of the household. A sufficient quantity should be available on a reliable, year-round basis near to or within the household where the water is to be used.

Sanitation[1] refers to the means of collecting and disposing of excreta and community liquid wastes in a hygienic way so as not to endanger the health of individuals and the community as a whole.

Safe excreta disposal should aim to prevent excreta (*a*) coming into direct contact with man; (*b*) contaminating ground or surface waters; (*c*) being accessible to animals or insects; (*d*) coming into contact with food; and (*e*) creating a public or private nuisance.

Adequate excreta disposal should provide each household with a safe excreta disposal system.

[1] The first WHO Expert Committee on Environmental Sanitation (September 1949) provided a broad definition of "environmental sanitation", which included in addition to excreta and wastewater disposal, other elements of the environment which might affect health, such as community water supply, housing, food, atmospheric conditions, occupational conditions, and disease vectors.

Safe wastewater disposal should provide for the prompt and complete disposal of household and other community wastewater, including accumulated rainwater, thereby preventing the creation of pools and surface channelling that could become breeding sites for disease vectors or that could otherwise compromise human health.

Adequate wastewater disposal should provide for wastewater collection from all human settlements and include its safe treatment and/or disposal.

Adequacy for water supply, excreta disposal, and wastewater disposal further implies that facilities are available at workplaces, schools, markets, public buildings, and other places where people congregate.

3.3 Appropriate technology

To be appropriate, a technology should:

— be as inexpensive as possible without jeopardizing the effectiveness of the improvements sought;
— be easy to operate and maintain at the village, community, or municipal level, and not demand a high level of technical skill or require a massive deployment of professional engineers;
— rely on locally-produced materials rather than on externally provided equipment and spare parts, where this is practicable;
— make effective use of local labour, especially in areas where there is a surplus of labour;
— facilitate and encourage the local manufacture of equipment and parts under the leadership of entrepreneurs;
— facilitate the participation of village communities in its operation, and maintenance; and
— be compatible with local values and preferences.

4. WATER SUPPLY TECHNOLOGY

4.1 Design criteria

To ensure the feasibility, acceptability and success of a planned water supply service, the adopted criteria must be responsive to the needs and constraints imposed by the existing and forecast conditions of the community concerned. Thus, design criteria must take account of technical, health, social, economic, financial, institutional and environmental factors which determine the characteristics, magnitude, and cost of the planned system.

In view of the wide differences in the needs of, and the conditions and constraints found in, different communities in developing countries, as illustrated in Table 1, design criteria, other than those related to the minimum public health requirements, cannot be standardized and applied indiscriminately. This is broadly illustrated in Annex 1 which describes the special features of rural water supply and sanitation projects.

Technical criteria that have been used in developed countries should be used merely as a guide and not as a substitute for rational local planning and sound engineering judgement. Developing countries will benefit more if the design criteria used have been derived from experience under conditions similar to those in their region.

Incremental improvement in the level of service is the appropriate approach in project planning. In addressing the needs of low-income communities, provision of basic sanitary measures and safe and adequate water supply and sanitation must be the first priority. In other communities, where there is an ability and willingness to pay for a higher level of service, charging the economic cost to the consumer will make resources available for a higher population coverage.

Admittedly, progress in the provision of rural water supplies has been slow and planners and designers have contributed to this situation by not always selecting design criteria which, along with other measures, would have made faster coverage possible. For example, by designing systems that would supply slightly less water to rural communities, a higher service coverage would be possible.

Since the need for urban water supply service in developing countries is now greatest in low-income communities, technologies suitable for this type of community, especially slums and squatter settlements, will have the greatest impact; in these situations, unnecessary automation and telemetering systems are inappropriate.

Advantage should be taken of the wider availability of electronic computer facilities in developing countries. With appropriate programming, a larger selection of alternative schemes can be more easily and speedily analysed under different conditions and using different criteria. Computers can also be very useful in the design and control of complex water and wastewater systems and in the handling of data.

4.2 Standards and specifications

If greater coverage is to be achieved with community water supplies and sanitation, there will often be a need for careful evaluation of the potential benefits to be gained by relaxing restrictive foreign construction standards and standards and specifications associated with imported materials and equipment. However, any reduction in the reliability of the system resulting from relaxation of standards should never be allowed to compromise public health. Greater flexibility in building codes and standards will allow low-income communities to benefit from the application of appropriate low-cost technologies. It is important to review local plumbing codes and household connection practices in many countries and to update these if necessary to take advantage of the availability of new materials.

Standardization of equipment is often difficult to achieve in most developing countries owing to the number of donors involved, and this creates problems in maintaining stocks of spare parts. It will therefore be in the best interests of recipient governments and communities if the aid programmes can be coordinated in order to limit the range of equipment types being supplied. Standardization will be facilitated when the production of reliable equipment can be achieved locally.

4.3 Water source development

4.3.1 *Assessment*

Assessment of all alternative water sources (including ground, surface and rain waters) is essential if the most suitable source is to be selected on the basis of technical and financial considerations; assessment of water rights may also be necessary. Use of a combination of different sources may be necessary in certain cases. Techniques are available for rainwater collection, and this may be a suitable way of providing rural water supplies. Because of the large quantities required and the difficulty of preventing contamination, however, rainwater collection would normally not be suitable for urban areas.

When selecting alternative sources, cost is an important criterion as well as water quality and safe yield. Sources providing water that does not require treatment will generally prove to be the most economical unless development costs are very high. Water-resources surveys require extensive technical resources and are being carried out by local consultants in many developing countries. New assessment technologies, such as satellite imaging, may expedite groundwater surveys and reduce the cost of investigations.

Hydrogeological expertise is essential in order to be able to assess the potential for groundwater utilization wherever knowledge of aquifer systems is limited, particularly when substantial investment is envisaged for a large-scale water supply programme. Hydrogeological assessment will improve the success rate in deep-well drilling. The technology for such assessment is well developed but appropriate technical expertise is not always available in water supply agencies, although it may be available locally, in other sectors (for example in irrigation, water resources and mineral resources departments). Investment in instrumentation is costly when only limited use is expected and other alternatives should be considered, including the engagement of private companies to carry out surveys.

Artificial aquifer recharge is widely practised in developed countries and should be considered more seriously in developing countries. It should be considered whenever safe yields are being exceeded.

Assessment of water resources for multiple uses is very important in order to rationalize their use, to view the demand for drinking-water supply in relation to that for other uses of water, and to plan for economies of scale. As groundwater resources decline and become less economical to exploit, greater use of available surface water sources is to be expected, and the critical hydrological conditions associated with surface water resources must be investigated in each case.

It is important to recognize the beneficial influence of land-use control in catchment areas on the quality of surface-water and groundwater sources. Source contamination from human settlements, industries, and agricultural practices is a problem in many developing countries. Integrated regional development of water resources should always include pollution control measures.

4.3.2 *Extraction*

A wide range of techniques is available for water-source development, but there is a great need to improve the transfer of technical information especially on small dams, underground dams, and infiltration galleries. Infiltration systems that upgrade surface water at the point of extraction are expected to have a wider role to play in developing countries; however, there is a gap in knowledge of procedures for assessing their potential and deciding on the design of such systems. The production of simplified design manuals could be of value to field engineers in developing countries.

Supervision of source development and construction is often poor, particularly in the case of wells, and this leads to problems in operation, such as the ingress of sand caused by poor selection and placing of gravel packs and well-screens. To overcome some of these problems, training programmes are essential with a wider dissemination of information.

In order to monitor and control water abstraction from aquifers it will be necessary to install appropriate measuring devices and instrumentation on the wells, and to provide adequate facilities for maintenance. A wide range of power-pump systems is available for water abstraction and a degree of standardization is desirable for easier operation and maintenance purposes, although difficult to attain in practice. A stock of spare parts is an essential component of any programme involving powered pumps.

The unreliability of electric power supplies in some developing countries creates additional expense for pump-set maintenance because it is necessary to provide alternative power generators. A comparison of the real cost of such alternative power supplies with the cost of maintaining a reliable power supply might justify the improvement of the regular service. However, accepting that electric power supplies in developing countries will continue to be unreliable, assessment of alternative prime-movers (diesel generators, etc.) is desirable and the provision of back-up maintenance is essential.

Photovoltaic cells harnessing solar energy may be suitable as alternative energy sources for application in rural water supply schemes. Research continues to reduce the cost of photovoltaic cells and this will increase their potential usefulness. In some locations, there might be applications for distillation of brackish waters using solar power. Wind-driven pumps may be suitable for use in in rural water systems but only in areas where there is adequate wind throughout the year.

Hand-pumps are now well developed and described but there is still a great need to improve the transfer of up-to-date information among developing countries. Such pumps are likely to remain useful for rural settlements but the risks of groundwater pollution, especially an increase in the level of nitrates from on-site sanitation, and of lowering the groundwater table through overpumping must be recognized. Maintenance remains a major problem in hand-pump programmes and an adequate supply of spare parts together with back-up support are essential components that are often overlooked.

Where local manufacture of hand-pumps is practicable, local research would be desirable to adapt the designs to local conditions so that they make village-level operation and maintenance (VLOM) possible. Furthermore, objective assessment of the operating performance of existing hand-pump projects will be of benefit to future programmes.

4.4 Water treatment

Despite some advances and refinements, the methods used for basic water treatment, i.e., for the removal of colour, turbidity, and organisms from raw waters, are still based on the processes of sedimentation, filtration, and disinfection with chlorine or other disinfectants. Advances have been made in the design of multi- or mixed-media filters and in the development of non-chlorine disinfectants, because of concern about the health risks associated with the trichloromethanes that result from the reaction of chlorine with traces of organic materials present in water. Some improvements have also been made in the settling processes for the removal of turbidity and taste- and odour-causing materials. There have also been advances in the automation of, and telemetry associated with, the operation of conventional treatment processes.

Techniques exist for upgrading, and increasing the capacity of, existing water-treatment plants; in most developing countries, however, the main problem has not been in the application of these techniques but in the operation and maintenance of even the simplest of the existing processes. Maintaining the supply of water-treatment chemicals is also a serious problem in most developing countries, particularly where they have to be imported.

For rural water supplies, there is a need for methods that are reliable with a minimum of supervision based on a treatment process that remains stable. Slow-sand filtration is now well developed but its use needs to be actively promoted in developing countries. There are still opportunities for research into cost-reduction and alternative construction materials. Methods of pre-treatment, which is most important when dealing with highly turbid surface waters, could still be improved. The horizontal roughing-filter is one alternative that is worthy of more widespread testing and adoption in appropriate settings.

The use of multi-media filters, declining-rate filters, and plate-settlers could be beneficial in reducing costs and increasing the capacity of existing treatment plants that need to be upgraded. A modular approach to treatment-plant design will usually be beneficial, and the mass production of components could also assist in reducing overall costs.

Disinfection with chlorine is still considered desirable, even after slow-sand filtration. Disinfection with gas-fed chlorinators relying on imported chlorine cylinders is not reliable in rural installations, even in developed countries, and is not suitable for developing countries because of the high degree of sophistication of the equipment required, the need to transport the chlorine, and the associated safety measures. Electrolytic-chlorine generators might have an increasing role to play, because they make it possible to produce chlorine on site. More information is required on the effects of storage of water and of household-level disinfection, for example using sunlight and transparent containers.

Although some concern about the effects of chlorination has been expressed from time to time, the provision of a chlorine residual in water is considered to be highly desirable because of its proven effectiveness in combating water-borne disease. Chlorination is thus likely to continue as the most appropriate form of disinfection for the foreseeable future; but the need for improvements in methods of chlorination and the development of techniques using other disinfectants is recognized.

Fluoridation of community water supplies for the prevention of dental caries continues to be one of the most important measures for the promotion of oral health. However, its application in the developing countries has been hindered by the lack of a simple technique and the need to import the required chemicals such as sodium fluoride or sodium fluorosilicate. Therefore, there is a real need to develop a simpler fluoridation technique, suitable for developing countries, that uses available materials and does not require imported chemicals. Studies along these lines have been carried out successfully in Brazil using crude fluorite (calcium fluoride) which is placed on top of the filtering layer of coarse sand.[1] More research on such techniques is required in the future.

Techniques are available for the removal of excessive levels of natural fluorides in water but their application has presented some problems in developing countries, particularly at the rural level. Methods available include chemical precipitation through coagulation (alum and calcium hypochlorite), ion exchange, filtration through a column of crushed bones (which contain carbonates and phosphates), the use of activated alumina, and reverse osmosis. Selection of the most appropriate method requires careful consideration of costs as well as of the reliability of the process under rural conditions in developing countries.

Simple techniques are available for the removal of iron and manganese from water and for the treatment of excessively hard or soft waters but they have not been widely adopted in rural areas. There is a need for the development of village-level treatment processes to handle hard and aggressive waters.

4.5 Water distribution

Water supply services for scattered rural populations will continue for the foreseeable future to rely on hand-pumps and hence will not normally include piped distribution. The provision of piped water supplies to nucleated rural areas through regional schemes and/or the extension of urban systems to contiguous rural areas would be appropriate, wherever feasible. However, extension of urban systems to low-income areas should not undermine the existing level of services in the urban areas already served.

Increased use of computers in the design of complex water distribution systems has improved and simplified design. This is especially important in the design of urban systems, where account must be taken of frequent changes in the patterns of consumption, and when it is necessary to monitor and control leakage.

As alternatives to increasing the capacity of existing water supply systems when it is necessary to serve more people, several options are available, such as: control of leakage and unaccountable losses

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[1] DINIZ, R.G. ET AL. Development of a simplified water fluoridation technique for small communities. *Bulletin of the Pan American Health Organization*, **16**: 224–232 (1982).

(for which the equipment exists but it is not widely used); metering, with the possibility of reducing unaccountable losses and the introduction of differential tariffs; flow-limiting and water-saving devices; and the use of dual water systems, of higher and lower quality, where feasible.

While control of water loss from systems is highly desirable, the application of the available techniques will depend on an assessment of their cost-effectiveness in specific areas. Leakage detection, by means of sound- and electronic-sensing devices and night-flow measurements with district metering, is a well known procedure, but it is still not sufficiently applied in developing countries, mainly because of managerial difficulties.

Household storage of water, made necessary because of intermittent supplies, raises some problems related to health and others of a more social nature. The need to allow for upgrading of the original designs of such cases is acknowledged. There is general agreement that the provision of intermittent water supply systems should be discouraged on health grounds, and that those systems now operating intermittently should be upgraded to allow continuous operation as soon as possible. However, since such upgrading will take a considerable time in many developing countries, it is necessary to study the health and economic implications of existing intermittent supplies.

In providing a water supply to urban squatter settlements, the possibility of adapting the methods used to supply water to rural areas should not be overlooked. Although the introduction of different types of system is likely to give rise to managerial problems, the solution to the existing problems of low level of service coverage in these communities requires a radical approach. The possibility of asking householders to pay for the cost of connections over a period of time is another means of extending and accelerating coverage. Private vending of water requires control to prevent squatters from having to pay very high rates for small quantities of water and to protect quality.

Attention is drawn to the need to reconsider plumbing regulations in relation to the levels of service. Outdated and inappropriate codes should be reviewed. In-house plumbing costs should be considered when deciding on the level of water service at the planning stage. There is a need to develop low cost and easy-to-repair taps, which can be locally manufactured, for households and public standposts. Although standpost systems are well developed, there are problems with the organization and management of such systems and there is a need for the dissemination of information. Evaluation of flow-restricting devices for distribution systems is desirable.

There is also room for the development of simple, inexpensive, and reliable water meters. Metering is considered highly desirable as a means of controlling consumption and waste, of collecting data for planning and evaluation, and of providing an equitable basis for tariff charges. However, this is not achieved without costs, including investments in maintenance and repair workshops and the recurrent costs of additional staff for meter reading. Thus a very careful cost/benefit analysis must be carried out before a decision is made on metering.

Galvanized iron and polyvinyl chloride (PVC) continue to be the main pipe materials in use although asbestos-cement pipes are still used despite some unproven health concerns. Pipe cost is a primary constraint in water supplies, and the optimization of system design, including storage considerations, is always important. Documentation on the comparison of different types of pipe is not always available to designers in developing countries and therefore the dissemination of such information would be very helpful.

Contamination of the water in pipes is a problem, particularly with intermittent supplies, and to minimize this problem more attention should be given to jointing and bedding techniques. There is also a need to evaluate the accessories associated with pipelines, such as pipe joints, etc. Pipe-laying in urban areas is a critical operation in view of the exposure to heavy traffic loadings, difficulty of repair, importance of leakage control, and the possibility of illegal connections. Training of qualified supervisors is essential.

In areas where piped water supplies may not be feasible in the foreseeable future there may be a need to study alternative systems for the carriage of water (for example, transport and vending of containerized water). Some attention should be given to the form of containers used for hand-carried water in order to ensure the maintenance of water quality.

Use of alternative energy sources affects the requirements for communal storage capacity. There is a need to assess alternative construction techniques and materials for storage reservoirs and elevated tanks. Standardization of small tanks or containers for household storage is desirable on a national basis. Information on low-cost container materials would be of value.

4.6 Water quality and control

It is considered that the three volumes of the WHO *Guidelines for drinking water quality*[1] adequately cover the various aspects of quality, surveillance, and control. Despite the availability of such guidelines there is concern that the analysis of new sources for quality variations is not being given sufficient attention in developing countries. Many countries do not yet have laboratories suitably equipped for the wide spectrum of analyses that are sometimes necessary. Even where laboratories exist, they are not always properly staffed, equipped, or utilized. The global environmental monitoring system (*GEMS*) is a potential source of water quality data in many countries. In addition to the need for well equipped and properly staffed central laboratories, there is also a need for unsophisticated laboratories at waterworks, containing equipment matching the skills of the operator.

5. SANITATION TECHNOLOGY

5.1 On-site sanitation

A range of appropriate on-site sanitation systems can (under specific conditions) provide the same health protection as conventional water-borne sewerage; many publications give details of such systems and indicate approaches to their application. Several demonstration projects have been initiated in rural and low-income urban areas in developing countries. However, owing to inadequate follow-up and lack of appropriate institutional mechanisms, little success has been achieved in replicating these, and this may account for the poor statistics on sanitation in most countries. Little attention has been given to the public health problems created by providing a water supply without adequate sanitation and drainage, which suggests a greater need to plan both services at the same time. Attention has been drawn to problems caused by lack of inter-agency coordination which may result in the use of different sanitation systems in different parts of one urban area.

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[1] WHO. *Guidelines for drinking-water quality*. Vol. 1, *Recommendations*; Vol. 2, *Helth criteria and other supporting information*, *Geneva*, World Health Organization, 1984; Vol. 3, *Drinking-water quality control in small community supplies*, Geneva, World Health Organization, 1985.

Removal of excreta and wastewater is a major problem in urban areas especially in the squatter settlements and it is sensible to consider possible solutions in relation to other aspects of community development including public utilities, road networks, etc. Rational development of urban sanitation might thus involve different methods in different areas, according to population, housing density, water supply, and other factors. For unsewered low-income areas, priority should be given to techniques that provide a relatively short-term solution at reasonable cost, but which can be integrated into a long-term master plan for urban sewerage, based on a proposed plan for socioeconomic development. The provision of sanitation in flooded areas, where squatter settlements often exist, is likely to raise complex problems. Information needs to be disseminated on appropriate techniques for such areas.

The use of unattended public latrines to provide sanitation in squatter areas has not been successful in most cases, owing to the lack of maintenance and misuse. On the other hand, limited experience with attended public latrines in some developing countries indicates that they may provide a satisfactory interim solution.

Although a range of on-site sanitation systems is available, including the ventilated improved pit latrine (VIP) and the pour-flush latrine, there is still room to improve the design criteria on the basis of local experience. Further study is required of septic tank performance at high ambient temperatures, leaching pit capacity for different soil conditions, and the desludging of pits. The risk of contamination of groundwater and water distribution systems by on-site sanitation should always be considered and kept under surveillance. Further improvements in latrine slab and superstructure construction are still possible. Pit stability in sandy soils and latrine construction in high water table areas are problems in many countries and suitable low-cost solutions have still to be found. The potential for very deep shaft or borehole disposal is worthy of consideration in some areas.

The integration of latrines with simple biogas systems receiving animal and agricultural wastes might sometimes be feasible in rural areas. Nightsoil and/or wastewater are reused in fish ponds or for irrigation in several developing countries; however, further epidemiological evidence is required on any effects on health before undertaking promotion for the safe reclamation of wastes. There is a need to improve methods for upgrading on-site latrine systems into small-bore sewerage as socioeconomic development occurs, without discarding the original investments. Evaluation of on-site sanitation systems is highly desirable, and information on experiences and costs would be of great benefit to most developing countries.

The absence of any institutional and management framework has retarded progress in implementing rural sanitation programmes as an integral part of regional development in many developing countries. A lack of awareness of the importance of sanitation is prevalent in rural communities of developing countries, and governments have not sufficiently promoted health education programmes focusing on the safe handling of excreta to prevent disease transmission. Sociocultural attitudes have a greater influence on the perceived need for, and use of, sanitation in rural areas than technological issues. More information is needed on these attitudes as well as on the effect of economic development on sanitation acceptability. Few attempts have been made to promote the implementation of rural sanitation programmes at the local level, through private enterprise, and this may be worthy of future consideration.

5.2 Off-site sanitation

There are particular problems with the selection and construction of sanitation systems for very-high-density, low-income urban areas. The health hazards increase with increasing population density and space for on-site sanitation becomes difficult to find. Different sanitation methods are required at different stages of development, particularly as water consumption rises. The objective must always be to provide a system that will give the same health protection as conventional sewers and prevent environmental and groundwater pollution.

In urban squatter areas consideration should be given to the use of shallow sewers receiving raw sewage yet laid at a flatter slope than for normal sewers. These, of course, must be equipped with grease traps. This alternative might be particularly suitable and economic where it is necessary to excavate into a rock formation. If the community is mobilized, a high connection rate can be anticipated and, in high-density housing areas, the cost can be as low as that for on-site sanitation. These sewers must be located where they are protected from traffic loading; if they are laid in backyards, short household connections contribute to cost-savings.

Problems that might arise with shallow sewers include: blockage at the upstream end of lines, easement or right-of-way difficulties concerning the laying of sewers in the neighbour's property, damage to sewers caused by building extensions, pollution of water distribution systems, the emptying of grease and grit chambers, and pollution at the end of the pipe. Low ambient temperatures might also create problems with shallow sewers. It should be accepted that any sanitation system must be maintained and that the organization of maintenance must be a precondition for shallow sewers, as for any other sanitation system. Normally the community should play an active role in sanitation programmes but community mobilization is particularly important in the case of shallow sewers.

Small-bore[1] sewerage to carry effluent or overflow from on-site sanitation systems is another form of sanitation that is likely to be more feasible than conventional sewerage because flatter slopes can be adopted. Such a system might be justifiable to improve existing on-site pour-flush latrine or septic-tank systems, especially in areas with a high groundwater table and/or with underlying rock. Even if end-of-pipe treatment is to be provided, care must be taken to ensure that all future connections to the system would also be preceded by on-site treatment (e.g., septic tanks) in order to reduce the risk of blockages. To be effective, small-bore sewerage requires a reasonable level of water supply. Designing for very flat slopes (less than 1:150) would make such a system even more economical.

Street disposal of wastewater from kitchens and bathing facilities (i.e., sullage) is also a major problem in many urban areas of developing countries, particularly if filariasis and other vector-borne diseases are endemic. Separate disposal of such wastewater in squatter areas, if carefully handled, is a possible solution but this requires further evaluation. One possibility would be the use of storm-water drainage systems for the removal of sullage and treated effluent in urban areas as an interim measure, but appropriate criteria must be established. An alternative would be the use of shallow and small-bore sewers to collect sullage from low-income urban areas for safe disposal.

Conventional sewerage is usually best for the central districts of major urban areas. The decision on whether to adopt a combined or a separate sewer system is one that depends on local climatic conditions, particularly the frequency, duration, and intensity of

[1] Up to 100 mm.

rainfall, and the conditions of the receiving surface waters. Wastewater collection and transmission is the most costly component of sewage disposal, but careful choice of equipment and materials provides opportunities for optimizing the design, minimizing the cost, and improving the maintenance of systems.

Methods and equipment are available for the maintenance, cleaning, and rehabilitation of sewers but these require wider dissemination in developing countries. Suitable budgetary provisions must also be made. Up-to-date information is available on techniques for minimizing the effects of sewer corrosion but this also requires wider dissemination in developing countries. The sharing of experiences with alternative sanitation systems and sewer materials, as well as experiences with different types of equipment will be of value. Poor selection of sewage pumps and treatment processes and inadequate operation and maintenance often create major health hazards owing to frequent interruption of services. Thus attention is drawn to the need to share available information and to disseminate relevant experiences.

5.3 Wastewater treatment and reuse

Although physical and biological processes remain the main methods for the primary and secondary treatment of wastewater, considerable advances have been made over the last two decades in the design of such systems (especially biological treatment) as a result of advances in microbiology. Developments have also occurred in processes for the treatment of industrial wastes and for the tertiary treatment of domestic wastes, in places where high effluent standards are enforced, especially in the developed countries. However, these developments have not made operation and maintenance of the systems any easier. Accordingly, developing countries must still exercise great caution when considering more advanced treatment processes, such as activated sludge and some of the tertiary processes, if a high level effluent quality is required.

Stabilization ponds are the simplest form of wastewater treatment; although they are land-intensive they are the most effective way of removing pathogens. This is particularly important when the effluent is to be reused in aquaculture, irrigation, or aquifer recharge. In applying the published design criteria for pathogen removal, care should be taken to ensure that pond die-off rate constants are verified for local conditions. If land is not available or is too costly to justify pond treatment, alternative wastewater treatment processes will have to be considered. Whenever reuse is intended, the treatment process must be chosen on the basis of effluent quality parameters appropriate to the use envisaged. Control of industrial effluents will be necessary to protect both the fabric of the sewerage system and the effluent reuse system.

6. EXTERNAL FACTORS INFLUENCING THE CHOICE OF TECHNOLOGY

6.1 Non-technological interventions and community involvement

The choice of technology and its application should be consistent with the socioeconomic and cultural attitudes of the people concerned and should provide a smooth transition towards better health protection. This has been one of the main concerns of international and multilateral agencies during the first half of the International Drinking Water Supply and Sanitation Decade (IDWSSD).

The Decade approach has been to question the wisdom of imposing technology on societies that may be resistant to, or unable to make, the necessary adaptation to such technologies within their sociocultural ethos. At the local level, cultural patterns, with their associated attitudes and perceptions and religious beliefs, have considerable influence. In such a complex situation, with perhaps different behavioural patterns in different regions within one country, the universal application of an apparently appropriate technology is not feasible without carefully planned interventions, including effective community participation. Such interventions must also provide understandable information on the health aspects of the proposed services and on their proper use so as to ensure maximum health protection. The interventions must attempt to change attitudes regarding the view that the central government must be responsible for everything, and must promote the idea of accepting responsibility at the community level.

In rural areas, interventions to motivate the people might best be made by primary health care workers and/or other local community workers who could be prepared for this task by the health and water and sanitation agencies as well as by volunteer and nongovernmental organizations under the guidance and supervision of national institutions.

Water supply and sanitation agencies often use traditional engineering approaches in project design and implementation; their organizational patterns are not such as to encourage adequate community involvement and build up community-level competence. There is a need to involve women and disadvantaged groups as much as possible, within the constraints of specific cultural settings.

6.2 Institutional aspects

Water supply and sanitation sector agencies are often not decentralized enough to be able to serve rural communities. Their outreach is limited; there is little devolution of authority. Central-agency staff are generally not willing to work in locations where water and sanitation systems have to be built and operated. Attempts to strengthen sector agencies often result only in a strengthening of their central offices, leaving field offices relatively weak to perform their referral and support functions. Adequate manpower is required in the field to support activities at community level.

Central agencies have been preoccupied with the needs of urban areas where investments are large and sophisticated technical skills are required. Yet, urban facilities are often heavily subsidized. It is imperative that the urban sub-sector should become self-supporting and not take up resources which would otherwise be available for water supply and sanitation development in rural areas. Also, in many countries there are programme areas (for example, rural sanitation) that are not effectively covered by the sector agency, by the community, or by any established intersectoral action. Interagency coordination is essential for participation in intersectoral projects.

For a water supply and sanitation agency to perform its functions effectively, an adequate legislative framework is necessary. In many instances this does not exist and an institution is handicapped in its operations until the laws, codes, and regulations can be reviewed. Where necessary, the modification of codes, regulations, and standards that prevent the application of appropriate technology will encourage the application of low-cost water supply and sanitation systems. Through such a process the agency will be able to develop institutionally and thereby to improve the performance of well-trained, well-paid, and well-motivated personnel.

A well developed national institution for water supply and sanitation will plan activities according to national plans and priorities. An important element of such planning is the projected coverage for rural and urban water supplies and sanitation. In this exercise, the user's ability to pay for, and willingness to accept, the proposed systems are socioeconomic factors that must be taken into account. Within this concept there are other underlying factors, such as the willingness to pay, the reliability of the collection of user fees, the consumer demand for the system, and the level of service provided.

Matters related to maintenance should also be taken into consideration, including: the procedures established for preventive and corrective maintenance, the availability of operators, and the quality of their training in operation and maintenance. The infrastructure for satisfactory operation and maintenance is often not given sufficient attention, and essentials, such as a stock of spare parts, maintenance equipment, workshops, alternative sources of energy, and communications and transport facilities, etc., are often overlooked.

Institutional and legislative measures should also be adopted to strengthen management, to ensure the improvement of career prospects within the water and sanitation authorities, and to promote the improvement of staff performance through appropriate incentives.

7. INFORMATION TRANSFER

7.1 Mechanisms for information transfer

There are serious deficiencies in information transfer mechanisms and activities related to water supply and sanitation technology. The need to increase the awareness in developing countries of the availability of existing information networks and materials is apparent. No single mechanism for information transfer is suitable for all the conditions and needs of the various countries. The mechanisms for information transfer likely to be useful for developing countries are:

— dissemination of existing publications to specific target groups;
— distribution of newsletters, technical journal indexes, and abstracts of selected papers and reports in periodical form;
— continuing education of professionals and training through short intensive courses, workshops, etc.;
— dissemination of information from project evaluations and demonstration projects;
— exchange of information and technical coordination among developing countries;
— publication of the results of research and development projects;
— support to engineering colleges and technical institutions, especially in the upgrading of curricula and laboratory facilities emphasizing the Decade approach, including appropriate technology and primary health care.

Regarding the strategy for increasing the transfer and dissemination of information, the strengthening of the role of the WHO International Reference and Collaborating Centres and other existing information networks and centres is appropriate. In countries where information activities are deficient, concerted efforts are needed to build up sensible and effective transfer mechanisms. National initiative is an important ingredient in the process. In selecting the type of information to be disseminated, priority should be given to information that will benefit target groups where the improvement of water supply and sanitation is most needed.

Information on new techniques in water supply and sanitation will be of most use, although as stated earlier national codes and regulations may prevent the application of such techniques. The development of standard basic libraries for different target groups is important in order to make the best use of the limited resources available for information transfer. Translation of information into local languages will often be essential to achieve concrete results. Increasing and coordinating the current efforts of national agencies and donor organizations in this area will assist developing countries in this field.

A commercial approach, with strong promotion, is considered to be an appropriate and effective information transfer mechanism. Identification of the market, based on the assessment of information needs and identification of information best suited to the different target groups at the national level, is a rational approach in development of information systems. The existing distribution of publications needs to be expanded to include universities, engineering colleges, and specialized libraries.

WHO regional information networks, which have adopted realistic information transfer mechanisms have proved their value; for example, the Pan American Center for Sanitary Engineering and Environmental Science (CEPIS) in Latin America, and the Centre for the Promotion of Environmental Planning and Applied Studies (PEPAS) in the Western Pacific Region. International donor support for such centres will be valuable in promoting such endeavours. Other forms of internationally-sponsored training networks for water and waste, like those at present receiving support from the World Bank and UNDP, may also prove to be successful.

7.2 Professional training

Curricula for the training of sanitary engineers, sanitarians, and other professionals in the institutions in developing countries must increasingly reflect the application of appropriate technology. Simplification of methods and their linkage to primary health care are consistent with the internationally adopted IDWSS Decade approach. The mechanisms to achieve these objectives are not yet clear and this area calls for greater emphasis during formal schooling or college training and better guidance in the early years of field practice of national professionals. Special attention must be given to the training of operational and maintenance staff; some progress has already been made, but more effort is required to extend the appropriate technology approach.

Universities in developing countries are not playing as active a role as they should in research and development of appropriate technology, or in the transfer of information to national agencies. While recognizing that this may not be entirely their fault in view of the present operational constraints and rigid regulations, it is vital that both incentives and opportunities are presented to faculty members to play a more active and innovative role in this endeavour. It is also important to train national librarians to become more effective in the collection, classification, and use of information.

7.3 Increasing public awareness

Public education on the importance of water and sanitation to health and on the proper use of facilities is not being given sufficient attention in developing countries. To achieve greater public awareness, appropriate forms of information and practicable information transfer mechanisms must be identified and tested. Successful results will bring about fruitful changes of attitude that will, in turn, help to increase the willingness of communities to participate to a greater extent. Schoolchildren and youths are very important target groups for such information, and their exposure to health education and demonstrations of the benefits of sanitation projects will assist in the evolutionary process of attitudinal change and may induce parental acceptance of, and desire for, improved household sanitation. It is important that both women and men are involved in attempts to improve public awareness of the impacts of sanitation. Women, being responsible for raising children, are especially susceptible and can be most effective agents in the promotion of safe water supply and sanitation.

7.4 Technical cooperation among developing countries

Special attention is drawn to the international collaboration that is fostered under the acronym TCDC. This collaboration aims to promote and strengthen the exchange of technical information and experience not only from developed to developing countries but specifically between the developing countries themselves. An information referral system has been established but so far it has not made sufficient impact in the water supply and sanitation sector. National agencies are therefore encouraged to explore the possibility of using this system in sharing their experiences, especially with neighbouring countries, and in exchanging visits for observation of local practices. The UNDP officer in charge of these activities, as well as WHO staff, can play an important catalytic role in developing this information referral system.

8. CONCLUSIONS AND RECOMMENDATIONS

(1) Appropriate water supply and sanitation technology is available to satisfy community needs and meet sanitary requirements. Nevertheless, in some places sociocultural factors are restricting the implementation of water supply and sanitation programmes. Some of these factors can be overcome through carefully planned educational, informational, and motivational

interventions particularly if these lead to increased community involvement.

(2) The provision of sanitation, in particular, is not receiving a reasonable level of investment and, in spite of the availability of low-cost systems, programme implementation is slow, mainly as a result of a lack of public awareness and the absence of health education. The training of field workers, to increase their awareness of available technology and the health benefits to be gained from sanitation, will assist in the promotion of programmes and contribute to their long-term success.

(3) Although effective and appropriate water supply and sanitation technology already exists, there is a need to adapt systems to suit local conditions and requirements, to reduce costs, and to take advantage of local resources. The major advance in recent years has been the innovative application of existing technologies, rather than the development of entirely new systems, but there are still opportunities for further improvement and innovation.

(4) Considering the limitations to resources available for water supply and sanitation in developing countries, primary emphasis should be placed on improving public health by means of wider service coverage, concentrating initially on basic needs rather than on the upgrading of existing adequate services. This should not be done, however, in a way that would undermine the public health safety of the services being provided. For this reason it would not be wise to design an intermittent piped water supply system for the sake of providing wider coverage. Such systems would encourage negative, or even hostile, public attitudes and would undermine public health safety through contamination with polluted groundwater. Ensuring full cost-recovery from the operation of existing urban water supply and sanitation systems is, in fact, one of the best ways of ensuring that the needs of the underserved low-income communities can be provided for.

(5) The Decade approach recognizes the advantages of complementary development of water supply and sanitation but little attention is being paid to this important objective in developing countries. Water services are being improved without apparent concern for the aggravation of wastewater disposal problems. Linking the developments of both services is the most rational

approach even when it results in some initial limitation in the coverage achieved by these services.

(6) It is not feasible to adopt a standard definition for "urban" and "rural" areas owing to the difference in outlook and administrative arrangements in different countries. Table 1 shows, however, that certain characteristics help to differentiate between such communities.

(7) Design criteria other than those affecting minimum health needs cannot be standardized or applied indiscriminately. In establishing appropriate criteria for design, account should be taken of the national coverage situation as well as technological, social, economic, financial, and institutional constraints. These factors will influence not only the selection of technology but also the rate at which water supply and sanitation coverage can be improved, and ultimately the magnitude of investment and the operation and maintenance needs.

(8) Although standardization of design criteria is not possible, it may be feasible to adopt national designs and construction standards so that a system can be replicated within a country or area, using modular systems for example. Standardization of this nature will help in achieving better selection of equipment, improved stock-keeping, and more reliable construction at considerable cost savings.

(9) In many places the application of appropriate water supply and sanitation technology may be hindered by unduly restrictive legislative controls and inadequate institutional arrangements. Governments should, therefore, be encouraged to review the legal frameworks, regulations, and codes relevant to the sector with a view to stimulating the use of appropriate technology.

(10) Further research and development with the participation of the private sector may prove to be fruitful, for example in the harnessing of wind power and solar energy. Information obtained from pilot projects of such developments should be more widely disseminated.

(11) In an effort to make better use of available low-cost technologies, governments should be encouraged to review their existing systems and investments in information transfer. They should also be invited to take advantage of the facilities available through the WHO reference centres and national collaborating

centres, as well as the facilities of the WHO regional environmental health centres, CEPIS in the Americas, PEPAS in the Western Pacific, and the Centre for Environmental Health Activities (CEHA) in the Eastern Mediterranean Region. The reproduction in developing countries of good-quality, low-cost publications, should be encouraged—in local languages wherever necessary.

(12) Results of project evaluations should be more widely distributed in the country concerned and among interested countries. This would help to avoid the repetition of costly mistakes and facilitate the application of improved systems.

(13) Universities and other training institutions in developing countries should play a more effective role than they have in the past in the transfer of information by introducing the use of appropriate technology into their curricula. They should concentrate on applied research and development of technology appropriate for, and adapted to, local conditions and needs. Those directing research in developing countries should take account of this in considering proposals and in the allocation of funds.

(14) To minimize the failure rate of water supply and sanitation systems in developing countries, more attention should be paid to operation and maintenance procedures during the planning and design stages; these matters should also be included in staff training programmes. Governments should be encouraged to evaluate their existing training programmes in the sector, with the objective of maintaining the level of skills among the work force.

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Annex 1

SPECIAL FEATURES OF RURAL WATER SUPPLY AND SANITATION PROJECTS

(1) Long-term projections (beyond ten years) of water demand for rural areas are unnecessary and unreliable in most cases.

(2) The absence, or low density, of industries reduces water demand and makes the quality of waste easier to deal with than in urban areas.

(3) Allowances may have to be made for animal water demand and, if applicable, for animal waste disposal in rural areas.

(4) The level of domestic water consumption in rural areas is much lower than in urban areas.

(5) In most rural areas, a piped water supply or water-borne sewerage may not be the most feasible solution. Other appropriate systems (e.g., protected bored wells or dug wells with handpumps) are more likely to be selected, at least in the early stages of national programmes.

(6) Water supply and sanitation services are likely to prove more practicable and more successful if dealt with through an integrated rural development approach. The provision of a safe water supply and basic sanitation are among the basic elements of primary health care and should thus be considered in this context.

(7) Self-help programmes must be carefully examined, and the availability of any assistance from such sources as the World Food Programme should receive full consideration in the feasibility studies.

(8) Rural areas might be served in conjunction with an urban water supply scheme if the rural community is within a reasonable distance of the urban centre.

(9) All rural water supply and sanitation schemes require special inputs for health education and community participation. Such inputs can be integrated into the general rural development programme or the primary health care activities.

(10) Institutional support for rural water supply and sanitation in rural areas requires special attention because it is far more difficult

to organize than in urban areas. A number of ministries may be involved, including ministries of health, agriculture, and rural development. It is, however, even more critical in rural areas to find the proper means to involve the local people more directly.

(11) Rural water supply and sanitation services are not likely to be as self-supporting as urban systems and thus subsidies will normally be needed. These projects must be justified as a "basic human need" to preserve human dignity and as a means of safeguarding public health; justification can also be made on economic grounds within the context of rural development.

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