Appropriate Methods of Treating

WATER AND WASTEWATER IN DEVELOPING COUNTRIES

Edited by

GEORGE W. REID

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PREFACE

This text has evolved over several years through the effort of a great many professionals from many countries. These are people who believe in the concepts of appropriate technology and in the importance of water and waste treatment to the development of the Second and Third Worlds.

The initial research, financed by The United States Agency for International Development (USAID), was a project under my direction on "Low Cost Methods in Water and Sewage Treatment." Using graduate students and some industrial contacts, the business of appropriate water and sewage technology in lesser developed countries was carefully cataloged, and the basic ideas of a predictive model were formulated. From this work and its several reports, thesis work of several students, and my own contribution, we developed a rather long working text called affectionately, "Le Book." The text was used in a series of five-day global workshops. The text and workshops were critiqued and evaluated. It was found that certain data were relatively unnecessary, and that additional information was needed, which I subsequently supplied.

Along the way, manuscripts and reports were reviewed by such international experts as Dr. Wilfredo Reyes (WHO/Indonesia), Dr. Abel Wolman (Johns Hopkins) and Dr. Hans Van Damme (Netherlands). I wrote papers for international meetings on the "Model," on "Consumers Acceptance," on "Economic Considerations," etc.

I supervised, compiled and contributed to "Le Book." The editing was done by Ms. Kay Coffee.

This text is composed of new material and material condensed from "Le Book," and was edited and compiled by myself. Those responsible for constructive inputs are identified in each chapter. The doctoral graduate students include: Clyde Arnold, at the University of Oklahoma; George Li, PhD, on the faculty at Taiwan; Richard Discenza, PhD, on the faculty at Northern Arizona University, Flagstaff; and S. Soetiman, PhD, at Bandung Institute of Technology. Dr. Huisman (Delft, Netherlands), Dr. Larry Canter (University of Oklahoma) and Dr. J. F. Malina (University of Texas) provided state-of-the-art papers on water and sewage. The technical work of Ms. Coffee and Ms. Townly, both PhD students, was greatly digested.

Without the help of these people and the USAID Project Officers Dale A. Swisher and Victor Wehman, "Le Book" would never have been written.

George W. Reid

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George W. Reid. School of Civil Engineering and Environmental Science, University of Oklahoma, Norman, Oklahoma.

A 1971-72 survey by the World Health Organization (WHO) of community water supply and excreta disposal conditions in developing countries revealed that nearly one-third of the world's population (over one billion people) have no adequate water supply, and only 0.8 percent of the total population of developing countries is served by sewage treatment facilities [1]. As a result of this survey the United Nations Second Development Decade goals included the supplying of all urban populations with water, either by house connections or by public standpipes, and the provision of reasonable access to safe water for one quarter of the population in rural areas by 1980. Based on achievements by 1975, percentage goals were increased to thirty-six percent of the rural population, and excreta disposal targets were established for the first time. However, despite great efforts, populations have increased more rapidly than new facilities can be installed.

In 1975, the "Global Workshop on Appropriate Water and Wastewater Treatment Technology for Developing Countries" was held in The Hague, Holland. This was a collaborative effort between the University of Oklahoma and the WHO International Reference Centre (IRC) for Community Water Supply. The objectives of this workshop were:

-to assess the state of the art and to identify the role that appropriate technology can play in the development of water supply and sanitation in developing countries;

-to formulate technical and organizational recommendations and to agree upon priorities for studies, projects or other activities; and

- to discuss the development of internationally coordinated programs and the operation mechanisms for implementing the activities planned as a result of the meeting.

In addition to confirming the WHO survey, the Global Workshop focused on the many types of failures in the planning and provision of water supply and sanitation in developing countries which result from imported technology. The Workshop emphasized the need for appropriate technologies consonant with local socio-economic conditions. Some of the factors which severely handicap programs to provide safe drinking water and efficient sewage disposal are:

- shortage of resources (including trained personnel and finances),

- lack of governmental support within the developing countries,

- inadequate institutional structures (insufficient organization and administration), and

- lack of local interest and acceptance of the project.

The Workshop's consensus was that water supply and sanitation must be considered an integral part of the development process, and overall national plans should be formulated. Each country should be urged to establish its own water resources agency to collect pertinent data and to plan with a regional approach rather than a case-by-case approach. Strong ties should be established between water agencies and universities. Efforts should be made to motivate governments to implement water supply and sewage schemes. Frequently, proper sewage treatment and excreta disposal have been given such a low priority that pollution control has been postponed until the problem was too great for a solution using available community resources. Hopefully, a national plan and greater governmental involvement would help to alleviate this problem.

The Workshop recommended, however, that it would be necessary to assist developing countries to improve their strategies for increasing the rate of rural water and sanitation coverage, if they were to be able to provide even the most basic water and sanitation services to all those who need them within any reasonable time frame. More international funds should be devoted to the rural sector and to low-income groups which are most in need of assistance. Although dispersed population are among that group which is in great need, actions to alleviate the situation could be made more effective if they were concentrated on groups such as nucleated units or villages.

The Workshop further suggested that when equipment or technology is supplied, it should be only after a means of supply for repair parts and maintenance equipment is known to be available. Many existing facilities are in bad condition due to poor selection of technology, inappropriate design, insufficient maintenance including preventive maintenance, a lack of spare parts, and a lack of trained personnel. Locally obtainable materials should be utilized whenever possible, and maintenance of equipment should be manageable by local people.

Experiences in Latin America, India, and elsewhere have shown that besides lower levels of technology, a high level of technology may also be useful in a developing area, where an advanced technology often may be applied and adapted using local materials.

Frequently, it has been the case that local professionals prefer to rely on a foreign consultant rather than risk a possible failure or introduce techniques based on their experience but without established records of performance. To encourage the use of lower levels of technology an effective approach seems to be the training of local engineers who in turn would train other local people. A "barefoot engineer" scheme analogous to the "barefoot doctor" concept is one approach.

Involvement of the people concerned from the beginning of a water supply or treatment project is important. Sometimes much persuasion and education are necessary to get people to use safe water. Local decision makers need to understand the basic principles of the various processes and support the ideas introduced. Ways to help bring this about are handbooks in simple language for laymen, pilot demonstration plants, short courses, and experimental plants connected with plants in operation.

Of utmost importance is the fact that groundwater should be given greater attention as a source of water supply because it usually does not require extensive treatment. Slow sand filtration has proven to be an effective treatment method in developing areas. Solution feeders are preferable to dry feeders in these locations because they are less expensive, more reliable and efficient and do not have to be imported. For flocculation and sedimentation all mechanical devices should be discouraged. It was emphasized that in summary, an appropriate technology is one which is accepted by the users and can be maintained by the community.

The importance of the quality and quantity of a water supply to human and economic health has been clearly demonstrated and has been the target of international development efforts in less developed countries (LDC's). Experience has shown that international investments have not been efficiently or effectively used where selection and use has been made of inappropriate technology. The genesis of this text was the recognition of these failures.

Developed countries (DC's) have generally supplied DC engineering which represented what was conceived to be the latest technology, and often LDC decision makers have wanted to be identified with the latest technology. Unfortunately, this has not always been the most appropriate choice for a particular situation. Engineers working on water supplies for low-income countries, have had "safe" water in mind as one objective. However, for the great majority of the world's population who live in rural communities or densely populated and unorganized urban areas with grossly inadequate access to safe water, there is little possibility that available financial and human resources would be able to give them the same high standards of water provision as that enjoyed by most people living in more developed areas. Because resources are very limited, it is necessary to examine closely the goals of water supply in order that what resources are available may be allocated in the most rational and effective manner. If a very high standard of water provision is unattainable, that does not mean there is nothing worth attempting. There are usually many improvements possible which, though falling short of the ideal, may have a very considerable impact on health or on other problems of the local community.

The approach presented here to aid in the resolution of this problem is: (1) to assist the consultant in using a systems approach and in identifying the major alternatives; (2) to devise ways to present the alternatives to LDC decision makers, thus facilitating diffusion; and (3) to assist LDC's in developing self-sufficiency in the selection or producing of appropriate technology. In 1973, the author undertook a study which resulted in a methodology to select appropriate low cost treatment methods for specific LDC sites. The methodology has been tested for user and consumer acceptance through exposure to engineering consultants, a global conference of LDC decision makers, international agencies, and financial institutions. During the study, it was necessary to acquire information on transfer failures, on the state of the art of LDC processes and LDC process costs, from literature and from on-site sources. Also undertaken were detailed studies of selected global sites as well as a historic study of the use of processes in DC's. It was found useful to develop a system of analytical tests that would be adequate for quality control and would be supportable in-country. These efforts resulted in several publications (See Appendix A) under the sponsorship of the United States Agency for International Development (USAID) and by the World Health Organization International Reference Centre for Community Water supply in the Netherlands. The resolution of the problem to date, has been to emphasize the training of water and sewage treatment plant operators. This is predoomed to defeat, because society as a whole must be able to support the facility. So rather than send WHO/PAHO consultants, etc., and conduct operator short courses, the emphasis should be on the education (and conversion) of the engineer process designer to the realities of appropriate technology and technology transfer.

In studying the problem of technology transfer, the engineer/client relationship was seen to be of critical importance:

> In the design of water supplies the choice of components, materials and dimensions is often governed by codes of practice or by professional conventions which engineers trained in the West too readily take for granted. And not only do these conventions tend to limit the adaptation of design to local needs, but like the WHO standards for water quality, they are suited to the needs or urban water supply in Europe rather than to village water supply in the tropics. Thus codes of practice may lead to the choice of unnecessarily expensive materials or equipment, or may discourage an engineer from improvising when the "correct" components are not available. Every village deserves the best possible engineering design for meeting all the immediate objectives, but given the kind of objectives which seem right for rural water supply, the "best possible" may not always look a good solution when measured against Western codes of practice.
>
> Some engineers are conscious of this dilemma, but feel that if they chose an unorthodox solution to a specific problem and the equipment failed and led to an outbreak of disease, they would carry an undue burden of responsibility; but if they had followed the "correct" design conventions, they would not be blamed [2].

The engineer working to bring technology to an LDC works in an alien, and in many ways, a very complicated environment. Pictorially (Figure 1), one can identify at least eight separable, frequently conflicting elements which he must take into consideration or deal with in his work. In his role of selecting appropriate technology, the engineer operates to meet national health standards and perhaps international standards. The plan must fit into larger water schemes; usually it must be designed without any sort of long-term physical data or national or local funding, and donors must be located. The environment must be able to support operation

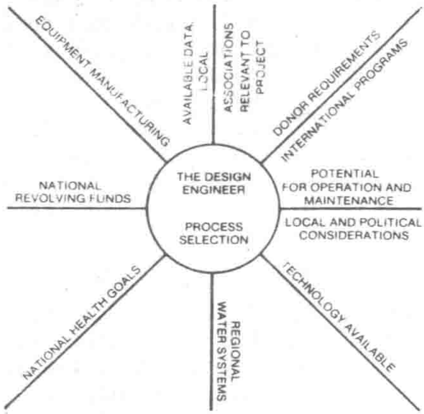

Figure 1. Conflicting elements that affect the engineer working in an LDC situation.

and maintenance (O & M), and local political and business interests exercise special requirements in many instances.

Another study by the author included research on the types of technology most often preferred by decision makers. The results showed that eighty percent of the decision makers what everyone else was currently using; fifteen percent wanted older, cheaper solutions; and only five percent would consider newer, innovative solutions. The decision maker was concerned about the present and the problems of the future, and problems associated with operation and maintenance (O & M) were considered to be for future decision makers. The engineer's interest, too, was shown to be limited to the immediate task of getting the plant built. This meant that neither the decision maker nor the engineer appeared to be interested in the ability of the site to keep the process going. In response to this common problem, there have been attempts to require the engineer to provide operational follow-ons for completed projects, such as including in the contract certain requirements for supervision and training for an initial period.

Quite often plants have been over-designed technologically. Financing has been based on capital costs only (ignoring O & M costs). Proper operation has been lacking and replacement parts and materials non-existent. If a piece of equipment failed, it was replaced rather than repaired. If enough parts failed so that the plant stopped functioning, a new plant was planned and built. One remedy sought by international agencies for this situation has been the provision of short-term training for operators and a more formal education in-country engineers.

It has often been the case that the in-country engineer has preferred to transfer design responsibility to an out-of-country expert, someone who would come in, execute the job, and leave. This has increased the difficulty of arriving at an appropriate selection of technology. In general, the international engineer would be unfamiliar with the local situation, involved in keeping people happy and in getting the job done, and little concerned about what happened after he left. The local engineer quite often would identify with out-of-country technology for reasons of prestige, and the client was in an insecure position, being approached by various equipment salesmen vying for contracts.

The following are nine specific problems associated with the use of expatriate advisers in developing countries:

1. The Promoters--These are people who present themselves as seasoned investors who sell grandiose projects to the government through contacts at high official levels. These schemes usually result in low returns or outright losses which are often borne entirely by the government. The solution offered is to "know your investors," admittedly a difficult task.

2. The Biased--Misallocation of resources may result because of biases in the experts' appraisal of investments. This problem can be solved by insuring that a careful economic feasibility study be carried out.

3. The Vacationers--This problem refers to foreign specialists whose professional interest is dominated by their desire to see the world. The nationals are often very sensitive to the degree of sincerity of the advisor and their attitudes and cooperation are influenced accordingly. Careful screening of candidates for foreign assignment is required to circumvent this problem.

4. The Impossible--This problem occurs when the advisor has been charged with a task that is too difficult to accomplish effectively, given the constraints under which he must perform. Recognition that the advisor does not possess all knowledge, especially as concerns intimate details of the country, and cooperation of resident specialists can alleviate this problem.

5. The Irrelevant--Donor countries may offer financial and technical assistance for a particular project that would be a misallocation of effort for the developing country. Development, in most cases, should be confined to a country's more obvious and immediate needs.

6. The Confusion--Too many advisors on the same project can cause confusion and result in inappropriate actions. The solution offered is for the developing country to be more selective and able in the use of foreign specialists.

7. The Out-of-Place--Technology of an advanced nation cannot be imposed upon the developing country unless it has been appropriately adapted to local conditions.

8. The Sophisticates--This problem arises when highly refined techniques of analysis or application are used when simpler procedures are in order. This is a special case of the previous problem category. A clear understanding of local issues and conditions will greatly aid the selection of appropriate techniques and procedures.

9. The Old Timers--After long tours of duty, some advisors may become out of date, complacent, and nonprogressive, and, therefore, ineffective in accomplishing the objectives. These characteristics do not apply to all "old timers" of course. [3]

The engineer/client relationship is important in technology transfer. There is also a need for an improvement in communication linkages between the LDC areas of need and sources of technology in DC's and LDC's. To develop in-country competence and self-sufficiency, it will be helpful to establish local and regional centers of technology. The extent to which LDC's use research and technology developed abroad is directly related to the "absorptive capacity" of these countries, that is, the readiness and capability of specialists and institutions to adapt, apply, and disseminate the technology. This capacity is important whether the technology is being transferred in the form of equipment, as technical information, or through exchanges of people. It embodies a capability to recognize the alternative technical approaches that are or could be available; to choose the technology that makes the most sense technically, economically, and socially; if necessary, to be able to adapt the technology to local conditions; to understand the direct impact and the more subtle long-term impacts of the technology; and to operate and maintain the technology.

Institutional orientation is often the decisive aspect of a developing country's capability to absorb technology. For example, there are a large number of LDC students at most DC universities. But are their courses of study truly of relevance to interests back home, or will they give further impetus to the brain-drain? While it is difficult for a United States university on an institutional basis to make sudden changes in the orientation of the content of its academic curriculum, individual professors and instructors can introduce elements into their courses which will enrich the experiences of developing country specialists and allow them to return home better prepared to face the realities of development. Many of our university professors maintain collaborative linkages with a large number of researchers abroad. The substantive aspects of those linkages, exchange of technical reports and joint research efforts, can do much to influence the orientation of research activities in developing countries.

It is difficult for a country that does not itself possess a reasonable number of trained scientific and technical personnel to know what usable technology exists elsewhere, to understand it, to adapt it to the country's special needs or peculiar conditions, to repair and maintain the necessary equipment, or indeed to operate it. If a country builds up its own scientific and technical capacity, it is in a much better position to utilize what exists elsewhere. Lack of appropriately trained persons is often an obstacle to the wider application of technology that is already known and to some extent used in a country. In addition, each country is better able to hold its place in international competition if it has the capacity itself to introduce innovations (new products or less costly methods of production) based on existing technology.

In the chapters which follow an attempt is made to describe an ordered method of selecting for a particular site and at a particular time, the most appropriate technology from those available in the LDC's as well as in the DC's. To develop such a scheme it was necessary to select certain limits. In this instance, the concern is drinking water and wastewater for organized communities (villages, towns, or cities, extending from the smallest nucleated settlement to perhaps all but the very large LDC cities which usually can afford water and wastewater treatment and have available a variety of high level expertise). This is not to say that rural areas without community systems are not important in LDC's, but certain limitations must be made, and as dispersed rural areas become nucleated, nonstructural systems of water supply and waste disposal or treatment are of special interest. It is for this reason that a management system of on-site processes is also examined.

There is a need to differentiate between that which is nucleated and that which is not, as concepts of community differ, particularly among professions (such as engineers, ecologists, sociologists, health workers, or economists). It is proposed here that a nucleated settlement begins at or above that population concentration level where there exists a physical water system and an associated managerial system. In general, the management system in a nucleated settlement will no longer be a volunteer operation, and this breakpoint occurs at a population of about 300 or more. At a higher population level of about 3000 persons, piped water becomes cheaper than unpiped water [2]. Piped water requires a distribution system and a higher level of technology than does a system of unpiped water. Population density is a significant factor in determining the cost of a piped system. For a piped system to be preferred on a cost basis, the population density should be about 1.7-2.0 people/acre or more. (Figure 2)

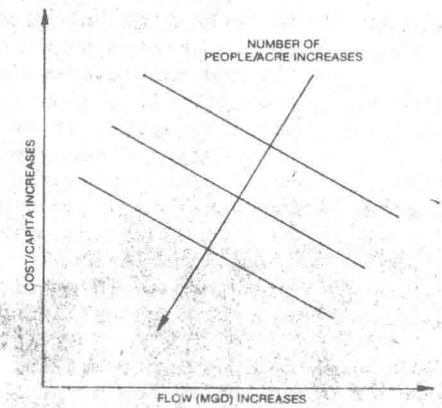

Figure 2. Effect of population density and economy of scale on unit cost of piped water.

In LDC settlements with a population of less than about 300, the technology of concern will be related to protection of the supply, provision of pumps, storage, and treatment, all of which will probably be manageable on a local, volunteer manpower basis. There is no room for sophistication. There is usually no liquid sewage and no water oriented industry. On the other hand, in a nucleated settlement with a system of piped water, unit use will be greatly escalated and benefits expanded.

In a non-nucleated situation, health is usually protected through supply protection, not through treatment. With nucleated settlements, the settlements which are of primary concern is this text, larger volumes of water are usually involved, and treatment and distribution will be factors of importance. Also, there is the potential of a considerable health risk because of the volumes of wastewater produced and the possibility of pollution of raw supplies by the effluents. Water and sewage treatment begin to be of real concern at a population level of 2000 to 3000 people. Consideration is also given in this text to a special case of the low density settlement, where on-site sewage disposal or treatment is used or water distribution is accomplished through a vending system, and a managerial system is required.

In this text, the primary concern is with a safe domestic supply of water and disposal of wastewater in LDC cities and towns. (not necessarily LDC countries, could be less developed area in USA for example.) The entire process could involve technologies ranging from a dam and intake, pipes and pipelines, to treatment and distribution followed by sewerage systems, treatment, and discharge. However, the main emphasis here is limited to treatment with the other components being left for examination by other interests.

The selection methodology is described in Chapter II. It involves the systems approach and aggregate modelling. The systems approach permits the analyst to look at various interrelationships and decision options at one time. Aggregation models use attributes expressed as averages, such as the level of education, the age, or the state of health of an average but non-existent representative of a population. For example, the average United States male might be described as a person who is five feet eleven inches in height, weighs 170 pounds, earns $14,000 per year, and uses two liters of water and 2,500 calories per day. The attributes for LDC modelling must be representative and must be based on available data on the LDC site either obtained directly or through the aid of a surrogate. Judgment in application is absolutely necessary.

Formally, the selection method includes the following components:

1. model: a symbolic representation of the problem;
2. metrics: specific goals such as parts per million (ppm), biochemical oxygen demand (BOD), and Most Probable Number (MPN);
3. alternative solutions: different processes or combinations of processes;
4. validation and diffusion.

In developing the methodology, it was necessary to describe sites and processes, identifying their efficiencies, costs, and manpower requirements. Resources had to be identified and goals and quality standards articulated. A system of socio-economic site classification had to be devised based on aggregate attributes of the site. In the use of the selection process the methodology proceeds as in Figure 3.

Table 1 presents a suggested classification of levels of economic growth in terms of gross national product per capita. This is related to the socio-economic system of site classification used in the methodology described above. There are several world agencies concerned with development that are attempting to provide people with opportunities for a better life. Although economic growth is an ultimate objective in development, the essence of the development process is human development. Modern concepts of development closely interrelate economic and social activities; they are inseparable and of equal importance. Social development deals with education, health, welfare, and public utilities.

Because of the desire to shorten the time needed for development, as compared to the time taken by countries such as the United States, Canada, and Australia, a great deal of attention is being paid to the selection of the most effective development investments among the many choices which are possible. The basic criterion, in most cases, is the economic return to the country concerned, and expenditures for services such as public health, malaria control, hospitals, and water resources must compete for priority with numerous other investment opportunities in fields such as transportation, agriculture, industry, and education.

In the past, health services have been promoted on the basis of their social rather than their economic benefits. Recognizing the current emphasis placed on economic development, the World Health Organization and the World Bank have accepted the impracticability of financing public health projects on a wide scale based on social benefits alone. However, there is a serious lack of reliable information on the relationship between the health and economic development. In accordance with modern theories of economic development, capital investment in public waste treatment and water supply, like the investments in malaria eradication or public health in general, should be considered as part of the social -overhead capital needed to develop and maintain a society.

The environment in which one attempts to make a selection of appropriate technology for water or sewage treatment has been described, and a methodology based on the systems approach and an aggregate model suggested.

The technological development process, which was in effect a revolution, enabled more people to be supported at a higher standard of living. Unfortunately, this process did not develop uniformly throughout the world. Therefore,