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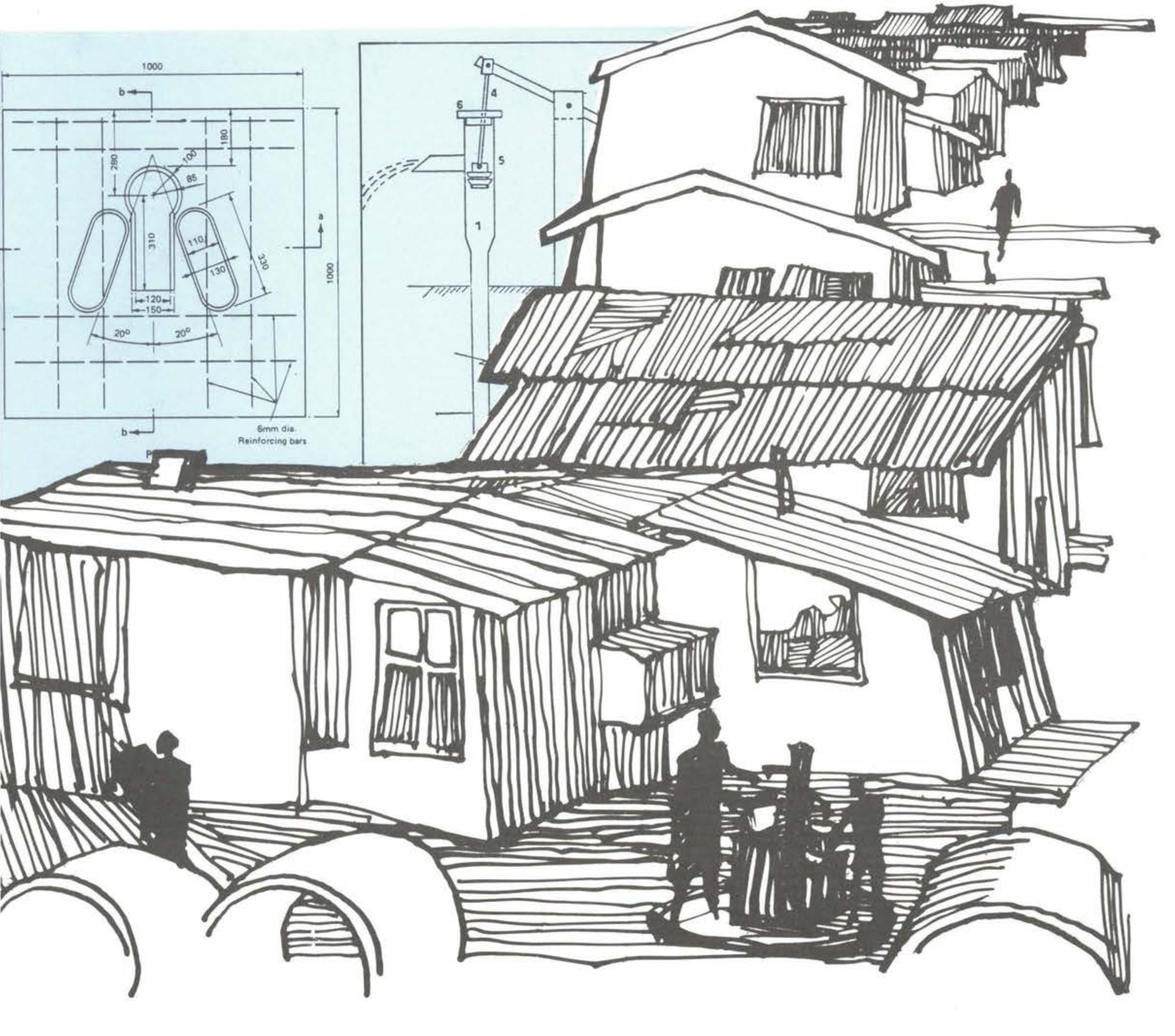
# Appropriate Technology for Water Supply and Sanitation

## Technical and Economic Options

by John M. Kalbermatten, DeAnne S. Julius, and
Charles G. Gunnerson

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A Contribution to the International Drinking Water Supply and Sanitation Decade

Volume 1

# APPROPRIATE TECHNOLOGY FOR WATER SUPPLY AND SANITATION:
# TECHNICAL AND ECONOMIC OPTIONS

Transportation, Water, and Telecommunications Department

The World Bank

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# A B S T R A C T

This paper reports technical, economic, health, and social findings of Research Project RPO 671-46, "Appropriate Technology for Water Supply and Waste Disposal in Developing Countries." The project identified a number of technologies less costly than waterborne sewerage, yet able to provide the same health benefits, socially and environmentally acceptable to the user. The project reviewed technologies, social/behavioral factors, economic and financial aspects, suggested technical improvements and new applications for traditional technologies, and developed selection criteria and demonstrated the feasibility of staging sanitation sequences to match demand for improvements reflecting user aspirations and rise in socioeconomic status. This report discusses the program planning necessary to implement technologies available to provide socially and environmentally acceptable low-cost water supply and waste disposal.

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## PREFACE

Over the past decade, the focus of development planners on economic growth has broadened to include a parallel concern with the distribution of the benefits made possible by that growth. In his address to the Board of Governors of the World Bank at the Bank's 1980 annual meeting, Mr. McNamara reiterated that, in order to achieve the twin objectives of economic growth and the eradication of absolute poverty, countries must do two basic things: assist the poor to increase their productivity and assure their access to essential public services.

Among these essential public services are water supply and waste disposal. It has become apparent, however, that development projects including water and sanitation projects or projects components must be specifically designed to reach the urban and rural poor if the poor are to be provided with services that they can afford and that meet their needs.

In particular, sewerage--the conventional method of human waste disposal in the developed countries--requires massive investments of both foreign and local capital that are generally not available in the developing nations. In acknowledgement of the limitations of traditional solutions, the World Bank in 1976 launched a 2-year research project entitled "Appropriate Technology for Water Supply and Waste Disposal in Developing Countries."

The objective of the project was to identify and evaluate alternative sanitation technologies for their potential to meet the needs and match the resources of project beneficiaries. To accomplish this, the health, social, institutional, as well as the technical and economic aspects of the various technologies had to be considered. The findings of the overall project are being issued in a collection of publications entitled Appropriate Technology for Water Supply and Sanitation, of which this report is Volume 1. Other volumes in this series are as follows:

(Vol. 1a) - A Summary of Technical and Economic Options

(Vol. 2) - A Planner's Guide, by John M. Kalbermatten, DeAnnes S. Julius, Charles G. Gunnerson, and D. Duncan Mara (a condensation of Appropriate Sanitation Alternatives: A Planning and Design Manual, forthcoming from Johns Hopkins University Press)

(Vol. 3) - Health Aspects of Excreta and Sullage Management-- A State-of-the-Art Review, by Richard G. Feachem, David J. Bradley, Hemda Garelick, and D. Duncan Mara (a condensation of Sanitation and Disease: Health Aspects of Excreta and Wastewater Management, forthcoming from John Hopkins University Press)

(Vol. 4) - Low-Cost Technology Options for Sanitation--A State-of-the Art Review and Annotated Bibliography, by Witold Rybczynski, Chongrak Polprasert, and Michael McGarry (available, as a joint publication, from the International Development Research Centre, Ottawa, Ontario, Canada)

(Vol. 5) - Sociocultural Aspects of Water Supply and Excreta Disposal, by Mary Elmendorf and Patricia Buckles

(Vol. 6) - Country Studies in Sanitation Alternatives, by Richard A. Kuhlthau (ed.)

(Vol. 7) - Alternatives Sanitation Technologies for Urban Areas in Africa, by Richard G. Feachem, D. Duncan Mara, and Kenneth O. Iwugo.

(Vol. 8) - Seven Case Studies of Rural and Urban Fringe Areas in Latin America, by Mary Elmendorf (ed.)

(Vol. 9) - Design of Low-Cost Water Distribution System, Section 1 by Donald T. Lauria, Peter J. Kolsky, and Richard N. Middleton; Section 2 by Keith Demke and Donald T. Lauria; and Section 3 by Paul B. Hebert.

(Vol. 10) - Night-soil Composting, by Hillel I. Shuval, Charles G. Gunnerson, and DeAnne S. Julius.

(Vol. 11) - Sanitation Field Manual, by John M. Kalbermatten, DeAnne S. Julius, Charles G. Gunnerson, and D. Duncan Mara.

(Vol. 12) - Low-Cost Water Distribution-- A Field Manual, by Charles Spangler

The more complete, book versions of volumes 1, 2 and 3 are forthcoming -- under the series title "World Bank Studies in Water Supply and Sanitation" -- from the Johns Hopkins University Press (Baltimore and London).

Additional volumes and occasional papers will be published as ongoing research is completed. With the exception of volume 4, all reports may be obtained from the World Bank's Publications Unit.

The main purpose of this volume is to summarize the technical, economic, health, and social findings of the research, and to discuss the aspects of program planning necessary to begin implementation of the findings. It is, therefore, directed primarily toward planning officials and advisors for sector policy in, and for, developing countries. Although the focus is primarily on sanitation options (because water supply technology is better known and understood), some information on levels of water service is included since water use is a determining factor in waste disposal. Technical details and designs are presented in Appropriate Technology for Water Supply and Sanitation Alternatives : A Planner's Guide.

The findings and recommendations of this appraisal are based on surveys of relevant literature (see Feachem and others, Sanitation and Disease, and Rybczynski, Polprasert, and McGarry, Low-Cost Technology Options), an evaluation of sociocultural factors (see Elmendorf and Buckles, Sociocultural Aspects of Water Supply), detailed field studies (see Kuhlthau, Country Studies, and Lauria, Kolsky, and Middleton, Low-Cost Design), and the personal observations, experience, and advice of colleagues in the World Bank and other institutions. Because the list of contributors is so large, only a few can be mentioned. We wish to acknowledge, in particular, the support given to this project by Yves Rovani, Director of the Transportation, Water, and Telecommunications Department at the time the research was done (who is currently Director of the Bank's Energy Department), and the valuable review and direction provided by Kim Jaycox, the Chairman of the Project Steering Committee. Advice and expertise in particular areas were freely provided by Jerry Warford and Harold Shipman, two of the early supporters of the project, and by William Cosgrove, Art Bruestle, Fred Hotes, Johannes Linn, Ragnar Overby, John Courtney, and Charles Weiss. In addition, David Bradley and Richard Feachem of the Ross Institute of Tropical Hygiene, Duncan Mara of the University of Leeds, Gilbert and Anne White of the University of Colorado, and Mike McGarry of the International Development Research Centre helped us considerably in shaping our approach to the health and social aspects of the study and in developing the algorithm for technology selection.

Special thanks are due to the field consultants whose tireless efforts to obtain and evaluate information under diverse, and sometimes difficult, conditions made possible our empirical analysis. Their individual contributions are acknowledged in the Appropriate Technology publications for which they were responsible, but we would like to extend our particular thanks to Kenneth O. Iwugo, who was responsible for the case studies of Nigeria, Ghana, and Zambia; Ng Kin Seng, who did the work on Taiwan and Malaysia; S.S. Soesanto for the excellent work of her team in Indonesia; Dong Min Kim for his Korean study; Mary Elmendorf and Chuck Pineo for their work in Nicaragua; Samir El Daher and Beshir Mohammed El Hassan who undertook the Sudan study; Shohei Sata and Katsuyoshi Tamono of Nihon Suido Consultants for their important work on the Japanese cities; Raphael Rodriguez, who undertook the work on Colombia; and Mike Blackmore and his team in Botswana. In addition, Mei-Chan Lo and Robert T.C. Lee, both of Taiwan, were instrumental in helping us evaluate the potential for wider replication of the interesting intermediate technologies for sanitation that were studied in their country.

This report could not have been produced without the dedication and cooperation of the secretarial staff: Margaret Koilpillai, Julia Ben Ezra, and Susan Purcell. David Dalmat's and Sylvie Brebion's efficiency in coordinating the graphics and other aspects of this publication with those of the other volumes in the "Studies in Water Supply and Sanitation" series is greatly appreciated. Acknowledgment is also made to Bank's Art & Design Unit for the charts and maps.

Finally, we owe a special thanks to our spouses--Nelly Kalbermatten, Ian Harvey, and Betty Gunnerson--who endured the extra travel and long hours that went into this research project.

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# CHAPTER I

## AN OVERVIEW

A convenient supply of safe water and the sanitary disposal of human wastes are essential ingredients of a healthy, productive life. Water that is not safe for human consumption can spread disease; water that is not conveniently located results in the loss of productive time and energy of the water carrier; and inadequate facilities for excreta disposal reduce the potential benefits of a safe water supply by transmitting pathogens from infected to healthy persons. Over fifty infections can be transferred from a diseased person to a healthy one by various direct or indirect routes involving excreta.

### Water Supply and Sanitation in Developing Countries

Coupled with malnutrition, these excreta-related diseases take a dreadful toll in developing countries, especially among children. It is invariably the poor who suffer the most from the absence of safe water and sanitation because they lack not only the means to provide for such facilities but also the information on how to minimize the ill effects of the unsanitary conditions in which they live. As a result, the debilitating effects of endemic disease lower the productive potential of the very people who can least afford it.

#### Dimensions of the Problem

To understand the magnitude of the problem, one only need consult the data collected by the World Health Organization (WHO) in preparation for the United Nations Water Conference (Mar del Plata, Argentina, Spring 1977). These rough estimates show that only about one third of the population in developing countries have adequate sanitation services; that is, about 630 million out of 1.7 billion (thousand million) people.1/ Population growth will add to this figure in the 1980s, another 700 million people who will have to be provided with some means of sanitation if the goal of the International Drinking Water Supply and Sanitation Decade--adequate water supply and sanitation for all people--is to be achieved. A similar number of people, about 2 billion, will require water supply by the same date.

One of the fundamental problems in meeting this goal is the high cost of conventional sanitation services. General estimates based on 1978 per capita costs indicate that up to $60 billion would be required to provide water supply for everyone and from $300 to $600 billion would be needed for sewerage.2/ Per capita investment costs for the latter range from $150 to $650, an amount totally beyond the ability of the beneficiaries to pay.

In industrialized countries, users and responsible officials have come to view the flush toilet as the absolutely essential part of an adequate solution to the problem of excreta disposal. This technology, however, was designed to maximize user convenience rather than for health

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1. Excluding the People's Republic of China.

2. All dollar figures in this study are in 1978 U.S. dollars. See chapter 3 for their derivations.

benefits. The former may be an important objective in developed countries, but it has a lower priority in most developing countries. The problem facing developing countries is a familiar one: high expectations coupled with limited resources. Decision makers are asked to achieve the standards of convenience observed in industrialized countries, but--given the backlog in service, the massive size of sewerage investments, and the demands on financial resources by other sectors--they do not have the funds to realize this goal.

At the present time, the first priority of excreta disposal programs in developing countries must be human health; that is, the reduction and eventual elimination of the transmission of excreta-related diseases. This health objective can be fully achieved by nonconventional sanitation technologies that are much cheaper than sewerage. The goals for the International Drinking Water Supply and Sanitation Decade intentionally do not specify sewerage, but call for the sanitary disposal of excreta--leaving the chosen method to the discretion of individual governments. Similary, objectives of the Decade include an adequate supply of safe water, but do not specify the methods to be used to achieve the goals. The challenge of providing as many people as possible with the required facilities is to find techniques to achieve these objectives with the resources available.

## The Constraints

The principal constraints to the successful provision of sanitation facilities in developing countries are lack of funds, lack of knowledge about nonconventional sanitation technologies, and weak institutions with few trained personnel. There is no foreseeable way that waterborne waste disposal, with an average investment cost of around $300 per person, can be made affordable in countries in which annual per capita income averages less than that amount. In addition, and implicit in the decision to provide sewerage, is a decision to provide a water connection to each house. About 40 percent of the water from this connection will be used for no essential purpose but to flush away wastes. Clearly lower-cost solutions have to be found for the majority of people.

The lack of interest in sanitation technologies other than sewerage is in part because of the standardized education of most planners and engineers in developing countries. Engineers are trained in sophisticated (and intellectually stimulating) advanced technology that is, in a sense, self-perpetuating: sewer systems lead to high water consumption and the attendant problems of source development and effluent disposal. Planners feel they have to press for sewerage because without it public health will not be secure. Yet sewer systems in developing countries are not well maintained. Sewage treatment works commonly discharge effluents in a condition little better (and in some cases worse) than the incoming sewage. In any case, current plant design concentrates on undoing the environmental problems waterborne collection has created rather than on health maintenance through pathogen removal. There is, therefore, little realistic basis for the commonly held view that Western sanitation techniques are the appropriate solution for developing countries. Rather, re-education of engineers to design for maximal health benefits, and to consider the whole range of available technologies, is essential.

Most municipalities in developing countries have difficulty attracting and retaining well-trained staff, and in consequence municipal services suffer. The potential for self-help in conventional sewerage is, however, minimal. The adoption of low-cost technologies can capture the strong desire of most people to improve their living conditions and this motivation can be put to good use. But, this implies that the municipality must become an active promoter and educator because experience makes it abundantly clear that technologies imposed on people without adequate consultation are likely to fail or go unused.

## A Glimpse of a Solution

Given these constraints, it is not suprising that levels of sanitation service in developing countries have remained low. A major effort is needed to identify and develop alternative technologies for sanitation that are appropriate to the conditions in developing countries and designed to meet health requirements at a cost affordable to the user. Clearly, the solutions also must reflect the communities' preferences.

The identification--and design--of appropriate excreta disposal systems does not require the invention of new processes or devices. Rather, it calls initially for a review of the historical development of the present technology, a re-examination of the decisions leading to sewerage, and the design of improvements to eliminate problems that caused the abandonment of earlier, low-cost solutions. Sewerage was not a grand design achieved in one giant step but is the end result of progressively sophisticated solutions. It took industrialized countries over a hundred years to achieve their present status in a close matching of needs and the economic capacity to take care of them.

What is needed in the developing world is a sequence of sanitation improvements, designed from the outset to provide maximum health benefits while minimizing costs over the long run. If sanitation facilities are to be used, each step of the sequence must consider consumers' preferences, financial resources and customs of personal hygiene. In fact, sequenced sanitation is likely to be more successful than the immediate installation of sewers has been because it allows the user to progress as he sees fit, to whatever level of convenience he desires and at his own speed.

Fortunately, low-cost alternatives to sewerage exist and work well. When properly constructed and maintained, they provide all the health benefits of sewerage and have fewer adverse environmental effects. They may not be applicable to parts of the dense, westernized, metropolitan centers of the developing world, where sewerage may remain the most appropriate technology, but they are ideally suited to rural areas, small towns, and metropolitan fringe areas, which closely resemble the environment for which they were originally developed. Their failures are usually attributable to poor design, inadequate education of users or lack of maintenance--problems that plague sewerage systems as well but can be overcome in developing countries if increased emphasis and attention are given to improving health and sanitation.

## The Use of Appropriate Technology

### An Operational Definition

A large body of literature has developed in recent years on the choice of appropriate technology, particularly in the manufacturing and agricultural sectors. The surge of interest in this topic dates from the publication of E.F. Schumacher's book Small Is Beautiful in 1973.1/ Before 1973, the theory of technological choice was written about mostly by economists and was concealed in technical jargon such as "factor proportions" 2/ or "induced bias." 3/ Schumacher's book served to bring some of the basic ideas into public view.

There is no concise and universally correct definition of technological appropriateness. The standards for determining the appropriateness of technology are related to the developmental goals of the country making the choice and to the circumstances of the technology's use. The operational definition used in this study is really an abbreviated description of the process of determining which technology is appropriate in a particular case. An appropriate technology is defined as a method or technique that provides a socially and environmentally acceptable level of service or quality of project with full health benefits and at the least economic cost.4/ This "definition" immediately provokes questions. How does one judge social or environmental acceptability? This study looks in detail at the process of identifying appropriate sanitation technology from the technical, economic, and social perspectives. The basic philosophy is that only those technologies that pass all three tests are appropriate. The operational definition incorporates long-run benefits and costs by using life-cycle costing and paying particular attention to the technical potential for upgrading each alternative as the incomes and aspirations of the users grow over time.

### The Selection Process

The process of selecting technology begins by identifying all of the technological alternatives available for providing the goods or service desired (in this case, sanitation). Within that set of possibilities there will usually be some technologies that can be readily excluded for technical,

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1. E.F. Schumacher, Small is Beautiful (New York: Harper and Row, 1973).

2. R.S. Eckaus, "The Factor Proportions Problem in Undeveloped Areas," American Economic Review, vol. 45 (September 1955), pp. 539-65.

3. C. Kennedy, "Induced Bias in Innovation," Economic Journal, vol. 74 (September 1964), pp. 541-47.

4. A more rigorous definition would be the technology for which the net present value of the stream of health and environmental benefits, subject to a constraint on social acceptability, is maximized. The difficulty of quantifying health and environmental benefits, however, prevents such a definition from being operationally useful. In effect, the definition proposed here is a sequential version of the more rigorous process of simultaneous solution.

health, or social reasons. Furthermore, some technologies may require institutional support that is infeasible in the given social environment. Once these exclusions have been made, the range of technically and socially feasible alternatives that provide full health benefits remains. For these technologies, cost estimates are prepared that consider their real resource cost to the economy. As described in Chapter 3, this may involve adjustments in market prices to counteract economic distortions or to reflect developmental goals such as the creation of employment.[1] Least-cost solutions for each technology are determined. On the basis of these economic costs and discussions with government planners, financial costs are prepared for all least-cost solutions. Those alternatives clearly outside the bounds of affordability for consumers are excluded. Because the benefits of various sanitation technologies cannot be quantified, it is impossible for the economist to do more than exclude various alternatives. The final step in identifying appropriate sanitation technology must rest with the eventual beneficiaries. Those alternatives that have survived technical, health, social, and economic tests are presented to the community with their corresponding financial price tags, and the users must decide the level of service they are willing to pay for.[2]

How the technical, health, social, and economic aspects of technological choice are actually coordinated is shown in figure 1-1, although the stages in the figure should not be interpreted too literally. A technology may fail technically if the users' social preferences militate against its proper maintenance. The economic cost of a system is heavily dependent upon social factors such as labor productivity as well as upon technical parameters. Because of these relations between the various boxes in figure 1-1, there must be a close working association among the different actors in the planning process. For simplicity, it is assumed that separate individuals or groups are responsible for each part, although in practice responsibilities may overlap.

Comparison with the Traditional Approach

The process above contrasts with that of the typical feasibility study. The conventional team conducting feasibility studies is heavily weighed with engineers. It may contain a financial analyst but rarely an economist and, almost never, a behavioral scientist. The alternative technologies considered are usually only a small subset of the group discussed in this report, and in many cases the terms of reference of the

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1. An ideal analysis would go beyond economic costing to include income-distributional factors by calculating social costs. Distributional weights, however, cannot be taken into account explicity in this analysis because benefit quantification is not possible. This is not a significant limitation because the major concern of this study is to identify technologies that are specifically appropriate for the rural and urban poor. The study's case studies themselves were chosen to embody this concern.

2. Because the consumer is presented with financial rather than economic costs, it is important that economic cost ranking of the technologies be preserved in deriving financial costs. This may preclude, for example, full construction grants for all technologies regardless of relative construction costs.

study (written by other engineers) limit the selection to waterborne sewerage with several collection configurations and treatment alternatives. Thus the selection process described in figure 1-1 is short-circuited and moves directly through technical criteria to final design. The conventional study team then prepares estimates of financial costs and writes up its report.

The main problems with this customary process are obvious from a comparison with the methods set forth in this study. In the conventional procedure, the most appropriate technologies may never get considered. No checks are made to ensure that the technical solution designed and costed is socially acceptable. By excluding a meaningful economic comparison, the usual method makes no guarantee that the solution offered is the one of least cost for the economy. The decision makers are presented at the end with a proposal that has not taken into account their own economic priorities or the ability to pay of their constituents, the ultimate beneficiaries.1/

The framework suggested in this report for the identification of appropriate technologies is probably more time-intensive than that of traditional feasibility analysis. It also requires the recruitment of additional personnel. Thus a clear case must be made for its superiority in choosing appropriate technologies that the cost of choosing an inappropriate technology is sufficiently high to warrant a more costly selection process. The case studies of sanitation systems in thirty-nine communities in nineteen countries, which form the basis of this report, lead us to believe that there is a very high cost both in terms of wasted resources and in poorer community health associated with the imposition of inappropriate sanitation technologies. Part One of this appraisal presents the detailed findings of the community studies.

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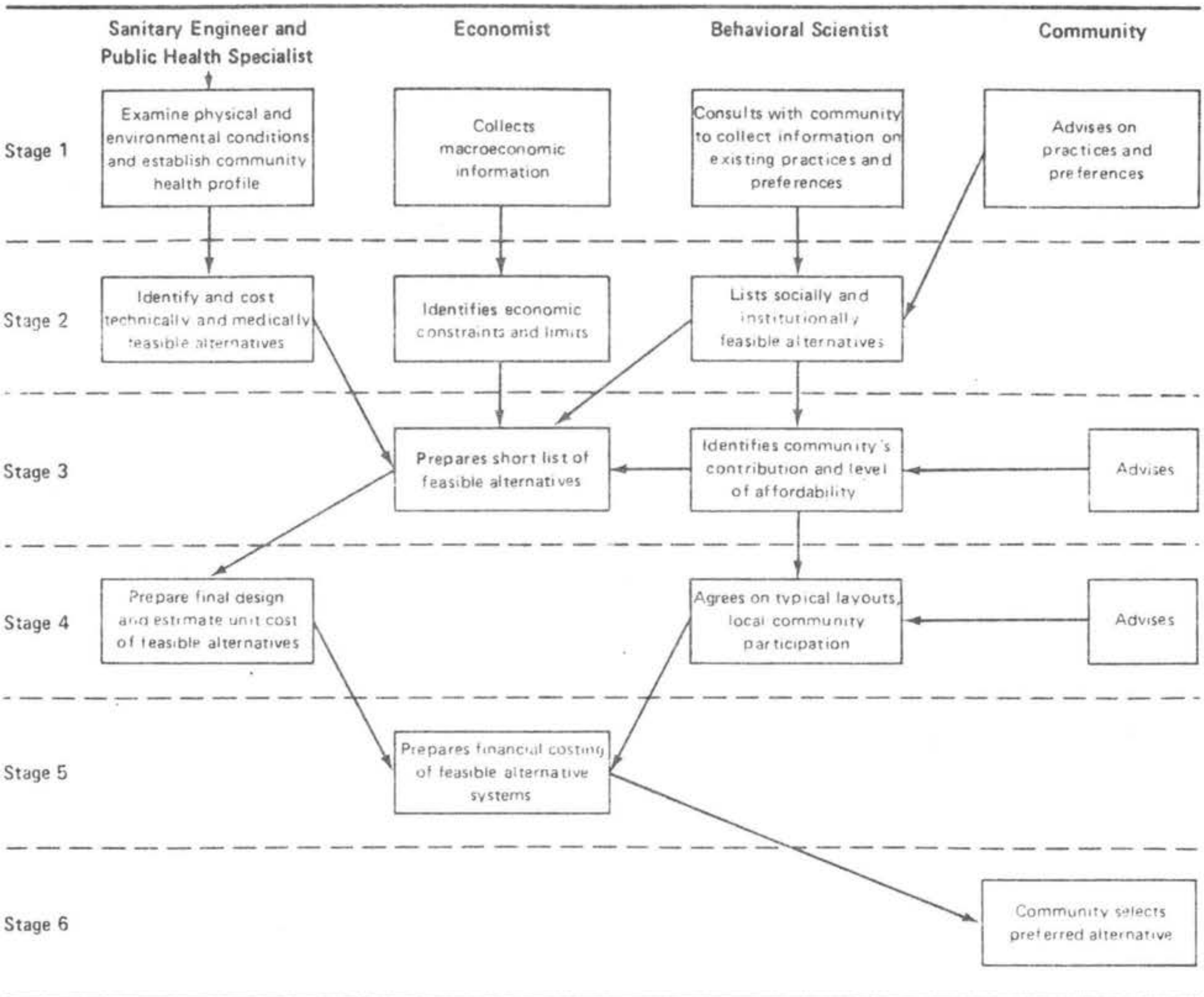
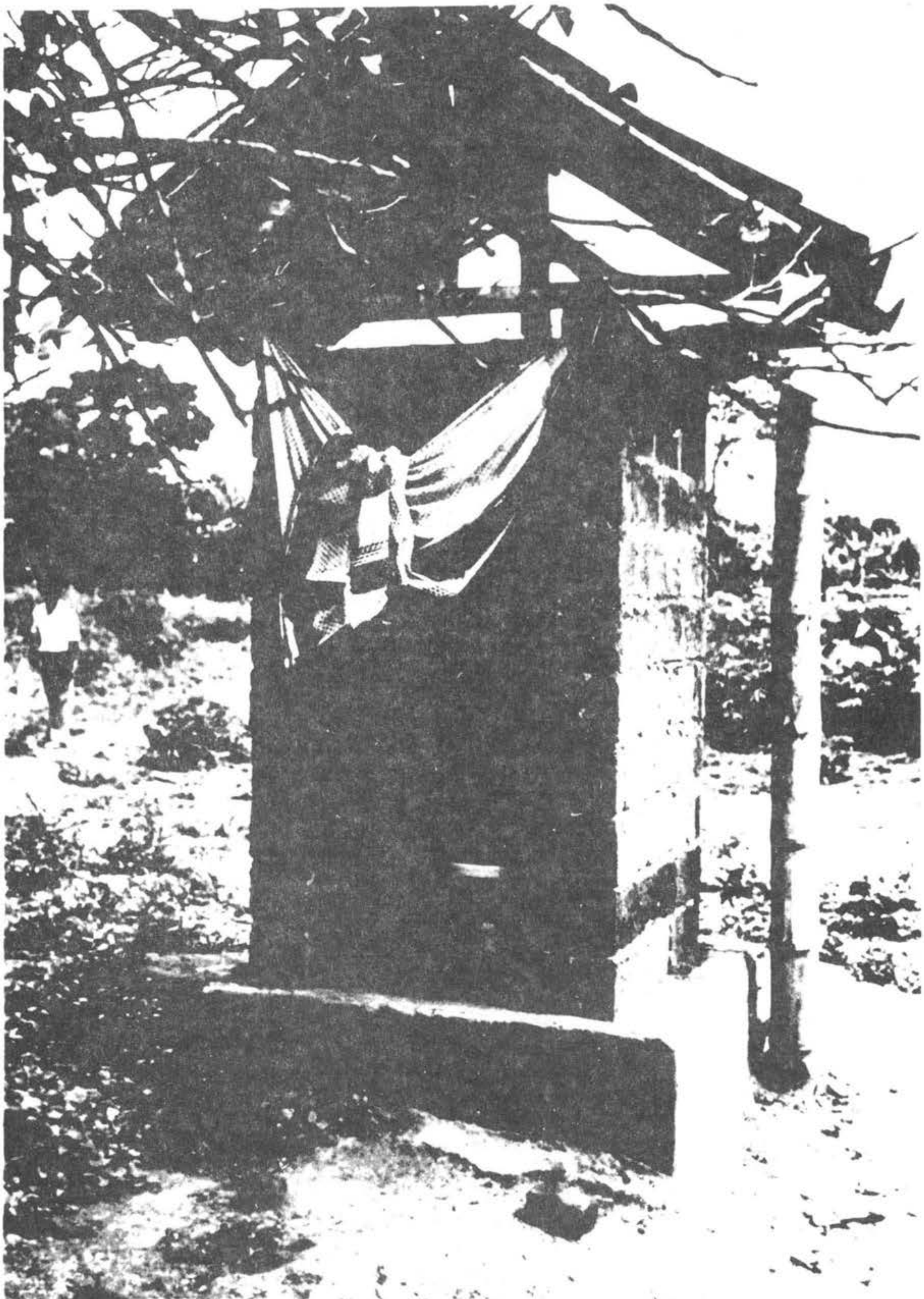
1. Blame should not necessarily be placed on the consulting firms who prepare such conventional studies, however. Often they are guilty of no more than the following of current practice in a highly competitive field and they must work within the constraints of their terms of reference. A number of firms, in fact, are already implementing some of the recommendations of this report and routinely use multidisciplinary teams in their work. The obstacles to the choice and adoption of appropriate technologies are discussed in Chapter 6.

**Figure 1–1. Recommended Structure of Feasibility Studies for Sanitation Program Planning**





A pour-flush toilet in Colombia
WORLD BANK PHOTO, 1979

# PART ONE

## ANALYSIS OF FIELD STUDY RESULTS

# CHAPTER II

## TECHNICAL AND ENVIRONMENTAL ASSESSMENT

Investigations of sanitation systems on sites in thirty-nine communities around the world have provided a wealth of practical design and operational data upon which to base a technical assessment of various sanitation alternatives. Although many variations of similar systems were observed, this chapter classifies all of the technologies studied into five types of household systems and four types of community systems. The cost and health implications of the technologies are presented in the following two chapters.1/ For a generic classification of the various sanitation systems, see figure 2-1.

### Household Sanitation Systems

Pit latrines, pour-flush toilets, composting toilets, aquaprivies, and septic tanks for use in individual homes are the major types of household sanitation systems. The distinguishing feature of these, compared with the community systems discussed in the next section, is that they require little or no investment in facilities outside individual homesites.

Pit latrines. By far, the most commonly observed technology around the world, particularly in rural areas, is the pit latrine (figure 2-1, no. 3). In its most elementary form, a pit latrine has three components: the pit, a squatting plate (or seat and riser), and the superstructure. The pit is simply a hole in the ground into which excreta fall. When the pit is about three-fourths full, the superstructure and squatting plate are removed and the pit is filled up with soil from a new pit dug nearby.

Most of the seven pit latrines evaluated in this study were of the simple, unimproved variety and consequently had both odor and insect (flies and mosquitoes) problems. These undesirable features were almost completely absent in the ventilated, improved pit (VIP) latrine and the Reed Odorless Earth Closet (ROEC) observed in southern Africa.

VIP latrines. In a VIP latrine (figure 2-1, no. 5), the pit is slightly displaced to make room for an external vent pipe.

For maximum odor control, the vent pipe should be at least 150 millimeters in diameter, painted black, and located on the sunny side of the latrine so that the air inside the pipe will heat up and create an updraft. If the vent pipe is letting enough light into the pit, and if the superstructure is fairly dark, flies will try to escape through the vent rather than back into the superstructure. Covering the

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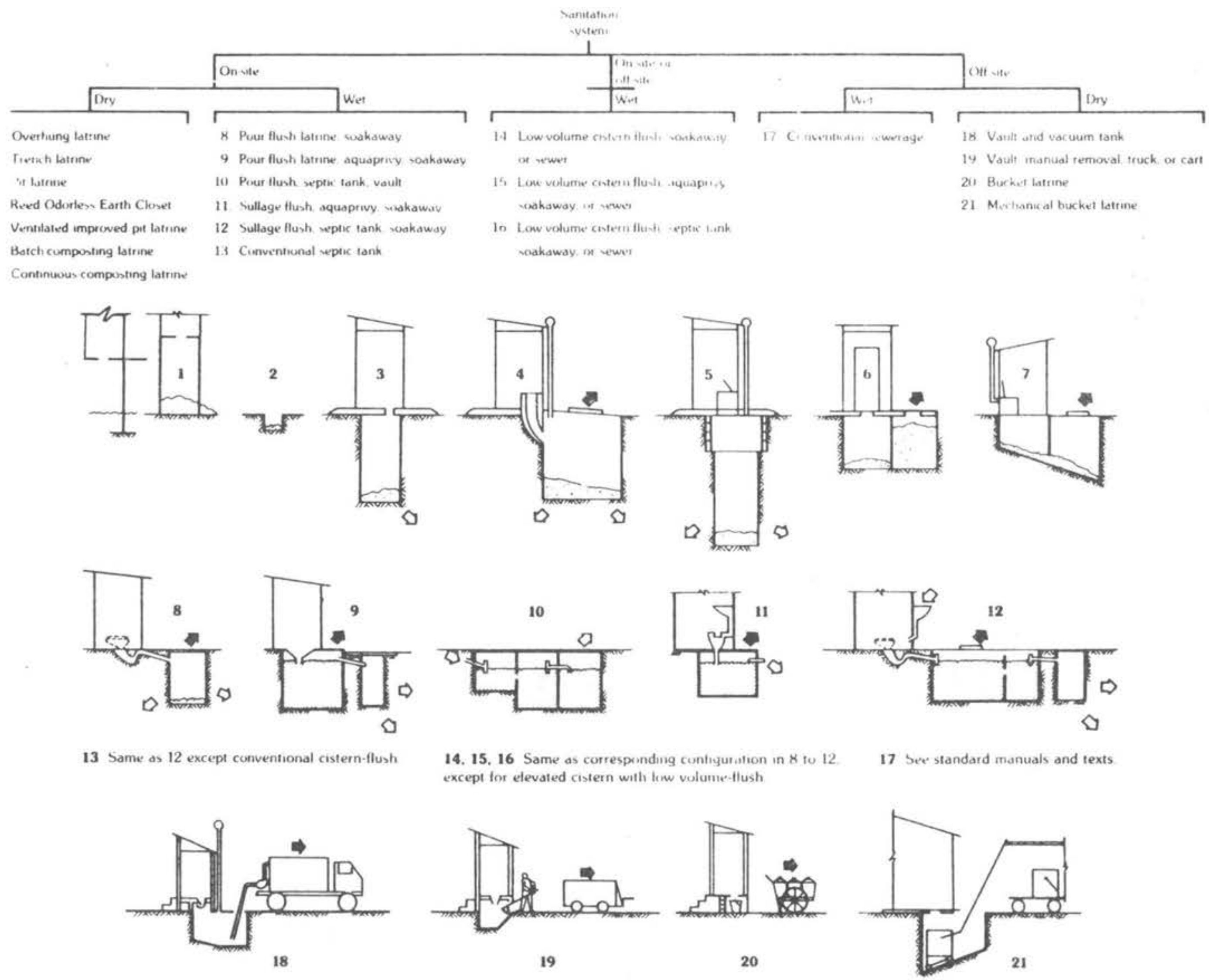
1. For engineering designs and detailed technical information on each technology, see also John M. Kalbermatten and others, Appropriate Sanitation Alternatives: A Planning and Design Manual, World Bank Studies in Water Supply and Sanitation, no. 2 (Baltimore: Johns Hopkins University Press, forthcoming).

gure 2-1. Generic Classification of Sanitation Systems




Movement of liquids; movement of solids

a The World Bank, Water Supply and Waste Disposal, Poverty and Basic Needs Series (Washington, D.C., September 1980) vent pipe with a gauze screen will prevent flies from escaping through that route and thus minimize the health hazard from the insects.1/ Where the user prefers a solid superstructure that cannot be moved or space is not available for moving a VIP latrine, a modification--a ventilated improved double-pit (VIDP) latrine--can be used. The VIDP latrine contains two pits, which are dug side by side and are covered by the same superstructure. Use of the two pits alternates, with the squatting plate being moved from the full to the empty pit as necessary. The full pit is emptied not less than 12 months after last use to be ready for renewed use when the second pit is full.

ROECs. Another successful variation of the pit latrine is the ROEC (figure 2-1, no. 4). Its pit is completely displaced from the superstructure and connected to the squatting plate by a curved chute. A vent pipe is provided, as in the VIP latrine, to minimize fly and odor nuisance. A disadvantage of the ROEC, however, is that the chute is easily fouled, thereby providing a possible site for fly breeding. The chute must, therefore, be cleaned regularly with a long-handled brush or a small amount of water. The advantages of the ROEC over the VIP latrine are that its pit can be larger and thus can have a longer life (because the superstructure is displaced), the users (especially children) have no fear of falling into its pit, and it may be more acceptable in some societies because the excreta cannot be seen.

Pit latrines are most suitable in low- and medium-density areas (up to about 300 persons per hectare) where houses are single storied.2/ It is customary to place the latrine 3 to 5 meters from the house. Where appropriate measures for odor and fly control are taken (as in VIP latrines and ROECs), the latrine may be placed adjacent to the house. In sandy soil the pits may need to be partially lined to prevent collapse, and where the ground is rocky they may be difficult to dig. In areas that have a specific high water table or that are prone to flooding, the latrine may need to be raised partly above the ground. In addition, if nearby groundwater is used for drinking, pit latrines should not be placed within 30 meters or so of the well. If the soil is fissured, the pollution from the latrine will be more extensive, and this distance may need to be increased.

Where these environmental limitations do not apply, or where the disadvantages of other systems outweigh those of pit latrines, the VIP latrine and ROEC are suitable for replication. Their technical designs are good; they can easily be upgraded to pour-flush (PF) toilets; their costs are low; and their potential for health benefits is high. When introduced with an appropriate educational program for new users, they can be very effective at providing sanitation services affordable to the majority of people in rural and urban fringe areas.

PF toilets. There are two types of PF toilets. The first is a simple modification of the unimproved pit latrine in which the squatting

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1. As is discussed in Chapter 4, a well-designed and well-maintained pit latrine can provide the same level of health benefits in the low-density areas as a properly maintained sewerage system can in the inner city.

2. Latrines have been used satisfactorily at twice this suggested density in areas where soil conditions or climatic factors are especially favorable.

plate is made with a 25-millimeter water seal. Approximately 1-2 liters of water (for sullage) [1] are poured in by hand to flush the excreta into the pit. This type of PF toilet is especially suitable wherever water is used for anal cleansing. The second type of PF toilet (figure 2-1, no. 8), which was observed in Indonesia and Colombia, has a completely displaced pit that is connected to a PF bowl by a short length of a 100-millimeter pipe. This type of PF toilet can be installed inside the house because it is free of odor and insect problems and its toilet fixture is displaced from the pit. When the pit is full, a new one is dug and the latrine is connected to it. Alternatively, and, especially in densely populated areas, a vault may replace the pit and be emptied by vacuum cart (see figure 2-1, no. 18). The displaced PF toilet can therefore satisfy the aspiration for an "inside" toilet at low cost. In addition, as water use increases, the pit can be fitted with an outlet that connects to a soakaway or small-bore sewer system. This option is examined more fully in the discussion of sanitation sequencing (Chapter 9, the section 2 "Sanitation Sequences").

The environmental requirements for PF toilets are much the same as those for pit latrines. In addition, however, 3-6 liters per capita daily of water is required for flushing. Thus, in areas where water is carried from distant standposts or surface sources, the pit latrine is probably a better choice until the community's level of water service is improved. The simple technical design, low operational requirements, and high potential for upgrading of PF toilets make them an attractive technology for widespread replication in many areas of the world. Their most severe limitations in practice are that users often do not use enough flushing water or that the toilets can become blocked by solid materials used for anal cleansing. For these reasons, an educational program for users should accompany the introduction of these facilities into a new area.

<u>Composting toilets</u>. There are two basic types of composting toilets: continuous and batch. The continuous composters (figure 2-1, no. 7) are developed from a Swedish design known as "multrums." The composting pit, which is immediately below the squatting plate, has a sloping floor with inverted U- or V-shaped channels suspended above it to promote aerobic conditions in the chamber. Grass, ash, sawdust, or household refuse are added to the pit to attain the necessary carbon-nitrogen ratios for composting to occur. Moisture must be carefully controlled. The material slowly moves down the sloping floor and into a humus vault from which it must be removed regularly.

If the temperature in the composting chamber is raised by bacterial activity to above 60°C, all pathogens in the excreta will be destroyed. In the units observed in southern Africa, however, the temperatures inside were only slightly above ambient. In addition, continuous composters were extremely sensitive to the degree of user care: the humus had to be removed at the correct rate; organic matter had to be added in the correct quantities; and only a minimum of water could be added. Even if all these conditions are met, fresh excreta may occassionally slide into the humus pile and limit the compost's

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1. Sullage is wastewater that does not contain excreta--for example, laundry water and bathwater.

potential for safe reuse. The conclusion of this study, therefore, is that continuous composting toilets should not be recommended for use in either the urban or the rural tropics.

Double-vault composting (DVC) toilets (figure 2-1, no. 6) are the most common type of batch composting toilet. They have two adjacent vaults; one of these is used until it is about three-fourths full, at which point it is filled with earth and sealed and the other vault is used. Ash and organic matter are added to the vault before it is sealed to absorb odors and moisture. The composting process is anaerobic and requires several months, preferably a year, to make the compost pathogen-free and safe for use as a soil fertilizer or conditioner.

DVC toilets require some care by users to function properly and thus are harder to introduce than VIP latrines or PF toilets. They are unsuitable in areas where organic waste matter or grass are not easily available or where the users do not want to handle or use the composted humus. These factors generally restrict their use to rural or periurban areas where users are most likely to have gardens and access to grass for the composting process. Even here, unless there is a strong tradition of reusing excreta in agriculture, DVC toilets have no advantages--and in fact have major disadvantages--over the VIP latrine.

Aquaprivies. The conventional aquaprivy consists of a squatting plate above a small septic tank that discharges its effluent to an adjacent soakaway (figure 2-1, no. 9). The squatting plate has an integral drop pipe which is submerged into the water of the tank to form a simple water seal. As long as the water level in the tank is properly maintained, odor and insect nuisance is avoided. In order to maintain the water level, the vault must be watertight and the user must flush sufficient water into the tank to replace any losses to evaporation. The tank normally requires desludging when it is about two thirds full, usually every 2 to 3 years.

In practice, maintenance of the water seal has generally been a problem, either because users are unaware of its importance to the system or because they dislike carrying water into the toilet. If the seal is not maintained, there is intense odor release, and fly and mosquito problems abound. A variation on the conventional design, called the self-topping or sullage aquaprivy (figure 2-1, no. 11), was developed to overcome the problem of losing the water seal. A sink is located either inside the toilet or immediately adjacent to it and is connected to the tank so that sullage is regularly flushed into the aquaprivy. Because this additional water necessitates a larger soakage pit, sullage aquaprivies cannot be used in urban areas where the soil is not suitable for soakaways or where the housing density or water table is too high to permit subsurface infiltration for effluent disposal. In such cases it is possible to connect the aquaprivy tank to a small-bore sewer system with eventual treatment of the sullage in a series of waste stabilization ponds. Desludging would still have to take place every 2 to 3 years.

If properly maintained, the conventional aquaprivy is a sound technical solution to excreta disposal. However, it has no technical advantage over the PF latrine, which is easier to build and maintain and costs less. In addition, with its more sophisticated water seal the PF latrine can be located inside the house and is more easily upgraded to a cistern-flush toilet (figure 2-1, no. 15). The only comparative advantage of the aquaprivy is that it is less easily blocked if users use solid cleansing materials or throw the material into the tank. Thus, except in cases in which users are unwilling to change such habits, the PF toilet should be preferred to the aquaprivy.

Septic tanks. The final household system to be discussed is the septic tank. The conventional septic tank (figure 2-1, no. 13) is a small, rectangular chamber sited just below ground level which receives both excreta and sullage. During the 1 to 3 days of hydraulic retention time in the tank, the solids settle to the bottom where they are digested anaerobically just as in the aquaprivy. Although the digestion is reasonably good--about 50 percent reduction in biochemical oxygen demand (BOD)--enough sludge accumulates so that the tank must be desludged every 1 to 5 years. The effluent is usually disposed of in subsurface drainfields. In impermeable soils either evapotranspiration beds or upflow filters can be used, although there is little operational experience with either of these systems in developing countries.

Septic tank performance can be improved by various modifications--for example, the use of three (rather than two) compartments (figure 2-1, no. 10) or the addition of an anaerobic upflow filter. This latter modification requires further testing and evaluation before its widespread application can be recommended. The former is a well-known modification that is particularly useful for systems in which excreta and sullage are disposed of separately (as in PF latrines). By this modification excreta can be emptied into the first compartment and sullage into the second, with the effluent discharged from the third. This arrangement improves the settling efficiency of the wastes (including the separation and inactivation of pathogens), increases the soil absorption of the effluent, and permits the effluent's limited reuse.

Septic tanks are suitable only for houses that have both a water connection (necessary for the cistern-flush toilet) and sufficient land with permeable soil for effluent disposal. They are an important sanitation option because they can provide a very high level of service to those who can afford it in a given community, without necessitating the commitment of community funds for the construction of a sewerage system. Thus, as part of a sanitation package which can meet the needs of all the members in a given community, septic tanks have a widespread potential for replication because, with proper soil conditions, they permit satisfactory excreta disposal even for users of cistern-flush toilets (figure 2-1, no. 16).

## Community Sanitation Systems

Bucket latrines, vault toilets, communal toilets, and sewerage systems for communities are examined in this section. All require both off-site facilities and a permanent organizational structure with full-time employees to operate successfully.

Bucket latrines. The traditional bucket latrine (figure 2-1, no. 20) consists of a squatting plate and a metal bucket, which is located in a small vault immediately below the squatting plate. The bucket is periodically emptied by a nightsoil laborer or "scavenger" into a larger collection bucket which, when full, is carried to a night-soil collection depot. From there the night-soil is normally taken by tanker to either a trenching ground for burial or to a night-soil treatment works.

During the course of this study, bucket latrine systems were observed in four countries in Africa and southeast Asia. Problems of odor, insects, spillage, and generally unsanitary conditions at collection and transfer points were ubiquitous. Although it is possible to make several improvements to the normal bucket latrine system (for example, by providing facilities for washing and disinfecting the buckets, covering collection buckets with tightly fitting lids, or mechanizing the system, as shown in figure 2-1, no. 21), it is still difficult in practice to ensure that the system is operated satisfactorily in developing countries. Thus, even an improved bucket latrine system, is not one that can be recommended for new installations. Existing bucket latrines should be improved as a short-term measure and replaced by some other technology in the long term. In the high-density urban areas where bucket latrines are most often found, the most likely replacements include vault toilets and communal facilities.

Vault toilets. Vault toilets (figure 2-1, nos. 18 and 19), which are extensively used in East Asia, are similar to PF toilets, except that the vault is sealed and emptied by a vacuum pump at regular intervals of 2 to 6 weeks. As with the PF toilet, the vault may be built immediately below the squatting plate or displaced from it and connected to it by a short length of pipe. In the latter case, the vault may be shared by adjacent houses with some savings in construction and collection costs.

The vault itself need not be large. For example, for a family of six and with the vault being emptied every 2 weeks, the required vault volume is only 1.25 cubic meters and about 0.6 cubic meters of night soil must be removed each time the vault is emptied. The collection cart or truck is equipped with vacuum tubing, which may be as long as 100 meters to permit access to houses distant from a road or path. Disposal of the collected night soil is usually by trenching or treatment works (see the section "Treatment Alternatives", below).

The vault toilet, emptied by either mechanically, electrically, or manually powered vacuum pump, is an extremely flexible form of sanitation for urban areas. Changes in urban land use are easily accommodated by redefining the routes for collection tanker trucks. Vaults are suitable for medium-rise buildings in which excreta can be flushed down a vertical pipe into a communal vault at, or below, ground level. From the user's point of there is little difference between vault and PF toilets; either can be built inside the house and no nuisance problems are likely. In addition, vault toilets require a minimum amount of water (3-6 liters per capita daily) and are suitable for any type of soil and at very high population densities. They can easily be upgraded into sewered PF toilets if at some stage it is desired to improve facilities for sullage disposal. Their main disadvantage is one shared by all community facilities: the need for an institutional capability to organize the collection service and operate the treatment facilities. The vault toilet systems for which quantitative data were obtained in this study were found in East Asian countries where municipal institutions were well developed. Although the vault toilet system is technically very promising, before it can be recommended for widespread replication in other parts of the world it needs to be subject to some prototype testing on a scale large enough to involve institutional development.

Communal sanitation facilities. There are no unusual technical requirements for a communal toilet. It may be a PF bowl, an aquaprivy, a low-volume cistern-flush toilet, or some other type. If shower, laundry, and clothesline facilities are not available in the houses, they may be provided at the communal sanitation block. Such block facilities are normally designed with a capacity for twenty-five to sixty persons per toilet compartment and up to thirty to fifty persons per shower. The most frequent problems encountered in the communal facilities visited during this study were inadequate water supply (for PF toilets) and poor maintenance. From a mechanical viewpoint, communal facilities may be the only low-cost alternative for providing sanitation to people living in very densely populated cities with no room for individual facilities. The social and institutional commitment to provide for their maintenance, however, can be a serious constraint.

Sewerage. The conventional sewerage system (see figure 9-4, D, in Chapter 9) consists of a cistern-flush toilet connected to a network of underground sewers, which transport sewage and sullage to a treatment or disposal facility. The cistern-flush toilet is a water-seal squatting plate or pedestal unit from which excreta are flushed away by 10-20 liters of water stored in an automatically refilling cistern connected to the household water supply.

Sanitary sewers are usually made from concrete, asbestos cement, vitrified clay, or polyvinyl chloride (PVC) pipe. Sewers are designed for transport by gravity of a maximum flow of up to four times the average daily flow, and they need to be laid with a steep enough slope to provide for a "self-cleaning" velocity of about 1 meter per second to avoid blockages. A conventional sewerage system will require a 225-millimeter pipe (the minimum recommended size) to be laid at 1 in 90 slope, whereas a sewered PF system with a vault to settle solids needs only a 100-millimeter pipe laid at a 1 in 200 gradient. Clearly, there is a considerable difference in excavation and pipe costs between the conventional and small-bore sewers, which will grow larger as the ground becomes rockier. Because small-bore sewers carry no solids, they also require fewer manholes than conventional sewers.

The main advantage of a conventional sewerage system is the high convenience to users it provides. The main technical constraints are its large water requirement, the difficulty of the excavation in very dense areas or in those with poor ground conditions (rocky soil, high water table, and the like), the problem of laying sewers in fairly straight lines through areas of "unplanned" housing without substantial demolition, the susceptibility of the pipes to corrosion in hot climates, and the blockage and extra maintenance problems that may arise during the early years following construction of a sewer (when it is underused).[1] A further problem of conventional sewerage systems is the environmental hazard created by point discharge of such large volumes of wastewater. This problem is reduced with (expensive) tertiary treatment plants, but developed countries are now discovering that even elaborate treatment does not remove all of the environmental hazards. In developing a sanitation package for a city, planners should consider sewerage only for those areas in which it is clearly the most appropriate sanitation system for social and economic, as well as technical, reasons.

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1. Japanese experience has been that there is a lag time of 5-10 years between commissioning and voluntary sewerage connection by a significant number of households.

Factors Affecting Choice of Technology

Before the discussion proceeds to treatment, reclamation, and disposal alternatives, a summary of the major technical and environmental factors that affect the choice of sanitation may be useful.

Physical Environment will often permit the exclusion of certain options. Winter temperatures affect the performance of waste treatment ponds, digesters, and biogas units because each decrease of about 10°C or 48°F causes a decrease in biochemical reaction rates by one-half. The distribution of precipitation indicates the general levels of flooding, runoff, water table, and plant growth. Climate diagrams show details of temperature and precipitation for specific locations considered. Aridity index maps show the ratios of potential evaporation to precipitation and indicate climatic zones, particularly those subject to desertification, in which the recovery of water, fertilizer, and energy from wastes is most important. The distribution of soil types and potential productivity reflect long-term effects of climate, and the latter is a measures of land or aquatic plant growth. Soil and weather allow for higher productivity in the tropics, where rapid cycling of material through the biosphere is a major element in the efficiencies of waste treatment ponds. Similarly, distributions of most of the diseases discussed in Chapter 4 indicate the environmental influence on health in the tropics. 1/

In contrast to the regional or global environmental influences, local changes in land use are often the limiting factor, especially in urban areas. The crowding in single-story residential areas of two cities, East Asian and West African, where average population densities of 1,000 to 1,500 persons per hectare (100,000 to 150,000 per square kilometer) are found, is shown in figure 2-2. The addition of rental rooms to what was previously relatively spacious housing is shown in figure 2-3. The smaller of the two houses is occupied by 61 people, each of whom has an average of about 5 cubic meters of living space (from figure 2-3) and no more than 8 cubic meters of total space (equivalent to about 1,100 persons per hectare). Even under these conditions, there is room for extended household latrines using buckets or vaults. By way of comparison, sewered communal latrines would occupy up to 3 percent of total land area where population densities are about 1,000 persons per hectare and up to 10 percent if shower and laundry facilities are provided (not including space for clotheslines).

Levels of Water Supply Service. Hand-carried supplies from a public water hydrant restrict feasible technologies to those not requiring water, such as VIP latrines, ROECs, and DVC toilets. PF toilets may be feasible in a sociocultural environment where anal cleansing practices already require the carrying of water to the toilet. Even then, however, a sufficient amount of water may not be available for flushing. A system that requires water to transport excreta is clearly not feasible. The facilities mentioned above can be converted to water-seal units, if desired, when the water supply service is improved by a yard or house connection.

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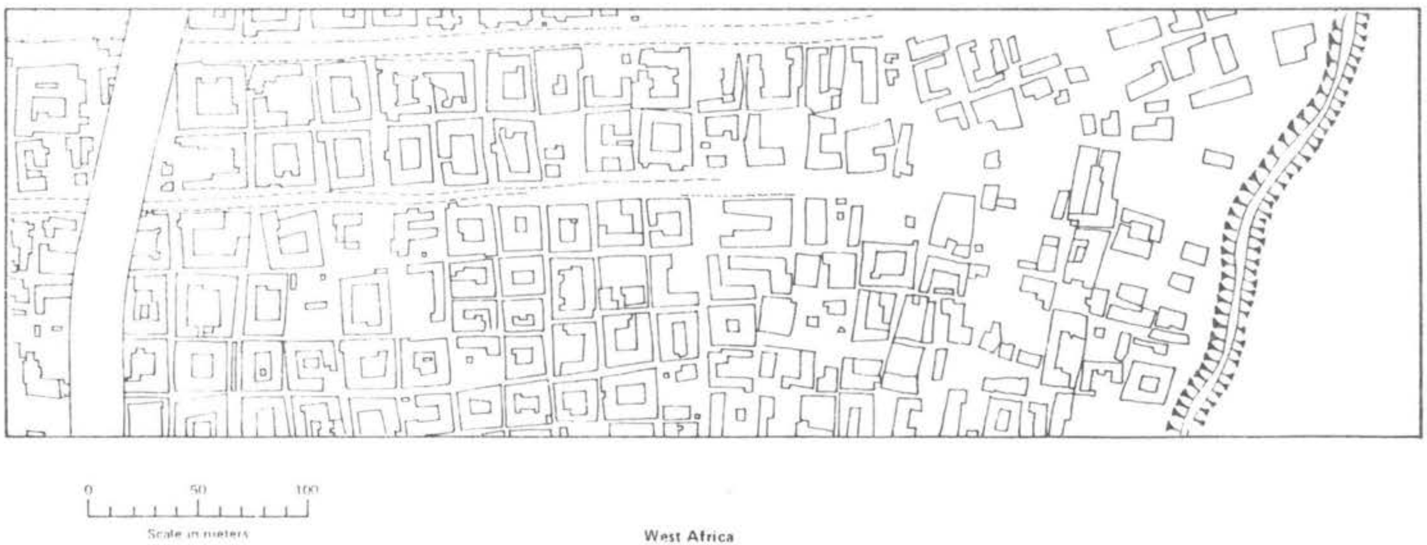
1. For further detail on sanitation-related infections, see Chapter 4 and Richard G.A. Feachem and others, Sanitation and Disease: Health Aspects of Excreta and Wastewater Management, World Bank Studies in Water Supply and Sanitation, no. 3 (Baltimore: Johns Hopkins University Press, forthcoming).

Figure 2–2. Special Plan of Two Low income Urban Residential Neighborhoods

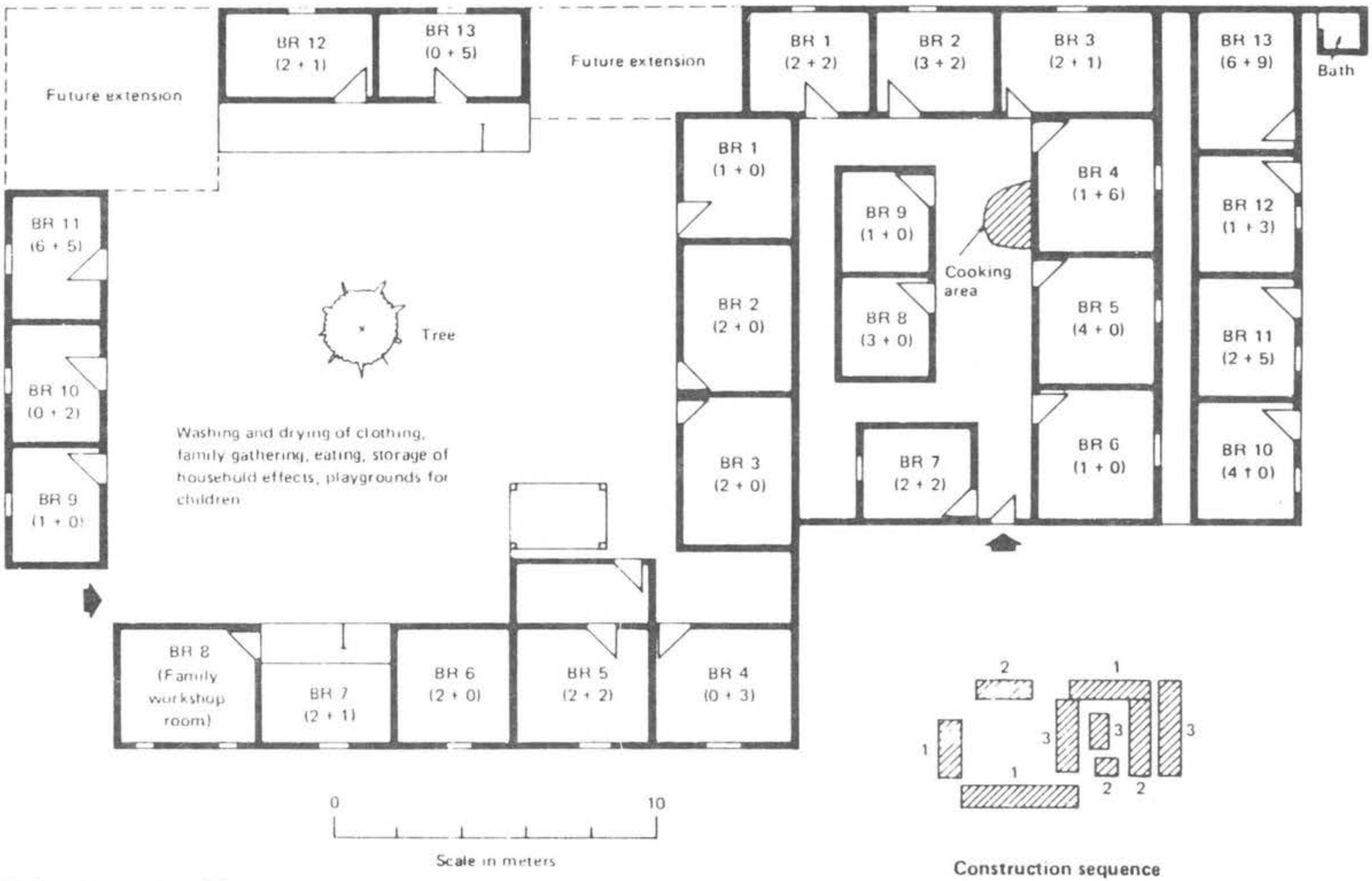

East Asia




West Africa

Source: The World Bank

Figure 2–3. Typical Floor Plan of Low-income Rental Units




CI, Served by standpipe. BR, bedroom

Note Numbers in parentheses indicate numbers of adults and children in each bedroom

Source The World Bank

Yard connections permit PF and vault toilets, but not cistern-flush toilets. If sullage generation exceeds 50 liters per capita daily, sewered PF toilets also become technically feasible. Household connections make cistern-flush toilets with conventional sewerage or septic tanks and soakaways technically feasible. Sewered PF toilets are also possible; but they have high capital costs and, as an interim measure, alternative improvements in sullage disposal may be economically more attractive. Figure 2-4 illustrates schematically how various levels of water use lead to different sanitation options.

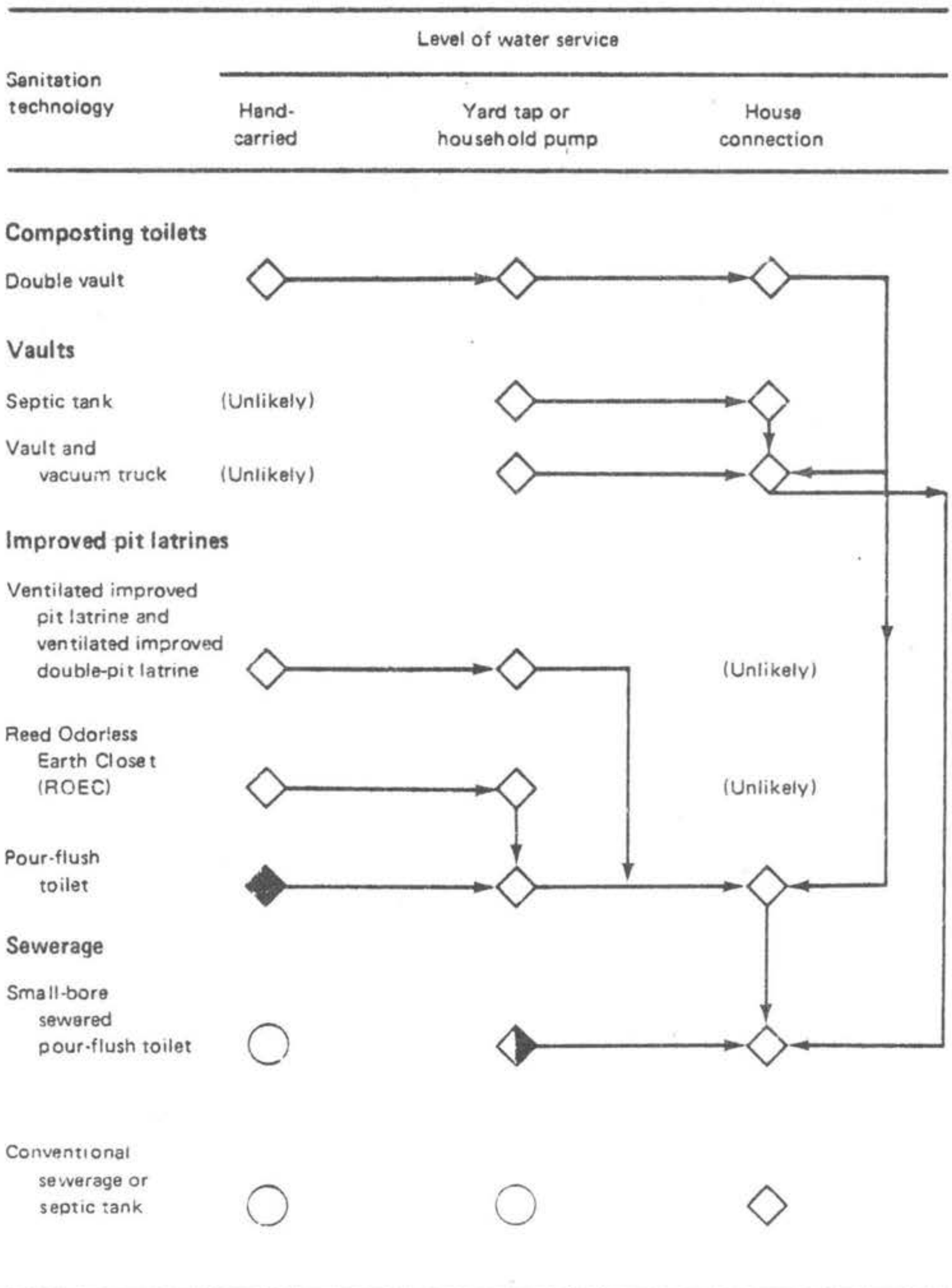
Housing Density. In densely populated areas, VIP latrines, ROECs, PF toilets, and septic tanks with soakaways may be infeasible. Conventional sewerage is feasible if gradients are steep enough to provide self-cleaning velocities. Sewered PF systems are also feasible and can be used with flatter gradients. Vacuum-truck cartage from vaults is a third possibility in dense areas. The choice among these possibilities is made essentially on economic grounds, although sullage disposal facilities and access for service vehicles are important for vault toilets.

It is not easy to define at which population density on-site systems (such as VIP latrines, ROECs, PF, and DVC toilets) become infeasible. The figure is probably most commonly around the 250-300 persons per hectare for single-story homes and up to double that for two-story houses. Pit latrines, however, have been found to provide satisfactory service at much higher population densities. The essential point is to determine, in any given situation, whether or not there is space on the plot to provide two alternating pit sites that have a minimum lifetime of 2 years, or whether the pit can be easily emptied if space for alternating pit sites is not available. For off-site systems (such as vaults and cartage), the limiting factor is normally the accessibility of the vault, not population density—so that, in very crowded and irregularly laid-out areas, bucket latrines and communal facilities may be the only options.

Complementary Investments. Off-site night-soil or sewage treatment works are required for vault toilets, sewered PF toilets, and conventional sewerage systems. Sullage disposal facilities must be considered for all household systems and vault, bucket, and communal facilities. For those systems, achieving disposal through reclamation (the reuse potential) must be thoroughly and realistically examined, especially in areas where excreta reuse is not a traditional practice. For example, DVC latrines may be provided where there is a demand for reuse. Other technologies which require off-site treatment facilities have high potential for sludge or night-soil reuse.

Potential for Homeowner Construction. Where financial constraints are severe, the potential for "self-help" construction of the various technologies should be considered. Self-help can provide the unskilled labor, and some (but not all) of the skilled labor, required for the installation of VIP latrines, ROECs, and DVC and PF toilets. It requires organization and supervision by the local authority, especially in urban areas. The other technologies have less potential for self-help labor and, indeed, require experienced engineers and skilled builders for their design and construction.

**Figure 2 –4. Potential Sanitation Sequences**




◇, Technically feasible; ◆, feasible if sufficient pour-flush water will be hand carried;
○, technically infeasible; ◆, feasible if total wastewater flow exceeds 50 liters per capita daily.

Hygienic Habits of Users. The choice of anal cleansing materials, in particular, can affect the choice of technology. PF and cistern-flush toilets cannot easily cope with some anal cleansing materials (for example, mud balls, corncobs, stones, or cement-bag paper) unless a traditional practice of disposing of such anal cleansing materials outside the toilet exists. The practice of using water for anal cleansing may present problems for pit latrines in soil with limited permeability or for DVC toilets, the contents of which may become too wet for efficient composting.

Institutional Constraints. Institutional constraints often prevent the satisfactory operation of sanitation technologies even when they are properly designed because adequate maintenance (at the user or municipal levels or both) often cannot be provided. Thus, educational programs for users and institutional development should generally form an integral part of program planning for sanitation. Changes, especially those in social attitudes, can be accomplished only slowly and may require a planned series of incremental improvements over time.

## Comparison of Technology

From the foregoing discussion of the factors affecting the selection of technology, the technical suitability of various technologies for application in a specific community can be determined. As a first step, comparative criteria must be defined. One possibility is to compare the technologies in a matrix that displays performance according to the established criteria as shown in table 2-1. Ranking technologies by means of subjective weighting produces a numerical comparison of spurious precision. Moreover, in any given community there are always basic physical and cultural attributes that--in conjunction with the existing level of water supply service and the community's general socioeconomic status--limit the choice of technologies considerably, irrespective of the overall scores achieved in a comparison by numerical matrix of all possible technologies. The most useful function of a matrix, therefore, is to exclude certain technologies in a given situation, rather than to select the best. The choice among the remaining technologies is often based principally on considerations of cost, user preferences, and reliability. Algorithms to aid in the choice of technology are described in Chapter 9.

## Treatment Alternatives

The objectives of night-soil or sewage treatment are to eliminate pathogens so that human health will be protected and to oxidize organic matter so that odors, nuisance, and environmental problems (such as algal blooms or fish kills) will be eliminated. The first objective may be achieved by the separation of feces from the community and the second by various combinations of separation, sedimentation, digestion, and oxidation.

Table 2-1. Descriptive Comparison of Sanitation Technologies

| Sanitation technology | Rural application | Urban application | Construction cost | Operating cost | Ease of construction | Self-help potential | Water requirement | Required soil conditions | Complementary off-site Investments[a/] | Reuse potential | Health benefits | Institutional requirements |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ventilated improved pit (VIP) latrines and Reed Odorless Earth Closets (ROECs) | Suitable | Suitable in low/medium-density areas | L | L | Very easy except in wet or rocky ground | H | None | Stable permeable soil; groundwater at least 1 meter below surface[b/] | None | L | Good | L |
| Pour-flush (PF) toilets | Suitable | Suitable in low/medium-density areas | L | L | Easy | H | Water near toilet | Stable permeable soil; groundwater at least 1 meter below surface[b/] | None | L | Very good | L |
| Double-vault composting (DVC) toilets | Suitable | Suitable in low/medium density areas | M | L | Very easy except in wet or rocky ground | H | None | None (can be built above ground) | None | H | Good | L |
| Self topping aquaprivy | Suitable | Suitable in low/medium-density areas | M | L | Requires some skilled labor | H | Water near toilet | Permeable soil; groundwater at least 1 meter below ground surface[b/] | Treatment facilities for sludge | M | Very good | L |
| Septic tanks | Suitable for rural institutions | Suitable in low/medium-density areas | H | H | Requires some skilled labor | L | Water piped to house and toilet | Permeable soil; groundwater at least 1 meter below ground surface[b/] | Off-site treatment facilities for sludge | M | Very good | L |
| Three-stage septic tank | Suitable | Suitable in low/medium density areas | M | L | Requires some skilled labor | H | Water near toilet | Permeable soil; groundwater at least 1 meter below ground surface[2/] | Treatment facilities for sludge | M | Very good | L |
| Vault toilets and cartage | Not suitable | Suitable | M | H | Requires some skilled labor | H (for vault construction) | Water near toilet | None (can be built above ground) | Treatment facilities for night soil | H | Very good | VH |
| Sewered PF toilets, septic tanks, and aquaprivies | Not suitable | Suitable | H | M | Requires skilled engineer/builder | L | Water piped to house | None | Sewers and treatment facilities | H | Very good | H |
| Sewerage | Not suitable | Suitable | Very high | M | Requires skilled engineer/builder | L | Water piped to house and toilet | None | Sewers and treatment facilities | H | Very good | H |

L, low; M, medium; H, high; VH, very high.

a/ On- or off-site sullage disposal facilities are required for non sewered technologies with water service levels in excess of 50 to 100 lcd, depending on population density.

b/ If goundwater is less than 1 meter below the surface, a plinth can be built.

Details of conventional sewage treatment processes--designed primarily to oxidize organic matter--are described in standard sanitary engineering texts.[1] A review here of the objectives and principles of the health aspects of sewage treatment insofar as they apply to developing countries, together with some principles of design of selected technologies particularly suited to the treatment of night soil and sewage in developing countries, is appropriate.

Conventional Treatment Processes. The conventional treatment observed in developing countries during this research had the technical disadvantages of extremely poor pathogen removal and frequent operation and maintenance problems from shortages of properly skilled personnel and imported spare parts.

Effluent from a trickling filter plant with about 5 hours of retention will contain significant concentrations of viruses, bacteria, and protozoa and helminth ova and is thus unsuitable for unlimited reuse in agriculture. Activated sludge plant effluent with, say, 12 hours of retention, is better than that from trickling filters but will still be microbiologically contaminated.

Batch digestion of sludge for 13 days at 50°C in a heated digester will remove pathogens and reduce volatile solids by some 50 percent. Digestion at 30°C for 28 days will remove protozoa and most enteroviruses. Digestion for 120 days at ambient temperatures will remove all pathogens except helminths. Sludge drying for at least 3 months will be very effective against all pathogens except helminth ova (see chapter 4).

Other methods of sewage treatment that are used in industrial countries include oxidation ditches, aerated lagoons, sand filtration, chlorination, and land treatment; these are described in a number of standard works.[2]

Waste Stabilization Ponds. Waste stabilization ponds are large, shallow ponds in which organic wastes are decomposed by a combination of bacteria and algae. The waste fed into a stabilization pond system can be raw sewage, effluent from sewered PF toilets or aquaprivies, or diluted night soil.

Waste stabilization ponds are an economical method of sewage treatment wherever land is available. Their principal technical advantage in developing countries is that they remove excreted pathogens with much

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1. For example, see Fair, Geyer, and Okun, Water Purification and Wastewater Treatment and Disposal, (New York: John Wiley and Sons, 1968).

2. Ibid. See also D. Duncan Mara, Sewage Treatment in Hot Climates, (New York: John Wiley and Sons, 1976).

less required maintenance than any other form of treatment. A pond system can be designed to ensure, with a high degree of confidence, the elimination of all excreted pathogens. This is not normally done in practice because the additional benefits resulting from achieving zero survival, rather than very low survival, are less than the associated incremental costs. For details on stabilization pond systems, see volume 2 of this series.

Snail and mosquito breeding in stabilization ponds will occur only if poor maintenance allows vegetation to emerge from the pond bottom or to grow down the embankment into the pond, thus providing shaded breeding sites. This can be prevented by providing pond depths of at least 1 meter and concrete slabs or stone riprap at the upper water level.

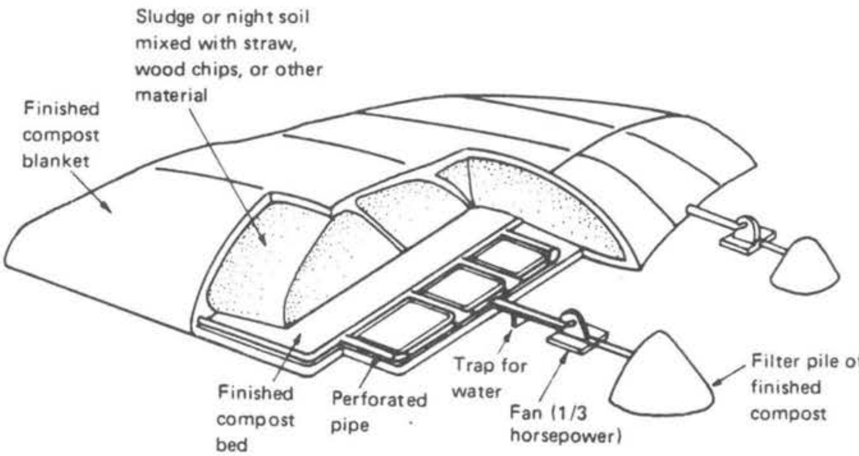
Aerobic Composting. Rapid stabilization and pathogen destruction is assured by aerobic composting, in which raw night soil or sludge is mixed with straw or some other organic matter or with previously composted night soil (or a combination of these) so as to provide a water content of 40-60 percent, a carbon to nitrogen ratio of 20-30:1, and bulk or workability of the mixture. This technology has been applied in the United States (notably, at the U.S. Department of Agriculture's Beltsville Agricultural Research Center, Beltsville, Maryland) to raw and digested sludge and to night soil. The least expensive scheme is to form windrows of the night-soil mixture over loops of perforated irrigation drainage pipe laid on the ground. Air is then drawn intermittently through the pile into the pipe by a 1/3-horsepower blower and expelled as exhaust through a small pile of finished compost to reduce odors. Equipment requirements are limited to front-end loaders and blowers; screens may be added if the bulking materials are to be separated and recycled. Temperatures in the pile are high enough (even in winter) for a sufficient time to ensure complete pathogen destruction. The operation is simple and reliable (figure 2-5).

Other schemes for sludge or night-soil treatment include incineration, wet oxidation, and pyrolysis; they are too expensive to be considered for general application in developing countries.

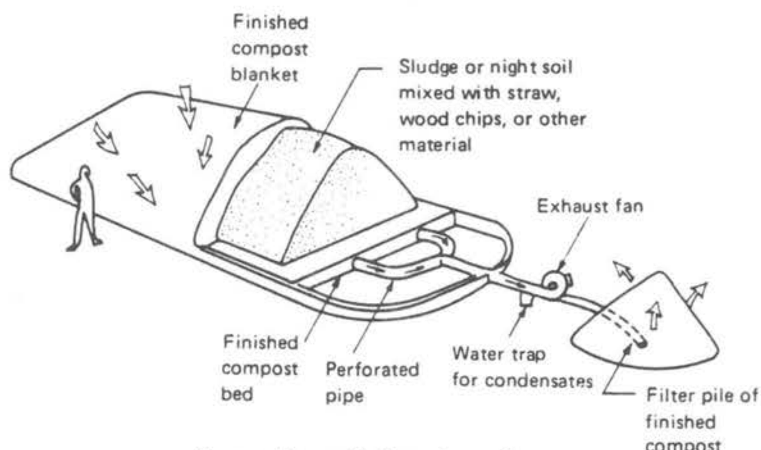
## Sullage Disposal

The adoption of any of the sanitation technologies, with the exception of septic tanks and conventional sewerage, requires that separate facilities be considered for sullage disposal. Sullage is defined as all domestic wastewater other than toilet wastes; it includes laundry and kitchen wastes as well as bathwater. It contains some excreted pathogens but, of course, considerably fewer than toilet wastes. It also contains many organic compounds and approximately 40-60 percent of the total household production of waste organics--that is, some 20-30 grams of biochemical oxygen demand by the standard test ($BOD_5$) per capita daily. This figure, however, depends on water consumption. A family with abundant water for personal and clothes washing and many water-using appliances will generate more sullage BOD than one which uses only small quantities of water for drinking and cooking.

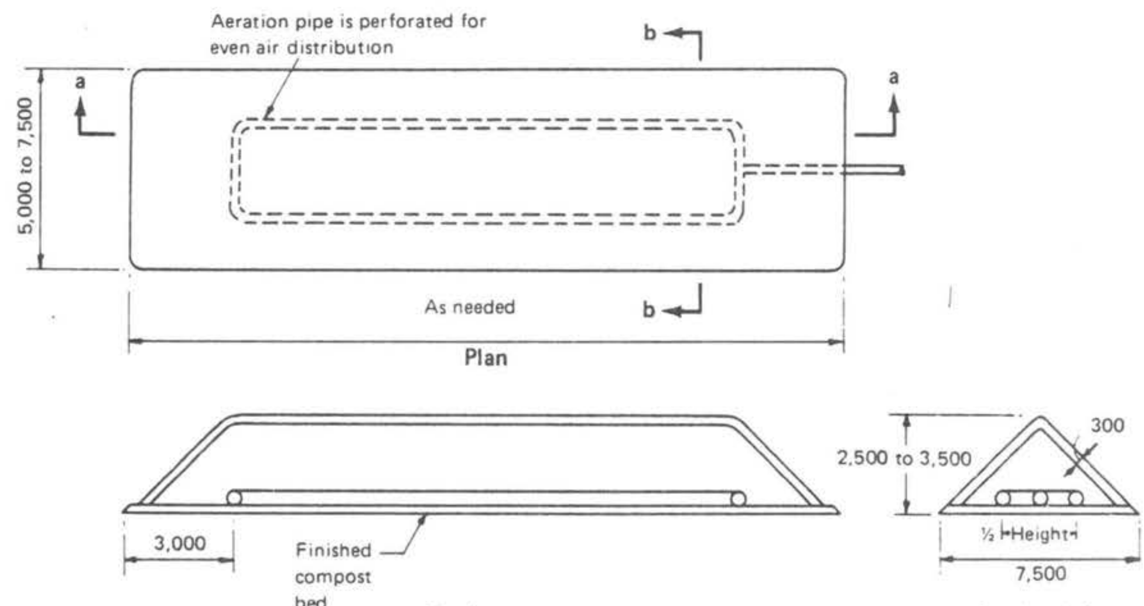
**Figure 2 - 5. Beltsville Agricultural Research Center (BARC) System for High-rate Thermophilic Composting (millimeters)**




**Composting extended piles with forced aeration**




**Composting with forced aeration**




**Section a-a**

**Section b-b**

**Schematic**

In developing countries, sullage is a wastewater with approximately the same organic pollution potential as raw sewage in North America. Although its environmental hazard can be great, its health hazard will be much less than that of sewage (see Chapter 4). Thus, an important factor to consider when choosing sullage disposal facilities is how much the community is willing to spend on environmental protection.

There are basically four kinds of sullage disposal systems: casual tipping in the yard or garden, on-site disposal in seepage pits, disposal in open drains (usually stormwater drains), and disposal in covered drains or sewers. The first will be adequate where water use is low and the soil and climatic conditions are such that the yard remains dry and puddles of water do not form. Seepage pits can handle more water but also require appropriate soil conditions. If stormwater drains are used for sullage disposal, they should be designed with a deep (rather than flat) center section so that the small volumes of sullage will not pond. In addition, drains must be carefully maintained to be free of debris that could block the flow, thereby providing attractive sites for mosquito breeding. Disposal in covered drains or sewers is subject to the same excavation and environmental problems as conventional sewerage.

Resource Recovery

Technologies for resource recovery in countries included within the present research provide for irrigation with treatment plant effluent; garden watering with sullage; crop fertilization by raw, digested, or anaerobically composted night soil or sludge; fish culture with raw night soil; and methane production from municipal sludge or night-soil digesters and from household biogas units.

Readily available data on health aspects were collected, but were not sufficiently detailed to show either presence or absence of detrimental effects from the various resource-recovery practices. Technologies characteristic of these and similar practices are presented in volume 2 of this series: A Planner's Guide. Their general features are summarized below.

Agricultural Reuse. Agricultural reuse is the most common form of excreta reuse. There are, however, health risks to people and animals working in the fields where excreta are reused and to those who consume the crops raised in excreta-enriched soil. There are also problems associated with the chemical quality of the compost, sludge, or sewage effluent--including concentration in crops of heavy metals and potential damage to the soil structure from high sodium concentrations.

Pigs are fed raw excreta in a number of South and Southeast Asian, Central American, and West African locations. They provide direct and efficient conversion of wastes to protein, but the health risks are obvious, and reliable epidemiological data are lacking. Thorough cooking of pork from excreta-fed swine is an essential measure of effective pathogen control.

Aquacultural Reuse. Human excreta can be used for raising plants and animals. The four main kinds of aquaculture are freshwater fish farming; marine culture of fish, shellfish, or shrimp; production of algae; and the emergent production of aquatic plants.

Reliable data on freshwater fish farming are available from South and Southeast Asia. In this practice there are hazards of passive carriage of a range of pathogens and, in some parts of the world, of Clonorchis sinensis (Chinese liver fluke) transmission as well. Control measures include enriching ponds only with settled sewage or stored night soil or sludge; placing the fish in clean water for several weeks prior to harvesting; clearing vegetation from pond banks to discourage the snail host of Clonorchis; promoting food hygiene in the handling and processing of fish and discouraging the consumption of raw or undercooked fish.

Yields of carp in fertilized ponds vary from 200 kilograms per hectare yearly in rural, subsistence ponds to 1,000 kilograms per hectare per year or more in commercial ponds; yields of tilapia are 2,000-3,000 kilograms per hectare yearly in well-maintained ponds. Fish yields can be doubled by rearing ducks whose feces provide additional nutrients. Ecological niches in the pond can be introduced; for example, the common carp (Cyprinus carpio) and the grass carp (Ctenopharyngodon idella) feed primarily on benthic zooplankton and aquatic weeds, respectively. Up to 7,000 kilograms per hectare yearly can be achieved if supplemental feeding with grass, other vegetation, rice bran, groundnut cake, or the like is provided and bottom-feeding fish are added to the ponds.

The design of fishponds is essentially the same as that of waste stabilization ponds. Depths are usually 1 meter to prevent vegetation from emerging from the pond bottom; deep ponds (2 meters) are disadvantageous because there is little oxygen, and hence raw fish, in the lower layers. What matters is the correct rate of supply of nutrients; regular batch feeding on an empirically determined basis is recommended.

Biogas production. Institutional and household biogas plants are operative in China, India, Korea, Taiwan, and elsewhere and use diluted animal feces with or without human excreta and with or without vegetable refuse. The effluent slurry from these plants can be used in agriculture and fish ponds. The dung from one cow or similar animal can produce around 500 liters of gas per day; it contains 50-70 percent methane and its calorific value is around 4-5 kilocalories per liter. In contrast, human excreta yields only 30 liters of gas per person daily. The process is very sensitive to temperature, and gas production is negligible below 15°C. Biogas may also be used for lighting, and large farms and institutions are also suitable sites for biogas units.

Example of Management Schemes for Sewerage and Night soil

An excellent comparison of well-designed, well-managed systems for excreta and sullage disposal can be found in Kyoto, Japan, a city of 1.4 million. Here, public health and esthetic requirements are met by conventional sewerage for about 40 percent of the population and by a vault and vacuum-truck system for another 40 percent. Sullage from the latter is discharged to surface drainage facilities. After collection, the 1.2 liters per capita daily of night soil undergo grit removal, comminution, screening, and storage and are released into sewers at off-peak hours for subsequent activated sludge treatment and incineration. Trucks are thoroughly cleaned at the night-soil transfer station after each trip.

The areas and water quality of streams in portions of the city served by the two systems are shown in map. Diffused discharges of sullage from unsewered areas do not affect concentration of BOD and suspended solids in the streams; increases in these constituents cannot be distinguished from those due to urban runoff in sewered areas. Moderate increases in stream BOD and solids downstream from the sewage treatment plants reflect both the excellent removals obtained by treatment and the impact of point discharges to the streams. Health data from the two areas reveal no differences. Costs of the two systems are presented in the following chapter.

The most significant findings from this case study are that the less expensive vault and vacuum-truck system can provide equal health protection and better protection of water quality in streams than does conventional sewerage. Both systems are providing reliable service to areas of an historic, beautiful, and modern city.

## Future Research Needs

Most of the technologies discussed in this chapter have been applied successfully at a specific site and, in the case of on-site systems, on an individual basis. It is therefore necessary to design, implement, and monitor pilot projects on a community scale to:

- Confirm the replicability of technologies;
- Test the transfer and adaptation of technologies for different sociocultural environments;
- Evaluate the ability of communities to organize and operate communal systems such as the emptying of vaults and septic tanks;
- Determine effects of sullage disposal and develop methods of sullage disposal for various population densities; and
- Test the large-scale application of appliances with low water use (for example, aerated spigots and shower heads, overhead low-volume flush tanks) and their effects on sanitation.

Research is also needed in various areas either to develop technologies further, to measure their effects or to find new, more efficient techniques. Among these areas for further research are:

- On-site and off-site sullage treatment and disposal methods (infiltration, evaporation, anaerobic filtration, oxidation ponds);

- Testing and monitoring of the performance of hand pumps for water supply in rural areas and development of a methodology for selection (similar to that of the algorithms for sanitation) that would reduce present, high failure rates of hand pumps;

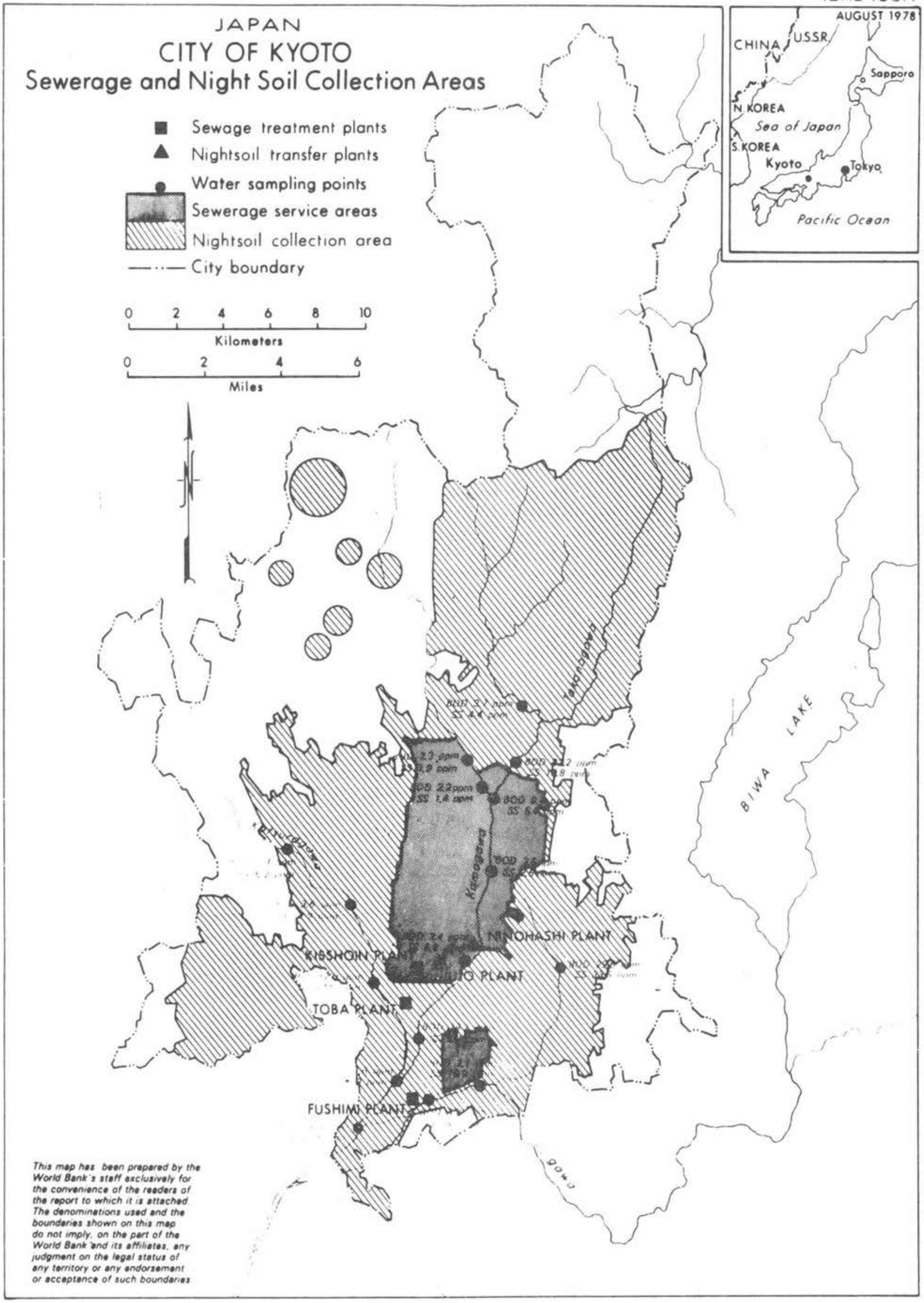
- Development of training materials, workshops, and seminars for disseminating information on low-cost water supply and sanitation systems and training of professionals in implementation;

- Development of a methodology to determine the most cost-effective mix of sewerage and low-cost sanitation in urban areas;

- Multidisciplinary evaluation and pilot testing of methods to convert waste material into usable products

Much work has been done in this last area, but usually only with a narrow (single-purpose) orientation. A multidisciplinary approach--studying many disposal and reuse possibilities and optimizing various simultaneous outputs--will result in more efficient and cost-effective solutions.

IBRD 13817


AUGUST 1978
JAPAN
CITY OF KYOTO
Sewerage and Night Soil Collection Areas
Sewage treatment plants
Nightsoil transfer plants
Water sampling points
Sewerage service areas
Nightsoil collection area
City boundary
0 2 4 6 8 10
Kilometers
0 2 4 6
Miles
CHINA
U.S.S.R.
Sapporo
N. KOREA
Sea of Japan
S. KOREA
Kyoto
Tokyo
Pacific Ocean
BIWA LAKE
Kamogawa
NINOHASHI PLANT
KISSHOIN PLANT
TOBA PLANT
FUSHIMI PLANT
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# CHAPTER III

## THE ECONOMIC COMPARISON

Comparative costing lies at the heart of the analysis of alternative sanitation technologies. The definition of technological "appropriateness" developed in chapter 1 is based partly upon a systematic ranking of feasible alternatives according to their economic costs. Implicit in this definition is the search for a common denominator for the objective comparison of diverse systems that should reflect both the positive and negative consequences of a given technology and also indicate its overall "score" (either on an objective scale or relative to other alternatives).

One scoring measurement commonly used in project evaluation is the benefit-cost ratio.1/ It has the advantage of providing a single, summary figure representing the net economic effect of a given project, which can then be readily compared with that of alternative projects. The disadvantages of benefit-cost calculations are that they do not easily accommodate noneconomic benefits and costs (particularly if these are unquantifiable); they may give misleading results when applied to mutually exclusive projects; and they may not reflect macroeconomic goals such as the creation of employment or the generation of savings and investment. Fortunately, the last two problems can be remedied by variations of the basic calculations.2/ The difficulties of measuring benefits for sanitation projects, however, cannot be readily overcome. Indeed, in the case of water supply projects, it has been concluded that the theoretical and empirical problems involved in quantifying incremental health benefits are so great as to make serious attempts at the measurement of benefit inappropriate as part of project appraisals.3/

There are also unquantifiable costs associated with alternative sanitation technologies. Although it is generally possible to assess qualitatively the environmental consequences of installing a particular system, it is very difficult to quantify them since no "market" for such public goods exists. It is even more difficult to compare consequences of installation with the environmental sanitation that would develop without the project's implementation, thus to determine net benefit or net cost figures.

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1. Variations of this calculation include the internal rate of return and the net present value. For a discussion of the set of conditions under which each is appropriate, see Lyn Squire and Herman G. van der Tak, Economic Analysis of Projects (Baltimore: Johns Hopkins University Press, 1975), pp. 39-43.

2. Ibid.

3. H. Shipman and others, "Measurement of the Health Benefits of Investments in Water Supply," Public Utility Note 20 (Washington, D.C.: The World Bank, Transportation, Water, and Telecommunications Department, January 1976; processed).

A scoring device that has been used on occasion for ranking alternatives with unquantifiable benefits is a matrix that lists both cost and benefit components and assigns values (or relative ranks) to each alternative based on an arbitrary scale (or the total number of alternatives). Varying degrees of complexity can be built into matrix ranking by weighing the criteria or by using complex, summary variables of the values. Regardless of the variations, however, the lack of objectivity in the procedure remains a major disadvantage.

In general, there is no completely satisfactory scoring system for comparing alternatives with unquantifiable benefits. Only in the case of mutually exclusive alternatives with identical benefits can a cost minimization rule be applied. In such cases the alternative with the lowest present value of cost, when discounted at the appropriate rate of interest, should be selected. For given levels and qualities of service, the least-cost alternative should be preferred. But, where there are differences in the output or service, the least-cost project often will not be the economically optimal one.

Alternative sanitation systems provide a wide range of benefit levels. Although most properly selected systems can be designed to provide the potential for full health benefits, many benefits exist in the mind of the user, and varying qualities of service result in varying benefit levels. For this reason, a least-cost comparison will not provide sufficient information to select among sanitation alternatives, nonetheless, it can provide an objective, common denominator that reflects tradeoffs in cost corresponding to different service standards. Once comparable cost data have been developed, the consumers or their community representatives can make their own determination of how much they are willing to pay to obtain various standards of service.

Thus, the economic evaluation of alternative sanitation technologies comprises three components: comparable economic costing, the maximizing of health benefit from each alternative through proper design, and the involvement of the user in making the final cost-benefit determination. This chapter deals with the first of these. Chapter 4 discusses the public health aspects of sanitation alternatives, and chapter 5 develops methods of promoting the involvement of users in choosing technology.

## Economic Costing in Theory

The principal intent of economic costing is to develop a price tag for a good or service that represents the opportunity cost to the national economy of producing that good or service. Translated into practice, this intent can be summarized in three principles to be followed in preparing cost estimates.

The first principle is that all costs to the economy, regardless of who incurs them, should be included. In comparing costs of public goods such as water or sanitation, too often only costs that the public utility pays, and not costs borne by the households, are considered in a cost comparison. For an economic comparison (that is, for the determination of the least-cost solution), however, it is necessary to include all costs attributable to a given alternative. The determination of which costs to include should rest on a comparison of the situation over time, with and without the project. Rather than using the status quo for the "without" scenario, the analyst must estimate how the current situation would improve or deteriorate over the project period were the project not to be undertaken. In the case of sanitation systems for urban fringe areas, for example, the costs of groundwater pollution and the difficulty in siting new latrines are likely to increase over time as population pressure mounts. There is likely to be an optimal time to undertake a sanitation project. By acting too soon the community may incur costs that could have been postponed. By waiting too long, the community might face a rise in the per capita cost of the project (in real terms) because of increases in population density, for example, which could aggravate construction difficulties for some technologies.

Once the relevant costs to be included have been identified, the second costing principle concerns the prices that should be used to value those costs. Since the objective of economic costing is to develop figures reflecting the cost to a particular country of producing a good or service, the economist is concerned that unit prices represent the actual resource endowment of that country.

Because governments often have diverse goals that may be only indirectly related to economic objectives, some market prices may bear little relation to real economic costs. For this reason it is often necessary to "shadow price" observed, or market, prices to arrive at meaningful costs for components of a sanitation technology. Calculating these shadow rates, or conversion factors, is a difficult task and requires intimate knowledge of an economy's workings.1/ The shadow rates used in this report were obtained from World Bank economists specializing in the countries concerned.

One of the most important shadow values is the opportunity cost of capital. This is defined as the marginal productivity of additional investment in the best alternative use. It can also be thought of as the price (or yield) of capital. In countries where capital is abundant, such as the industrialized countries of Europe, one expects the yield on capital to be relatively low. In many developing countries, however, capital is a scarce commodity and therefore has a relatively high opportunity cost and should be used in those areas where it produces a very high return. Therefore, a least-cost comparison of alternatives that differ in their capital intensity should reflect the real cost of capital to the economy rather than use capital's market price.2/

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1. See Squire and van der Tak, Economic Analysis of Projects, pp. 99-132, for a description of the data requirements and methods of computing conversion factors.

2. For example, in one Islamic country market interest rates are set by law at 3 percent, whereas the opportunity cost of capital has been estimated at 16 percent. With such a wide discrepancy, it is very likely that the least-cost alternative using the market discount rate would be much more capital intensive than that selected by an economic least-cost analysis.

The third principle of economic costing is that incremental rather than average historical costs should be used. This principle rests upon the idea that sunk costs (those already incurred) should be disregarded in making decisions about future investments. Analysis of the real resource cost of a given technology must value the components of that technology at their actual replacement cost rather than at their historical price. In the case of sanitation systems, this is particularly important in the evaluation of water costs. Because cities develop their least expensive sources of water first, it generally becomes more and more costly (even excluding the effect of inflation) to produce and deliver an additional liter of water as the city's demand grows. The decision to install a water-carried sewerage system will increase the newly served population's water consumption by around 50 to 70 percent.1/

Special Problems of Sanitation Projects

The application of these costing principles to sanitation projects is difficult for several reasons. The chief difficulty is the problem of finding a scaling variable that allows comparison among diverse technologies that are designed to serve different numbers of people. On-site systems, such as pit latrines, are generally designed for a single family or household. The latrine's overall lifetime will depend on how many people use it. The life of some components (such as a vent pipe), however, may be independent of usage, so that the annuitized per capita construction cost of a latrine used by six people will probably not be the same as that of one used by ten people. For this reason, all costs presented in this chapter are given per household as well as per capita units.

A further difficulty is that the per capita construction cost of a sewerage system will vary considerably as the design population varies. In addition, it would be misleading to use the design population in deriving per capita sewerage costs to compare with those of a pit latrine. In the case of sewerage, the benefits only reach a portion of the users during the early years. The latrine's "design population," in contrast, is served immediately upon completion of the facility. Any technology that exhibits economies of scale will result in a diversion of the cost and benefit streams. With such a facility, the investment costs are incurred at the beginning of its lifetime and the benefits (services) are realized gradually over time. A schematic representation of this diversion between cost and benefits streams is provided in figure 3-1.

Just as costs incurred in the future have a lower present value than those incurred today, benefits received in the future are less valuable than those received immediately. To divide the cost of a sewerage system by its design population would understate its real per capita cost when compared with that of a system that is fully utilized upon completion.

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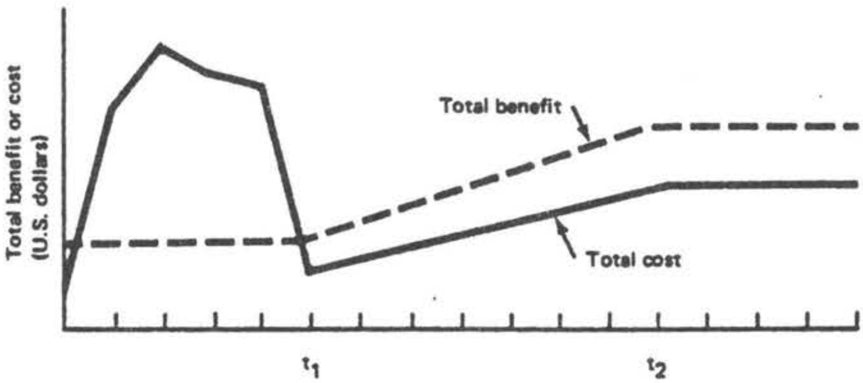
1. This percentage is based on data from developed countries, which shows that the water used to flush toilets is around 40 percent of total domestic water use (excluding garden watering).

Figure 3–1. Benefit–Cost Divergence Over Time




$t_1$, Time of sanitation facility's commissioning; $t_2$, time of full use of facility's capacity.

A good method that has been used to overcome the problem of rates of capacity utilization differing across systems is the average incremental cost (AIC) approach.[1] The per capita AIC of a system is calculated by dividing the sum of the present value of construction (C) and incremental operating and maintenance (O) costs by the sum of the present value of incremental persons served (P):

$$AIC_t = \frac{\sum_{t=1}^{t=T} (C_t + O_t)/(1+r)^{t-1}}{\sum_{t=1}^{t=T} N_t/(1+r)^{t-1}}$$

in which R is the opportunity cost of capital and T is the life of the facility. All costs are in constant (noninflated) prices and have been appropriately shadow priced. Note that, for a system that is fully utilized immediately, this calculation reduces to the familiar calculation of annuitized capital and incremental operating and maintenance costs divided by the design population.

In practice it is often easier to calculate the AIC on the basis of a volume measure (for example, cubic meters) rather than by persons served. For the sewerage costs in this study from the cities of Gaborone, Khartoum, Malacca, Managua, and Ndola, the AIC per cubic meter was calculated first because year-by-year projections of treated wastewater were available. These volumetric costs were then transformed into per capita and per household costs using per capita demand figures.

The AIC method is useful in deriving per capita costs that can be meaningfully compared with those of systems with different rates

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1. See R. J. Saunders, J. J. Warford, and P. C. Mann, Alternative Concepts of Marginal Cost for Public Utility Pricing: Problems of Application in the Water Supply Sector, World Bank Staff Working Paper, no. 259 (Washington, D.C.: The World Bank, May 1977).

of use. This is especially important in evaluating sanitation systems because of the large variation in economies of scale (for example, sewerage versus on-site systems or cartage). Whereas economies of scale are often the engineer's best friend (in the sense that he can overdesign "to be on the safe side" without incurring unduly large increases in cost), they cause institutional and financial headaches when demand assumptions turn out to be optimistic or the city grows in a different direction from the one expected. Because of the inflexibility of large-scale sanitation systems once they are built, their financial feasibility and even technical success are extremely sensitive to the assumptions used in the design analysis. In communities where there is no demand history on which to base forecasts, it is extremely risky to recommend a system with large economies of scale and with a correspondingly long design period.[1]

An additional problem in deriving comparable costs for sanitation systems is the differing treatment of sullage wastes. In sewerage, most septic tanks, and some aquaprivy systems, sullage is disposed of along with excreta. In most of the on-site technologies, sullage disposal must be accomplished separately, through stormwater drains or ground seepage. If stormwater drains are present (or would be constructed anyway), then the incremental cost of disposing of sullage is very small because storm drains are usually designed to handle flood peaks.[2] If sullage is left to soak into the ground, nuisance and possible health risks may be created (depending on climate, soil conditions, and groundwater tables).[3]

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1. This degree of risk can be explicitly built into the alternative selection process. Suppose technology A yields a net present value of 100 and technology B one of 900, given the demand forecast. There is a 30 percent probability that the forecast is too high and a 10 percent probability that it is too low. If it is too high, technology A's net present value drops to 30 because of its large unused capacity during the early years, whereas technology B can be modified to cut costs so that its net present value falls only to 70. If demand is too low, A's net present value falls to 90 and B's falls to 85. The weighted average, or expectetd value (E), of the net present value of the two technologies can be calculated as follows:

$$E_A = 0.3(30) + 0.1(90) + 0.6(100) = 78.0$$

$$E_B = 0.3(70) + 0.1(85) + 0.6(90) = 83.5$$

Given the uncertainty attached to the demand forecast, technology B should be selected, despite the fact that its lower present value is lower if the demand forecast is correct.

2. The environmental cost of depositing sullage into nearby watercourses must, of course, also be assessed. The limited information available on the composition of sullage wastes suggests that its health hazard is low. This should also be assessed, however, for the site in question.

3. The development of low-water-use appliances, such as showers, is a very promising means of realizing sanitation cost savings. Reducing the amount of sullage water to dispose of not only saves water but also extends the range of applicability for on-site disposal systems.

Separate disposal of sullage may be considered a positive benefit in areas where the population recycles kitchen water and bathwater to irrigate gardens or dampen dust. In such cases, the removal of sullage through the introduction of a sewerage system would produce a negative benefit. In a particular case it is not difficult for the analyst to decide how to treat costs of sullage removal when comparing different sanitation streams. For the purpose of this study, however, and because a more general comparison is required, a consistent assumption has been applied. Therefore, the costs in tables 3-1 through 3-11 include sullage disposal only if the sanitation system itself is designed to accommodate it. This is true of all of the sewerage systems, all of the septic tanks, and the Ndola and Newbussa sewered aquaprivies.

A final problem in preparing comparable cost figures for sanitation systems is the method to be used in gathering data. This study is statistically based, in contrast to a synthetic framework that develops an ideal model and tests the effects of varying assumptions. Both methods have their advantages and disadvantages. Because so little is known about the technology or costs of nonconventional sanitation systems, it was decided that a broadly based study involving many systems in many different settings would provide the best comprehensive frame for designing particular studies or, indeed, for selecting "typical" technologies and settings to proceed from in developing a synthetic model. The major disadvantage of a statistical approach, however, is that it is very difficult to identify the factors that cause increased or decreased costs because it is impossible to vary one factor at a time while holding all others constant. Cross-country comparisons can be misleading unless one is familiar with the background of the cases compared. For this reason, most technological comparisons are made within a single country--whenever possible, within the same community.

## Field Results

The costs discussed below have been disaggregated in two ways; by function and by investment versus recurrent costs. In disaggregating by function, the categories used are on-site facilities, collection, treatment, and reuse. This distinction is made primarily because disaggregating by function allows a broad examination of costs of repackaging components. For example, many treatment alternatives can be linked with a variety of collection systems, on-site facilities, or both. In addition, disaggregation by function is amendable to "value engineering" by its identification of the areas in which the greatest potential for cost savings exists. It also provides the financial analyst with a rough guide for determining the proportion of system costs that must be borne by the utility relative to the costs incurred directly by the household. The latter cost is a useful figure for estimating the willingness of the consumer to pay utility rates; this willingness will be based, in part, on the costs to the household of obtaining the private facilities that will enable it to make use of the utility's service.

The second type of disaggregation is the separation of capital and recurrent costs. The difference between technologies with high capital cost and high recurrent cost generally parallels that of capital-intensive versus labor-intensive technologies. This is because the investment costs of most systems are mainly in capital and recurrent costs are mainly in labor. The distinction is made here between investment and recurrent costs--rather than between capital and labor--partly to emphasize the main cause of the difference and partly to stress the important institutional implications of managing a system with high recurrent costs.

Comparison of costs by technology

The single most useful figure for cost comparisons of technologies is the total annual cost per household (TACH), which includes both investment and recurrent costs (properly adjusted to reflect real opportunity costs and averaged over time by the AIC method). The TACH would, however, be misleading when applied to communal facilities or cases where several households share one toilet. In those entrances, an adjusted TACH has been calculated by scaling up per capita costs by the average number of persons in a household. Because both investment and recurrent costs must be included for a least-cost comparison, and because different technologies have different lifetimes, the TACH is an annuitized (or annual) figure. It should not, however, be interpreted as an amount of money to be spent annually for a particular technology.

The TACHs obtained for ten technologies (arranged by ascending mean TACH) are summarized in table 3-1. Several summary statistics are shown because of a wide variation in the number of these studies and the range of costs.1/ Contrary to expectation, the technologies do not divide cleanly into community and individual systems when ranked according to cost. The divisions between high-, medium-, and low-cost technologies are fairly sharp, with large buffer areas available for upgrading systems. The fact that variations on septic tanks and vacuum-truck cartage appear in two categories indicates the potential for installing a low-cost facility at an early stage of development and improving its standard of service as development proceeds.

Within the low-cost group of technologies there is a fairly large variety of systems, ranging from aquaprivies and simple septic tanks to pit latrines and PF toilets. Of course, since all of the costs summarized in table 3-1 are derived from particular case studies, none can be considered an accurate representation of what it would cost to build a particular system in a different country.2/

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1. All costs presented in this chapter are in 1978 prices and U.S. dollars. For price and foreign exchange conversion factors for each country studied, see Richard Kuhlthau (ed.), Appropriate Technology for Water Supply and Sanitation, vol. 6, Country Studies in Appropriate Sanitation Alternatives, (Washington D.C.: The World Bank, 1980).

2. The anomalies introduced by aggregating countries are illustrated by a comparison of the TACHs of the pit latrine and PF toilet in table 3-1. The mean cost of the former in the seven cases studied was higher than that of the latter in its three case studies. Yet it is clear that, on any one site, a pit latrine would be cheaper than a PF toilet because of the extra components and water required for the latter.

Table 3-1. Summary of Total Annual Cost per Household (TACH) for Sanitation Technologies

(1978 U.S. dollars)

| Technology | Observations (number) | Mean | Median | Highest | Lowest |
|---|---|---|---|---|---|
| **Low-cost** | | | | | |
| Pour-flush (PF) toilet | 3 | 18.7 | 22.9 | 23.3 | 10.1 |
| Pit latrine | 7 | 28.5 | 26.0 | 56.2 | 7.6 |
| Communal septic tank a/ | 3 | 34.0 | 39.0 | 48.0 | 15.0 |
| Vacuum-truck cartage | 5 | 37.5 | 32.2 | 53.8 | 25.7 |
| Low-cost septic tank | 3 | 51.6 | 45.0 | 74.5 | 35.4 |
| Composting toilet | 3 | 55.0 | 56.2 | 74.6 | 34.3 |
| Bucket cartage a/ | 5 | 64.9 | 50.3 | 116.5 | 23.1 |
| **Medium-cost** | | | | | |
| Sewered aquaprivy a/ | 3 | 159.2 | 161.4 | 191.3 | 124.8 |
| Aquaprivy | 2 | 168.0 | 168.0 | 248.2 | 87.7 |
| Japanese vacuum-truck cartage | 4 | 187.7 | 193.4 | 210.4 | 171.8 |
| **High-cost** | | | | | |
| Septic tank | 4 | 369.2 | 370.0 | 390.3 | 306.0 |
| Sewerage | 8 | 400.3 | 362.1 | 641.3 | 142.2 |

a. Per capita costs were used and scaled up by the cross-country average of 6 persons per household to account for large differences in the number of users.

Cross-country cost comparison

It is useful to consider the overall variation of cost in different countries before making an examination of the cost data for each technology. The magnitude of the total variation is quite large, as is indicated in the last two columns of table 3-1.

A sampling of the most important input costs across countries is shown in table 3-2. A wide range is exhibited in three of the main inputs to sanitation systems: unskilled labor, water, and land. The sensitivity of system costs to changes in factor input prices is not easy to investigate in a cross-country study such as this. The final section of this chapter, however, presents general conclusions on cost sensitivities.

Investment and recurrent costs

The distinction between investment and recurrent costs is an important one for both financial and technical reasons. A city or community with very limited present fiscal resources but with a good growth potential might find it impossible to raise the investment finance to build a system with large initial capital requirements, but it could build and maintain another system (with the same TACH) whose recurrent costs were relatively high. Conversely, a major city in a developing country that has access to external sources of funds might prefer to build an expensive system initially with the help of grant or low-interest loan capital and possibly reduce its need for recurrent funds.[1] The breakdown for investments and recurrent costs for the technologies studied is presented in table 3-3. There is no consistent relation between the overall cost of systems and their percentage of investment or recurrent costs. This somewhat surprising lack of correlation is in part because of the nature of the figure for recurrent cost. Because economic--rather than strictly financial--costs are used in this study, a major item is included in recurrent cost that typically does not appear in engineering cost estimates: the water used to flush some systems. In order to see how the inclusion of the cost of water for flushing would affect the breakdown of investment versus recurrent costs, separate calculations excluding water costs were made for those six systems that require water.[2]

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1. Note that this would not be an economically efficient solution because the opportunity cost of capital does not depend on the source of funds or the terms of a particular loan package.

2. As would be expected, those systems requiring the most flushing water are most affected by the change. The recurrent cost component of sewerage systems drops from 33 to 19 percent, whereas that of septic tanks falls from 36 to 24 percent.

Table 3-2. Selected Input Costs and Conversion Factors for Sanitation

(1978 U.S. dollars)

| Country | Unskilled labor (daily) a/ | Water (per cubic meter) b/ | Land (per hectare) c/ | Capital (percent) | Conversion factors: Unskilled labor | Conversion factors: Foreign exchange |
|---|---|---|---|---|---|---|
| Japan | 10.50 | 0.85 d/ | n.a. | 10 | 1.0 | 1.0 |
| Taiwan | 3.95 | 0.40 d/ | 800 | 12 | 0.9 | 1.0 |
| Korea | 4.00 | n.a. | n.a. | 14 | 0.8 | 1.12 |
| Indonesia | 1.80 | 0.11 d/ | n.a. | 20 | 1.0 | 1.0 |
| Malaysia | 3.40 | 0.35 | 200 | 12 | 1.0 | 1.0 |
| Sudan | 1.90 | 0.39 d/ | 100 | 16 | 1.0 | 1.25 |
| Zambia | 4.00 | 0.70 | 65 | 12 | 0.6 | 1.25 |
| Botswana | 1.80 | 0.38 | 100 | 10 | 0.7 | 1.0 |
| Nigeria | 3.40 | 1.60 | n.a. | 12 | 0.8 | 1.15 |
| Ghana | 5.50 | n.a. | 65 | 12 | 0.8 | 1.75 |
| Colombia | 3.20 | 0.30 | n.a. | 12 | 0.3 | 1.0 |
| Nicaragua | 2.10 | 0.13 | n.a. | 20 | 0.5 e/ | 1.1 |
| Mean | 3.80 | 0.36 | 222 | | | |
| Median | 3.40 | 0.39 | 100 | | | |
| Range | 8.70 | 1.49 | 735 | | | |

n.a. Not available.

Source: World Bank country economists and field consultants reporting on case studies. For more detail, see Richard Kuhlthau (ed.), Appropriate Technology for Water Supply and Sanitation, vol. 6, Country Studies in Sanitation Alternatives (Washington, D.C.: The World Bank, Transportation, Water, and Telecommunications Department, 1980).

a. Market price in studied communities including benefit package where applicable.
b. Average incremental cost (AIC).
c. Estimated opportunity cost; collected in those cases where land costs were part of waste treatment.
d. Average of several community studies.
e. Unskilled rural labor only; for urban unskilled labor, conversion factor is 1.

Table 3-3. Average Annual Investment and Recurrent Cost per Household for Sanitation Technologies

(1978 U.S. dollars)

| Technology | Mean TACH | Investment cost | Recurrent cost | Percentage of total investment | Percentage of total recurrent |
|---|---|---|---|---|---|
| Low-cost | | | | | |
| PF toilets | 18.7 | 13.2 | 5.5 | 71 | 29 |
| Pit latrine | 28.5 | 28.4 | 0.1 | 100 | ... |
| Communal toilet | 34.0 | 24.2 | 9.8 | 71 | 29 |
| Vacuum-truck cartage | 37.5 | 18.1 | 19.3 | 48 | 52 |
| Low-cost septic tank | 51.6 | 40.9 | 10.7 | 79 | 21 |
| Composting toilet | 55.0 | 50.9 | 4.8 | 92 | 8 |
| Bucket cartage a/ | 64.9 | 36.9 | 28.0 | 57 | 43 |
| Medium-cost | | | | | |
| Sewered aquaprivy a/ | 159.2 | 124.6 | 34.6 | 78 | 22 |
| Aquaprivy | 168.0 | 161.7 | 6.3 | 96 | 4 |
| Japanese vacuum-truck cartage | 187.7 | 127.7 | 60.0 | 68 | 32 |
| High-cost | | | | | |
| Septic tank | 369.2 | 227.3 | 141.9 | 62 | 38 |
| Sewerage | 400.3 | 269.9 | 130.4 | 67 | 33 |

... Negligible.

a. Per capita costs were used and scaled up by the cross-country average of six persons per household to account for large differences in the number of users.

The overall conclusion from table 3-3 is that nearly all of the sanitation systems are relatively high in investment, as opposed to recurrent, cost. If costs of water for flushing are excluded from recurrent costs, as is done in table 3-4, only vacuum-truck cartage and bucket systems show recurrent costs of more than 30 percent.

There are several implications of this concentration in investment costs. One is that there is probably scope for external financing regardless of which technology is chosen by a particular city or community. High initial costs almost invariably require some sort of financial mechanism to smooth payments so that they are more in line with benefits to (and are paid for by) the consumers. A second implication is that, where funding constraints are binding, the size of the initial investment requirement may be the most important determinant of technological choice. There is relatively little scope for substituting a system of higher recurrent cost. In that sense, a distinction based on the relative importance of investment and recurrent costs of different systems becomes moot. Whereas sewerage and PF toilets both entail recurrent costs of about 30 percent of their respective TACHs, the important point is that the investment cost (per household) of the former is more than 20 times larger than that of the latter.

Considering only the community systems covered in this study, the distinction between investment and recurrent costs becomes more relevant. The three cartage systems are much more intensive in recurrent costs than are the water-carried systems (or even communal latrines) when water costs are excluded. The financial result of a system with high investment cost is that relatively fixed costs must be met regardless of how much service is provided (or how many new connections are made). This can put a real financial burden on the utility or municipality during the early years of such a system. It also means that the financial viability of the utility is extremely sensitive to the accuracy of the demand forecast. With systems having high recurrent costs (such as cartage), the response to slow growth in demand is delayed investment in new trucks and fewer new workers hired. With systems having high investment costs, however, there is little scope for reducing costs in response to reduced demand. This is perhaps not a major worry in cities that already have sewerage in some areas, for example, and are ready to expand their system. In cities of the developing world, however, where no such service already exists (and where the ability to pay for the necessary on-site investment is limited), it is extremely risky to choose a system that has a high investment cost on the basis of hypothetical demand projections. In such a case, economies of scale are a two-edged sword.

On-site, collection, and treatment costs.

The separation of TACH into its functional components is useful in determining where to direct the design effort in an attempt to reduce costs. For most of the individual systems, of course, all (or greater than 90 percent) of the cost is on-site. Thus, an investigation of the potential for cost reduction must concentrate on the on-site system components and the materials and methods used to produce and install them.

Table 3-4. Percentage Investment and Recurrent Cost of Community Sanitation System

| Technology | Percentage of Total Investment cost | Recurrent cost |
|---|---|---|
| Sewerage | 81 | 19 |
| Sewered aquaprivy | 84 | 16 |
| Japanese vacuum-truck cartage | 68 | 32 |
| Other vacuum-truck cartage | 48 | 52 |
| Bucket cartage | 57 | 43 |
| Communal toilets | 88 | 12 |

Note: Percentages are calculated excluding costs of water used in flushing.

The functional breakdown of costs for the twelve systems is given in table 3-5. Even among the six community systems, on-site costs account for at least 45 percent of the total. The size of the costs incurred by the household in total system costs shows the importance of finding ways for funding on-site facilities. The very low connection rates of many sewerage systems in developing countries (even when connection is a legal requirement) can probably be explained by the large household expenditure involved.

Two of the systems, sewerage and vacuum cartage, exhibit an interesting variety of cost patterns across the case studies. The sewerage costs for the eight cities covered are shown in table 3-6. This variation is caused by the more elaborate internal plumbing facilities that are found in middle-class Japanese homes and the high cost and relatively large amount of flushing water required by the Japanese systems.[1] The investment costs of collection for the sewerage systems do not fall into any clear groupings but vary with the terrain and population density of the cities. Recurrent costs of collection are uniformly low. In treatment costs there is an expected split between those with conventional plants (activated sludge or trickling filter) and those with ponds.

The costs from the case studies involving vacuum-truck cartage are shown in table 3-7. The major difference between the Japanese systems and the others is in the investment cost to the household. The collection vehicles used in Japan are more expensive than those used elsewhere, and labor costs for vehicle operation and maintenance are much higher. These two factors, however, are far outweighed by the very large differential in household facility costs. This has important implications for the upgrading of cartage systems. As long as the utility provides efficient and hygienic vacuum truck collection, individual households have the option of improving their individual facilities as their income permits.

## Controlled Comparisons

As mentioned previously, the major disadvantages of conducting cross-country comparisons of technology is that it is difficult to draw conclusions about how particular technologies would compare in a given country or site. Analysis of a single country or site requires controlled tests. Fortunately, the present study did include selected cases in which various technologies were competing within a small geographic area. Two controlled comparisons are discussed below: one between sewerage and cartage systems in the same cities and one between four on-site technologies and sewerage.

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1. Twenty liters per flush compared with 8-15 liters in the other countries.

Table 3-5. Average Annual On-site, Collection, and Treatment Costs per Household
(1978 U.S. dollars)

| Technology | Mean TACH | On-site | Collection | Treatment | Percentage of Total: On-site | Percentage of Total: Collection | Percentage of Total: Treatment |
|---|---|---|---|---|---|---|---|
| **Low-cost** | | | | | | | |
| PF toilet | 18.7 | 18.7 | ... | ... | 100 | ... | ... |
| Pit privy | 28.5 | 28.5 | ... | ... | 100 | ... | ... |
| Communal toilet | 34.0 | 34.0 | ... | ... | 100 | ... | ... |
| Vacuum-truck cartage | 37.5 | 16.8 | 14.0 | 6.6 | 45 | 37 | 18 |
| Low-cost septic tanks | 51.6 | 51.6 | ... | ... | 100 | ... | ... |
| Composting toilets | 55.0 | 47.0 | ... | 8.0 | 85 | ... | 15 |
| Bucket cartage a/ | 64.9 | 32.9 | 26.0 | 6.0 | 51 | 40 | 9 |
| **Medium-cost** | | | | | | | |
| Sewered aquaprivy a/ | 159.2 | 89.8 | 39.2 | 30.2 | 56 | 25 | 19 |
| Aquaprivy | 168.0 | 168.0 | ... | ... | 100 | ... | ... |
| Japanese vacuum truck | 187.7 | 128.0 | 34.0 | 26.0 | 68 | 18 | 14 |
| **High-cost** | | | | | | | |
| Septic tanks | 369.2 | 332.3 | 25.6 | 11.3 | 90 | 7 | 3 |
| Sewerage | 400.3 | 201.6 | 82.8 | 115.9 | 50 | 21 | 29 |

... Negligible.

a. Per capita costs were used and scaled up by the cross-country average of six persons per household to account for large differences in the number of users.

Table 3-6. Annual Sewerage Costs per Household
(1978 U.S. dollars)

| | On-site | | | Collection | | Treatment | | |
|---|---|---|---|---|---|---|---|---|
| City | Investment | Recurrent | Flushing water | Investment | Recurrent | Investment | Recurrent | Total |
| Kyoto, Japan | 166.1 | 41.3 | 126.4 | 88.9 | 12.1 | 147.1 | 59.4 | 641.3 |
| Hannoh, Japan | 146.0 | 45.5 | 112.8 | 58.5 | 13.3 | 96.0 | 89.4 | 561.5 |
| Higashi Kurume, Japan | 153.4 | 37.6 | 71.3 | 36.2 | 3.9 | 55.4 | 42.6 | 400.4 |
| Khartoum, Sudan | 89.2 | ... | 32.3 | 174.3 | 8.5 | 255.0 | 12.8 | 572.1 |
| Managua, Nicaragua | 80.8 | 7.1 | 10.2 | 105.1 | 2.6 | 89.8 | 28.2 | 323.8 |
| Ndola, Zambia | 105.8 | 17.6 | 153.3 | 23.5 | 5.9 | 5.9 | 5.9 | 217.9 |
| Malacca, Malaysia a/ | 98.9 | 10.3 | 34.2 | 56.9 | 25.1 | 8.2 | 9.3 | 242.9 |
| Gaborone, Botswana | 61.4 | ... | 11.0 | 40.9 | 6.6 | 16.2 | 6.1 | 142.2 |

... Negligible.

a. Based on a sewerage master plan.

Table 3-7. Annual Vacuum-Cartage Costs per Household
(1978 U.S. dollars)

| City | Population served (thousands) | On-site | | Costs/Collection | | Treatment | | Total |
|---|---|---|---|---|---|---|---|---|
| | | Investment | Recurrent | Investment | Recurrent | Investment | Recurrent | |
| Kyoto, Japan | 1,462 | 92.5 | 18.5 | 6.1 | 35.3 | 15.3 | 4.1 | 171.8 |
| Hannoh, Japan | 56 | 113.3 | 22.7 | 7.5 | 43.3 | 18.7 | 5.0 | 210.4 |
| Higashi Kurume, Japan | 103 | 118.2 | 18.8 | 3.8 | 16.5 | 16.9 | 18.0 | 192.2 |
| Tatayama, Japan | 57 | 106.3 | 20.0 | 3.3 | 21.2 | 8.9 | 16.8 | 176.5 |
| Keelong, Taiwan | 342 | 9.6 | 2.2 | 1.9 | 12.2 | 8.9 | 2.4 | 32.2 |
| Tainan, Taiwan | 85 | 9.6 | 2.2 | 2.2 | 15.3 | ... | ... | 29.2 |
| Pingtung, Taiwan | 175 | 9.6 | 2.2 | 0.8 | 8.1 | 2.4 | 2.6 | 25.7 |
| Chuncheon, Korea | 141 | 20.9 | 6.6 | 0.1 | 5.7 | 5.0 | 8.1 | 46.4 |
| Malacca, Malaysia a/ | 95 | 13.5 | 7.8 | 3.9 | 19.9 | 7.3 | 1.4 | 53.8 |

... Negligible.

a. Based on a hypothetical system design.

Sewerage versus cartage

Three of the Japanese communities studied were served by both sewerage and vacuum-truck cartage. In Kyoto and Higashi-Kurume, about 45 percent of the population is connected to public sewers and an equal number enjoys vacuum-truck collection. In Hannoh, nearly 60 percent are served by vacuum trucks, 15 percent by sewerage (with the rest using individual systems). The TACHs of the two systems are as follows (TACHs are in U.S. dollars):

| | TACH | |
|---|---|---|
| City | Sewerage | Cartage |
| Kyoto | 641.3 | 171.8 |
| Higashi-Kurume | 400.4 | 192.2 |
| Hannoh | 561.5 | 210.4 |
| Average | 534.4 | 191.5 |

In Kyoto, where sewerage is especially expensive (partly because of the high average incremental cost of water), cartage costs only about one-fourth as much per household. In the other two cities, cartage costs are about half those of sewerage.1/

There is a growing demand on the part of Japanese householders in Kyoto for the sewer system to be extended to areas presently served by night-soil collection. Because the tabulation above shows that sewerage costs nearly four times as much as cartage, it might seem that people who can afford it value the increased convenience of sewerage almost at least as much as the difference in cost. But, it is worth repeating that the costs developed in this economic comparison reflect real resource costs to the economy, not financial costs actually charged to households. In Japan, as in many other countries, the construction costs of sewers and treatment facilities are heavily subsidized by the national government. In addition, the city of Kyoto provides municipal loans at no interest for the installation of a flush toilet and indoor plumbing, and the sewerage authority in Kyoto operates at a substantial loss (based on its

1. In all three cities the night soil from the cartage systems is treated by dilution and transferred to the sewage treatment plant. It is likely that cheaper treatment methods could be used in cities without sewerage systems.

sewerage revenues). In fiscal year 1976, subsidies from other city accounts represented 47 percent of Kyoto's total revenues. Thus, the financial cost of sewerage (and also of cartage) in Kyoto to the householder significantly understates its true economic cost.1/

A more detailed controlled comparison between sewerage and vacuum-truck cartage was carried out for Malacca, a city of about 90,000 in Malaysia. Currently the city is served by a combination of bucket latrines, septic tanks, PF toilets, and privies directly overhanging the river. The wastes from kitchen and bath are discharged to open, surface water drains. A sewerage master plan was prepared for the city in 1968, but --because of lack of money, potential technical problems stemming from a high water table, and community dissatisfaction with the proposed marine outfall--there has been no follow-up implementation of the study's recommendations. A Malaysian engineer who was familiar with the local conditions and history was asked to prepare an alternative master plan to serve the city with vacuum-truck collection and to compare the costs with those of the sewerage study (adjusted for inflation).

The annual costs of waste disposal per household for the two systems in Malacca are shown in table 3-8. No social weighting for employment benefits has been used in calculating these costs, but the cartage system would employ more than twice as many people as the sewerage system, including 100 general laborers (compared with 14 for sewerage).

On-site systems

A controlled cost comparison of on-site systems is possible with the results of the study of Gaborone, Botswana. The International Development Research Centre sponsored an experimental latrine program in Botswana to build and monitor a variety of on-site designs. The four designs that performed best were costed for inclusion in this study. While the costs for all systems appear high relative to those for similar systems in other countries, this should not affect the relative comparison of technologies. The high costs are because of the pilot nature of the project, the difficulty of obtaining even simple inputs (such as cement) locally, and some overdesign (particularly in the superstructure) of the systems. The results of the costing analysis for ventilated improved pit (VIP) latrines, aquaprivies, double-vault composting (DVC) latrines and Reed Odorless Earth Closets (ROECs) in Gaborone are shown in table 3-9. To enable a better comparison with the cost of sewerage in Gaborone, the cost of substructures alone are also shown.

No analysis of the benefits derived from the compost eventually available from the DVC was possible because all experimental units were recently constructed. Design parameters suggest that the DVC would require emptying only at 5-year intervals, so that the amount a firm analysis of the benefits from composting cannot be undertaken until more operational experience is available. It is unlikely, however, that such benefits would affect the net cost ranking of these alternatives.

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1. See Chapter 6 for a discussion of the effect of such policies on the choice of appropriate technologies.

Table 3-8. Comparative TACHs of Sewerage and Vacuum-Truck Cartage in Malacca, Malaysia (1978 U.S. dollars)

| TACH | Sewerage | Cartage |
|---|---|---|
| On-site | | |
| Investment | 98.9 | 13.5 |
| Recurrent | 43.5 a/ | 7.8 |
| Collection | | |
| Investment | 56.9 | 3.9 |
| Recurrent | 25.1 | 19.9 |
| Treatment | | |
| Investment | 8.2 | 7.3 |
| Recurrent | 9.3 | 1.4 |
| Total | 242.9 | 53.8 |

a. Includes $34.2 for water used in flushing.

Table 3-9. Comparative TACHs of On-Site Systems and Sewerage in Gaborone, Botswana
(1978 U.S. dollars)

| Technology | TACH | Annual substructure cost per household |
|---|---|---|
| Ventilated improved pit (VIP) latrine | 56.2 | 21.3 |
| Reed Odorless Earth Closet (ROEC) | 56.2 | 21.3 |
| Double-vault composting (DVC) latrine | 74.6 | 38.6 |
| Aquaprivy | 87.7 | 50.6 |
| Sewerage | 142.2 a/ | 142.2 |

a. Superstructure costs are included in the house construction.

The conclusions from these three exercises in controlled costing are in line with those of the cross-country, comparative analyses of technologies. Sewerage costs are at least twice, and generally four to five times, as large as those of well-run, vacuum-truck cartage systems. On-site technologies can effect even larger savings, particularly if superstructure costs can be kept low.

## Benefits from Reuse

As discussed earlier in this chapter, it is assumed in this study that the major benefits of sanitation systems are related to health and convenience and therefore cannot be meaningfully quantified. Some of the technologies studied, however, provide economic benefits in the form of fertilizer or biogas, to which a monetary value can be assigned.[1] One of the original aims of the study, in fact, was to determine the scope for offsetting sanitation costs with reuse benefits.

Unfortunately, it has been very difficult to locate working examples of human waste disposal systems with a sizable reuse component in developing countries. A few of the sewage treatment systems produce small amounts of methane from their digestors, and this is used for heating. There is some demand from orchard farmers in Korea for the night soil collected by vacuum truck, but the municipality makes no effort to set up a delivery system or to charge a market-clearing price. The composting latrines built in Botswana are too new to yield useful data on reuse. All except one of the biogas units observed ran on animal, rather than human waste. In short, although there is much experimental and theoretical information on the economic potential of reuse technologies, there is a dearth of empirical data on actual experience.[2]

All of the significant reuse technologies found in this study were located in the Far East. Biogas plants were found at the household level in Taiwan and Korea. Municipal systems involving reuse of human excreta as an input into agriculture and aquaculture were found in Taiwan and, to a lesser extent, in Indonesia. In none of these cases was the reuse element developed to its full potential through marketing analyses of optimal pricing strategies. The cases described below, therefore, should not be taken as examples of how much (or, more accurately, how little) reuse benefits can affect the economics of sanitation.

### Biogas

There were about thirty family-size biogas units in operation in one of the Taiwanese communities studied in 1977. Each biogas unit consisted of a 6-foot-diameter, excavated digester with an inverted steel lid that floated up and down on a water seal. The methane generated was transported to the kitchen through a pressure hose connected to the

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1. Other potential reclamation benefits include stock and garden watering with sullage and irrigation with sewage.

2. The obvious exception to this statement is the experience of China, but scientific documentation of Chinese experience is rare, and it was not possible to include first-hand observation in this study. Much data are also available on biogas production in India, but most units use animal instead of human excreta.

outlet pipe at the top of the inverted lid. The digester was emptied twice a year, and the sludge was sold to neighboring farmers. All of the digesters studied ran on a mixture of human and animal wastes. The usual input to a unit was the night soil from five persons and the manure from five pigs. This input loading produced sufficient gas for cooking purposes all year for a family of five, a replacement for the 20-kilogram cylinder of liquid petroleum gas formerly purchased each month. The net cost of a typical biogas unit in Taiwan is shown in table 3-10. This net cost does not represent the full cost of the total system of hog raising-excreta disposal biogas production. The cost of hog feed and upkeep is not included, nor is the benefit from the sale of the animals.

In addition, although the net cost of this sanitation system is attractively low compared with that of the other units considered above, its initial investment cost is very high. In a subsistence economy, large investment costs may present an insurmountable obstacle to the adoption of a low-cost system unless subsidized loan capital can be made available or less expensive designs developed. The requirement for such large volumes of animal waste is also likely to exclude the lowest income classes, who generally do not own animals (or land on which to build the digester). Furthermore, the fact that this biogas unit is economically attractive on a household scale does not imply that it would be advantageous on a community scale. Aside from the technical questions of the economies of scale of the digester itself, the collection and transportation of human and animal wastes to a single point and the subsequent redistribution of gas would involve large capital outlays and operating requirements that are avoided by a single family unit located in the courtyard of the house.

A second case of household biogas production was observed in Korea. There, the family claimed to be using only human excreta and kitchen wastes to stock the unit. It produced sufficient gas to satisfy all of the cooking needs during 9 months of the year. Insufficient cost data were available, however, to permit a calculation of net cost.

Agricultural reuse

Reuse of composted night soil as fertilizer is also practiced at the household level in rural areas of Korea. The large size of household pit privies in two rural villages studied was puzzling until it was discovered that the farmers deposited the animal wastes from nearby cattle pens into the pits and then allowed the entire quantity to "compost" over a 6- to 12-month period before spreading it on the vegetable fields and orchards. Based on the Korean government's imputed cost of such organic fertilizer, the composting operation yielded the farmer an annual net benefit of $37 on an annual cost of $34. These figures do not include any cost for the farmer's time in digging out the latrine and transporting the compost to the field. Nonetheless, they indicate the potential for agricultural reuse at the household level in rural areas.

Table 3-10. Net Cost of Household Biogas Unit, Taiwan
(1978 U.S. dollars)

| Item | Total cost | Annual cost | Lifetime (years) |
|---|---|---|---|
| Cost | | | |
| Construction a/ | 236.0 | 31.6 | 20 |
| Land (for 15 sq. meters) | 348.0 | 41.8 | Infinite |
| Annual desludging | 16.6 | 16.6 | - - - |
| TACH | | 90.0 | |
| Benefit | | | |
| Biogas (12 cylinders of liquid petroleum gas at 6.25) | | 75.0 | - - - |
| Net annual cost per household | | 4.0 | |

--- Not applicable.

a. Includes household latrine facilities.

At the community level, again, very few data are available. In Chuncheon, Korea, some of the night soil collected by vacuum truck is sold to farmers (before treatment) for about $7.00 per truck (or $3.50 per cubic meter). At this rate, demand is sufficient to absorb about half of the night soil produced by the city. Because the demand is seasonal, the night soil treatment plant, which was designed for peak volumes, operates inefficiently during the spring and summer months. There is very little net benefit, therefore, to the city (about 3 percent of the cost on an annual basis) from the sale of untreated night soil, and the health hazards to the farmer from handling it are probably considerable. If a simple composting treatment plant had been built instead of the two-stage digestor, a market for treated night soil might have developed that would have minimized sanitation costs to the community while providing a safe and valuable product to nearby farmers.

### Aquacultural reuse

The best case study involving community scale reuse was conducted in Tainan, Taiwan. Both public and private night-soil collectors operate there, and untreated night soil is sold primarily to fish farmers. The private collectors work only during the 10 months of the year in which there is a demand for night soil. The public system, of course, operates year-round and is able to sell about 80 percent of its total collection. The public system charges $0.65 per ton plus $0.57 per kilometer for transport costs, whereas the private collectors charge $7.00 per ton inclusive of transport (most trips were less than 10 kilometers).

No investment or operating costs were available on the private collectors. The TACH of the public system was $28.85, and the sale of night soil during the 10 months of the year yielded $1.28 on a household basis. Because the private operators presumably earn a positive income on their operations, the public system must either incur significantly higher costs or charge too little for its product, or both.

## Financial Implications

The purpose of deriving economic costs is to make a meaningful, least-cost comparison among alternatives. Such a comparison is extremely useful to the planner and policymaker. The consumer, however, is much more interested in financial costs--that is, what he will be asked to pay for the system and how the payment will be spread over time. The difficulty in developing financial costs is that they are entirely dependent upon policy variables that can change dramatically. Whereas economic costs are based on the physical conditions of the community (for example, its abundance or scarcity of labor, water, and so forth) and are therefore quite objective, financial costs are entirely subject to interest-rate policy, loan maturities, central government subsidies, and the like.

The financial cost of a sewerage system for a community can be zero if the central government has a policy of paying for such systems out of the general tax fund.

To promote the economically efficient allocation of resources, financial costs should certainly reflect the economic costs as closely as possible, given the government's equity goals and the degree of distortion in other prices in the economy. This correspondence could be accomplished with sewerage, for example, by setting a surcharge on the water bills of connected consumers that is equal to the AIC of sewerage per cubic meter of water consumed.1/ In the case of most on-site systems, the consumer would pay to construct the original facility (either initially or through a loan at an interest rate reflecting the opportunity cost of capital) and then pay a periodic sum to cover the facility's operation and maintenance expenses (if any). In cases such as these, the financial cost would be identical to the economic cost except for any taxes and shadow pricing of inputs that must be purchased in the market.2/ To the extent that they account for a significant part of total economic costs, financial costs may be above or below economic costs.

In deriving financial costs in any particular case, it is necessary for the analyst to consult with officials of the central and local government to determine their financial policies and noneconomic objectives. If the government places a high priority on satisfying the basic needs of all of its citizens, then it may be willing to subsidize part or all of the construction costs of a simple sanitation system. The general policy of international lending agencies such as the World Bank is that, if the cost of the minimal sanitation facility necessary to permit adequate health is more than a small part of the household income of the lower income consumer (say, 5-10 percent), then the central or local government should attempt to subsidize its construction to make the facility affordable. If, however, some consumers wish to have better or more convenient facilities, they should pay the additional cost themselves. Similarly, if more affluent communities decide that, beyond meeting basic health needs, they wish to safeguard the cleanliness of their rivers or general environment by building a more expensive sanitation system, then they should pay for that system either through direct charges to users or through general municipal revenues. Because the majority of the poorest people in most countries live in rural areas, it is usually not appropriate to subsidize urban services from national tax revenues.

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1. Suppose, for example, that the AIC of sewerage is $1.00 per cubic meter of sewage collected and treated. Because water rather than sewage is metered, this AIC must be related to the water consumed. If, for a given city, sewage flows are 75 percent of water consumption, then the sewerage surcharge should be $0.75 per cubic meter of water consumed.

2. Note that the shadow price of capital may be reflected in the financial cost by using it as the interest rate at which money is loaned to construct facilities. If market rates are lower, however, the consumers will presumably borrow the money elsewhere and pay for the new facility immediately. Shadow rates for labor and water (the other important inputs in this analysis) cannot be incorporated into financial costs if the consumer pays for them separately.

Because financial costs are dependent upon policy decisions, it is not possible to present comparable financial costs of the various technologies in the same way that economic costs can be developed. It is, however, possible to use the economic costs to derive total investment costs per household that will provide a basis for the financial comparison of alternatives. The other useful figure to be extracted from economic costs is the annual recurrent cost (with water costs shown separately), which will give an indication of periodic financial requirements. The financial requirements for the various low-, medium- and high-cost systems examined are given in table 3-11.

Table 3-11. Financial Requirements for Investment and Recurrent Cost per Household
(1978 U.S. dollars)

| Technology | Total investment cost (1) | Monthly recurrent cost (2) | Monthly water cost (3) | Hypothetical total monthly cost a/ (4) | Percentage of income of average low-income household b/ (5) |
|---|---|---|---|---|---|
| Low-cost | | | | | |
| PF toilet | 70.7 | 0.2 | 0.3 | 2.0 | 2 |
| Pit latrine | 123.0 | ... | ... | 2.6 | 3 |
| Communal toilet c/ | 355.2 | 0.3 | 0.6 | 8.3 | 9 |
| Vacuum-truck cartage | 107.3 | 1.6 | ... | 3.8 | 4 |
| Low-cost septic tanks | 204.5 | 0.4 | 0.5 | 5.2 | 6 |
| Composting toilet | 397.7 | 0.4 | ... | 8.7 | 10 |
| Bucket cartage c/ | 192.2 | 2.3 | ... | 5.0 | 6 |
| Medium-cost | | | | | |
| Sewered aquaprivy | 570.4 | 2.0 | 0.9 | 10.0 | 11 |
| Aquaprivy | 1.100.4 | 0.3 | 0.2 | 14.2 | 16 |
| Japanese vacuum-truck cartage | 709.9 | 5.0 | ... | 13.8 | 15 |
| High-cost | | | | | |
| Septic tanks | 1,645.0 | 5.9 | 5.9 | 25.8 | 51 |
| Sewerage (design population) | 1,478.6 | 5.1 | 5.7 | 23.4 | 46 |

... Negligible.

a. Assumes that investment cost is financed by loans at 8 percent of 5 years for the low-cost systems, 10 years for the medium-cost systems, and 20 years for the high-cost systems.

b. Assumes that average annual income is $180 per capita with six persons in a household.

c. Based on per capita costs scaled up to household costs to account for multiple household use in some of the case studies.

# Chapter IV

## Public Health Aspects

Improved community health is generally considered the major benefit of improved sanitation. As the discussion in the previous chapter has indicated, however, it has so far been impossible to determine precisely how much improvement in health in a given community can be attributed directly or indirectly to a sanitation improvement. Even if a figure for the health improvement could be agreed upon (for example, x fewer man-days of sickness annually), it is very difficult to assign a meaningful economic value to it. Much of the illness without the sanitation improvement would have been borne by children and others unemployed in the monetary sector. The noneconomic value to society of their improved health may be equal to that of an employed adult, but the economist has no way of quantifying such a nonmarket value. Moreover, of those man-days of illness incurred by the employed population, some (perhaps all) work is probably made up during the days following absence because of illness at no cost to society. To use an entire daily wage to value saved man-days of illness is almost certainly an overestimate. These inherent limitations of the health sciences in quantifying the effects of environmental changes on community disease profiles, and of economics in quantifying benefits which have no market value, combine to frustrate the measurement of health benefits.

Fortunately, the measurement of benefits is not the primary objective of improved sanitation; achieving the benefits is. If funds are inadequate to build and maintain the elaborate sewerage systems known to provide all these benefits, then it is essential to choose the alternative technology that will maximize the health benefits achieved with the available funds. This effort requires a more precise analysis of the relations between disease and sanitation than has been attempted in the past. Toward this end, consultants from the Ross Institute of Tropical Hygiene of the London School of Hygiene and Tropical Medicine were contracted, as part of this study, to focus specifically on the transmission process of excreta-related diseases and to investigate the relation of the various sanitation technologies described in chapter 2 to this process. Their findings are summarized below.1/

### Water and Health

Although the primary concern of the present study is sanitation, the relation between water and health should be kept in mind.2/ Water is important to health in two ways: contaminated water or insufficient amounts of water for personal hygiene can be a direct cause of disease; and the disposal of sullage (wastewater or graywater; see chapter 2, the section "Sullage Disposal") can, theoretically, serve as a transmission vehicle for some kinds of disease. For these reasons, not only poor water quality, but also too little and too much water consumption, present problems.

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1. Much of this chapter is taken from the volume issuing from the Ross Institute's study. For a complete account of the Institute's work and its bibliographic base, see Richard G. Feachem and others, Sanitation and Disease: Health Aspects of Excreta and Wastewater Management, World Bank Studies in Waste Supply and Sanitation, no. 3 (Baltimore: Johns Hopkins University Press, forthcoming).

2. For a more complete discussion of this topic, see chapter 5 in Richard G. Feachem and others, Water, Wastes, and Health in Hot Climates (Chichester: Wiley and Sons, 1977).

Available evidence indicates that most of the health benefits from safe water are attainable at service levels of 30-40 liters per capita daily on site. These service levels will provide protection against the range of water-related diseases and are adequate for the personal hygiene that will lead (with health education) to a lowered incidence of diarrheal disease and skin and eye infections. For control of the latter group, provision of water is more important than its microbiological or chemical quality. In addition, concentrations of chemicals (nitrate, for example) in drinking water in developing countries sometimes exceed the published standards or guidelines, which were developed in industrial countries. Such standards were developed in industrial countries to eliminate the risk of methemoglobinemia ("blue baby syndrome") in bottle-fed infants, but they may be less applicable in areas where infants are breastfed.

The fecal hazard of sullage has yet to be demonstrated. Crude estimates--based on data from the United States and assuming a high value of 150 liters per capita daily of sullage--indicate that per capita discharges of the indicators of bacterial pollution (fecal coliforms and fecal streptococci) in sullage are 106 and 105 bacteria per day, respectively.1/ Corresponding per capita discharges in feces are approximately 1010 for fecal coliform and 109 for fecal streptococci, some four or five orders of magnitude greater than those for sullage. This means that, even though ratios of pathogens to indicators may be higher for sick people than for healthy ones, relative risks of infection from night soil or sewage are four or five orders of magnitude greater. This is consistent with the results of the inquiry into possible differences in health profiles between people living in sewered areas and in adjacent areas with night-soil collection and sullage discharge to surface drains reported in chapter 2.

Some concern has been expressed over a possible contribution of sullage to increased populations of the Culex pipiens mosquito, which breeds in polluted water and is a vector of filariasis. The potential importance of sullage to mosquito breeding is determined by environmental factors in which low aridity and local soil permeability would allow the water to remain on the surface long enough to permit mosquito breeding. Where there are extended periods of relative drought, surface impoundments of sullage could contribute to extending periods during which mosquitoes normally breed.

In sum, although disposal of large amounts of sullage resulting from high water service levels may be provided by sewerage in densely populated areas, in areas of lower water consumption or lower population density, the problems of sullage is one of lower priority.

## Excreted Infections

Excreta are related to human disease in two ways. First, the agents of many important infections escape from the body in the excreta and thence eventually reach others. These are the excreted infections. In some cases the reservoir of infection is almost entirely in animals other than man. These are not considered here because such infections cannot be controlled through changes in practices of human excreta disposal. A number of infections for which both man and other animals serve as a reservoir, however, are included.

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1. Feachem and others, Sanitation and Disease.

Second, excreta relate to human disease because their disposal sometimes encourages the breeding of insects. These insects may be a nuisance in themselves (flies, cockroaches, mosquitoes); they may mechanically transmit excreted pathogens either on their bodies or in their intestinal tracks (cockroaches and flies); or they may be vectors for pathogens that circulate in the blood (mosquitoes).

In considering the transmission of excreted infections, the distinction between the state of being infected and the state of being diseased must be kept in mind. Very often the most important group of the population involved in transmitting an infection shows little or no sign of disease; conversely, individuals with advanced states of disease may be of little or no importance in transmission. A good example occurs in schistosomiasis, where as much as 80 percent of the total output of schistosome eggs in feces and urine reaching water from a human population may be produced by children 5-15 years old; many of these children will show minimal signs of disease. Conversely, middle-aged people with terminal disease conditions may produce few or no viable eggs.

If an excreted infection is to spread, an infective dose of the relevant agent has to pass from the excreta of a case, carrier, or reservoir of infection to the mouth or some other portal of entry of a susceptible person. Spread will depend upon the numbers of pathogens excreted, upon how these numbers change during the particular transmission route or life cycle, and upon the dose required to infect a new individual. Infective dose is in turn related to the susceptibility of the new host. Three key factors govern the probability that, for a given transmission route, the excreted pathogens from one host will form an alternative dose for another. These are latency, persistency, and multiplication. Diagramatically, the concepts can be represented thus:

```
                 (    Latency        )
                 (                   )
EXCRETED LOAD -->(    Persistence    )--> INFECTIVE DOSE
                 (                   )
                 (    Multiplication )
```

There is wide variation in the excreted load of pathogens passed by an infected person. For instance, a person infected by a small number of nematode worms may be passing a few eggs per gram of feces, whereas a cholera carrier may be excreting more than $10^6$ *Vibrio cholerae* per gram, and a case may pass $10^{13}$ vibrios per day.

Where large numbers of organisms are being passed in the feces they can give rise to high concentrations in sewage. Thus, even in England, where water use is relatively high and salmonellosis relatively rare, raw sewage may contain $10^4$ *Salmonella* per liter. At these concentrations, removal efficiencies of 99 percent in conventional sewage treatment works will still leave $10^2$ pathogenic organisms per liter in the effluent, and their implications for health will depend upon their ultimate disposal, their ability to survive or multiply, and the infective dose required.

Latency is the interval between the excretion of a pathogen and its becoming infective to a new host. Some organisms--including all excreted viruses, bacteria, and protozoa--have no latent period and are immediately infective when the excreta are passed. The requirements for the safe disposal of excreta containing these agents are far more stringent than for those helminthic infections in which there is a prolonged latent period. In particular, infections that have a considerable latent period are largely risk free in areas where night soil is being carted by vacuum truck, whereas the others constitute a major health hazard in fresh night soil. Therefore, in the environmental classification presented below the first two categories (in which no latency is observed) are separated from the remaining categories (in which a definite latent period occurs).

Persistence, or survival, of the pathogen in the environment is a measure of how quickly it dies after it has been passed in the feces. It is the single property most indicative of the fecal hazard, in that a very persistent pathogen will create a risk throughout most treatment processes and during the reuse of excreta.

A pathogen that persists outside the body only for a very short time needs to find a new susceptible host rapidly. Hence, transmission cannot follow a long route through sewage works and the final effluent disposal site back to man, but rather will occur within the family by transfer from one member to another as a consequence of poor personal hygiene. More persistent organisms can readily give rise to new cases of disease further afield, and, as survival increases, so also must concern for the ultimate disposal of the excreta.

Though it is easy to measure persistence or viability of pathogenic organisms by laboratory methods, to interpret such results it is necessary to know how many pathogens are being shed in the excreta (which is relatively easy to determine) and the infective doses for man (which is extremely difficult to discover).

Under some conditions, certain pathogens will multiply in the environment. Originally low numbers can be multiplied to produce a potentially infective dose. Multiplication can take the form of reproduction by bacteria in a favorable environment (for example, *Salmonella* on food) or of the multiplication by trematode worms in their molluscan intermediate hosts.

Among the helminths transmitted by excreta, all the trematodes infecting man undergo multiplication in aquatic snails. This introduces a prolonged latent period of a month or more while development is taking place in the snail, followed by an output of up to several thousand larvae into the environment for each egg that reached a snail.

In principle, from a knowledge of the output of pathogens in the excreta of those infected, the mean infective dose, and the extractive efficiency of the excreta treatment process, simple calculation should enable one to assess risk. In practice, disease transmission is much less predictable than this because of the variable infective dose of most pathogens and the uneven distribution of infection in the environment. Whereas the minimal infective dose for some diseases may be a single organism, or very few, the doses required in most bacterial infections are much higher. Data bearing on this are very hard to acquire, since they involve administering a known dose of a pathogen to a volunteer. Information is scanty and is generally concerned with doses required to infect, say, half those exposed, rather than a minute proportion, at a single exposure. The volunteers have usually been well-nourished adults from nonendemic areas. Such results have to be applied with great caution (if, indeed, they can be applied at all) to malnourished children continuously exposed to infection.

Host response is important in determining the result of an individual receiving a given dose of an infectious agent. In particular, acquired immunity and the relation of age to pathology are important for predicting the effects of sanitation improvements. In general, the balance between exposure to infection and a host's response to it will determine the pattern of excreta-related disease. If transmission, creating exposure to a particular infection, is low, then few people will have encountered the infection and most will be susceptible. If a sudden increase in transmission of the disease occurs, it will affect all age groups in epidemic form. Improvements in sanitation will have a great effect under these circumstances by reducing the likelihood of an epidemic and, should one incur, its magnitude.

By contrast, if transmission is very high the population will be repeatedly exposed to an infection and first acquire it in childhood. Subsequent exposures may be without effect if long-lasting immunity is acquired from the first attack. Alternatively, immunity may be cumulative from a series of attacks. The infection will always be present and is described as endemic. Under these conditions much transmission is ineffective because of human acquired immunity, and reduced transmission as a result of improved sanitation will only delay the date of infection until later in life. Large sanitary improvements will either render the infection rare or, if the disease were originally highly transmitted, make it an adult disease. Examples are typhoid, which can be completely prevented in the community by adequte management of excreta and of water supplies, and poliomyelitis virus infection, which requires extreme hygienic precautions to prevent. In practice, improved sanitation increases the disease problem by deferring infection to an age where its clinical course is more severe.

Consequences of a juvenile age-prevalence are that not only children suffer chiefly from the diseases but also they are the main sources of infection, so that the most important need for better community excreta disposal is among young children, the group perhaps least inclined to use any facilities that may be available.

Some excreted diseases are infections exclusively or almost exclusively of man, but many involve other animals either as alternatives to man as host or as hosts of other stages in the life cycle. In the case in which wild or domestic vertebrate animals act as alternative hosts, control of human excreta is not likely to achieve complete prevention of the infection. Alternatively, if the infection under consideration needs an animal host for some intermediate stage, but also requires man, then the control of human excreta can be very effective in controlling the disease.

## Environmental Classification of Excreted Infections

The list of human pathogens in excreta given in table 4-1 is essentially a biological classification. To the sanitation program planner it is interesting, but not very helpful. An environmental classification that groups excreted pathogens according to common transmission characteristics is much more helpful in predicting the health effects of sanitation improvements and understanding the health aspects of excreta and sewage treatment and reuse processes. The environmental classification presented in Table 4-2 distinguishes six categories of excreted pathogens and indicates primary means of pathogens controls.[1]

1. For a more detailed description of the environmental classification, and more complete epidemiological information on the excreta-related infections, see Feachem and others, Sanitation and Disease.

Table 4-1. Excreted Infections

| Biological Group and Organism | Disease a/ | Reservoir b/ |
|---|---|---|
| VIRUSES | | |
| Cocksackievirus | Various | Man |
| Echovirus | Various | Man |
| Hepatitus A virus | Infectious heptatitis | Man |
| Poliovirus | Poliomyelitis | Man |
| Rotavirus | Gastroenteritis in children | ? |
| BACTERIA | | |
| Campylobacter spp. | Diarrhea in children | Animals and man |
| Pathogenic Escherichia coli | Gastroenteritis | Man |
| Salmonella typhi | Typhoid fever | Man |
| S. paratyphi | Paratyphoid fever | Man |
| Other salmonellae | Food poisoning | Man and animals |
| Shigella spp. | Bacillary dysentery | Man |
| Vibrio cholerae | Cholera | Man |
| Other vibrios | Diarrhea | Man |
| Yersinia spp. | Yersiniosis | Animals and man |
| PROTOZOA | | |
| Balantidium coli | Mild diarrhea | Man and animals |
| Entamoeba histolytica | Amoebic dysentery and liver abscess | Man |
| Giardia lamblia | Diarrhea and malabsorption | Man |
| HELMINTHS | | |
| Ancylostoma duodenale | Hookworm infection | Man-soil-man |
| Ascaris lumbricoides | Ascariasis | Man-soil-man |
| Clonorchis sinensis | Clonorchiasis | Animal or man-snail-fish-man |
| Diphyllobothrium latum | Diphyllobothriasis | Animal or man-copepod fish-man |
| Enterobius vermicularis | Enterobiasis | Man-man |
| Fasciola hepatica | Fascioliasis | Sheep-snail-aquatic vegetation-man |
| Fasciolopsis buski | Fasciolopsiasis | Pig or man-snail-aquatic vegetation-man |
| Gastrodiscoides hominis | Gastrodiscoidiasis | Pig-snail-aquatic vegetation-man |
| Heterophyes spp. | Heterophyiasis | Dog or cat-snail-fish-man |
| Hymenolepis spp. | Hymenolepiasis | Man or rodent-man |
| Metagonimus yokogawai | Metagonimiasis | Dog or cat-snail-fish-man |
| Necator americanus | Hookworm infection | Man-soil-man |
| Opisthorchis felineus | Opisthorchiasis | Animal-snail-fish-man |
| O. viverrini | Opisthorchiasis | Animal-snail-fish-man |
| Paragonimus westermani | Paragonimiasis | Animal or man-snail-crayfish-man |
| Schistosoma haematobium | Schistosomiasis | Man-snail-man |
| S. mansoni | Schistosomiasis | Man-snail-man |
| S. japonicum | Schistosomiasis | Animal or man-snail-man |
| Strongyloides stercoralis | Strongyloidiasis | Man or dog (?)-man |
| Taenia saginata | Taeniasis | Man-cow-man |
| T. solium | Taeniasis | Man-pig-man or man-man |
| Trichuris trichiura | Trichuriasis | Man-soil-man |

? Uncertain

a. With all diseases listed, a symptomless human carrier state exists.

b. For helminths, the transmission process is given.

Source: Richard G. Feachem and others, Sanitation and Disease: Health Aspects of Excreta and Wastewater Management, World Bank Studies in Water Supply and Sanitation, no. 3 (Baltimore: Johns Hopkins University Press, forthcoming).

## Table 4-2. Environmental Classification of Excreted Infections

| Category | Epidemiological feature | Infection | Dominant transmission focus | Major control measure |
|---|---|---|---|---|
| I | Nonlatent, low infective dose | Enterobiasis<br>Enteroviral infections<br>Hymenolepiasis<br>Amoebiasis<br>Giardiasis<br>Balantidiasis | Personal<br>Domestic | Domestic water supply<br>Health education<br>Improved housing<br>Provision of toilets |
| II | Non–latent medium or high infective dose, moderately persistent and able to multiply | Typhoid<br>Salmonellosis<br>Shigellosis<br>Cholera<br>Path. *Escherichia coli*<br>Yersiniosis<br>*Campylobacter* infection | Personal<br>Domestic<br>Water<br>Crop | Domestic water supply<br>Health education<br>Improved housing<br>Provision of toilets<br>Treatment prior to discharge or reuse |
| III | Latent and persistent with no intermediate host | Ascariasis<br>Trichuriasis<br>Hookworm | Yard<br>Field<br>Crop | Provision of toilets<br>Treatment of excreta prior to land application |
| IV | Latent and persistent with cow or pig intermediate host | Taeniasis | Yard<br>Field<br>Fodder | Provision of toilets<br>Treatment of excreta prior to land application<br>Cooking, meat inspection |
| V | Latent and persistent with aquatic intermediate host (s) | Clonorchiasis<br>Diphyllobothriasis<br>Fascioliasis<br>Fasciolopsiasis<br>Gastrodiscoidiasis<br>Heterophyiasis<br>Metagonimiasis<br>Paragonimiasis<br>Schistosomiasis | Water | Provision of toilets<br>Treatment of excreta prior to discharge<br>Control of animal reservoirs<br>Cooking |
| VI | Excreta-related insect vectors | Bancroftian filariasis (transmitted by *Culex pipiens*), and all the infections listed in I–V for which flies and cockroaches can be vectors | Various fecally contaminated sites in which insects breed | Identification and elimination of suitable breeding sites |

Source: Feachem and others, *Sanitation and Disease*.

Health Effects of Treatment and Reclamation

Some of the infections in categories II-V require proper treatment before disposal or reclamation for their control. Waste treatment technologies for developing countries depend upon the level of water service and the kind of sanitation system involved. The health aspects of three treatment options--stabilization ponds for waterborne wastes, night-soil digestion with or without methane (biogas) recovery, and composting--may be evaluated according to the time-temperature relations that achieve the death of excreta-related pathogens.

Minimal times and temperatures that will ensure pathogen death are shown in figure 4-1. The most resistant pathogens are enteric viruses and Ascaris eggs; by the time these are killed, all the others have died. The curve for Ascaris eggs is based upon a large body of data; that for the viruses is less certain. In any event, the typical temperatures reached during aerobic composting by the Beltsville Agricultural Research Center (BARC) process described in chapter 2 are more than enough to destroy all known pathogens.1/

Figure 4-1 also indicates that anaerobic night-soil or sludge digestion--at the ambient or slightly raised temperatures found in night-soil storage pits or vaults (say, 35°C) for detention periods of 20 to 30 days--will substantially reduce but not eliminate Ascaris eggs in the sludge.2/ For digesters heated to 45 or 50°C, complete destruction will occur. Storage in a well-drained pit for 1 year will also suffice for an essentially complete kill; the same is true for excreta in a pit privy or a composting latrine.

If pathogens are not removed by prior treatment, they can survive on soil as follows:

| Pathogen | Survival time |
|---|---|
| Viruses | less than or equal 6 months, but generally 3 months |
| Bacteria | less than or equal 3 years, but generally 2 months |
| Protozoa | less than or equal 10 days, but generally 2 days |
| Helminths | less than or equal 7 years, but generally 2 years |

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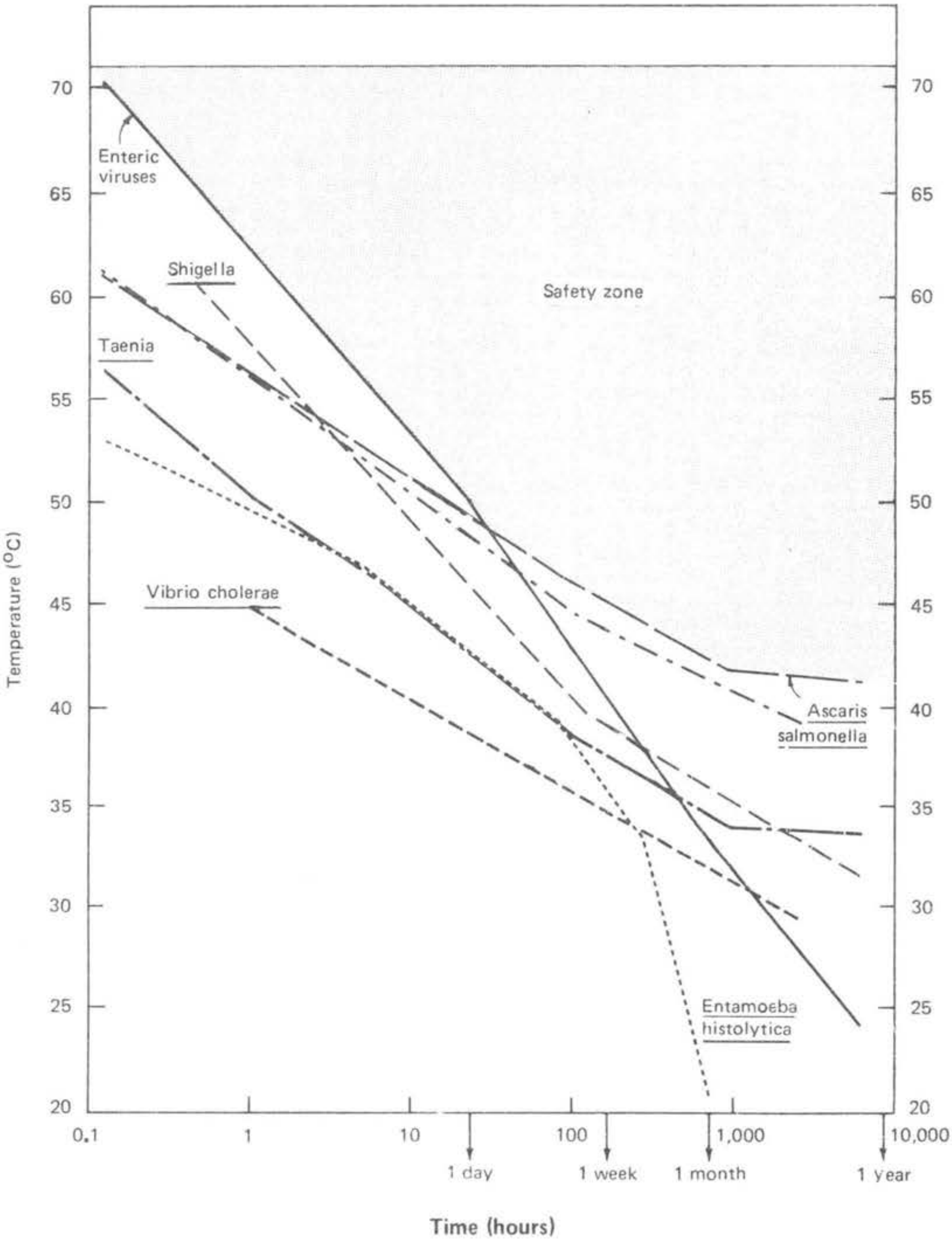
1. H.I. Shuval, C. G. Gunnerson, and D. S. Julius, Appropriate Technology for Water Supply and Sanitation, vol. 10, Night-soil Composting, Washington, D.C.: The World Bank, Transportation, Water, and Telecommunications Department, 1980).

2. M. G. McGarry, and J. Stainforth (eds.), Compost, Fertilizer, and Biogas Production from Human and Farm Wastes in the People's Republic of China, Publication no. IDRC-TS8e. (Ottawa: International Development Research Centre, 1978).

**Figure 4 -1. Influence of Time and Temperature on Selected Pathogens in Night Soil and Sludge**




Note: The line represents conservative upper boundaries for pathogen death--that is, estimates of the time-temperature combinations required for pathogen inactivation. A treatment process with time-temperature effects falling within the "safety zone" should be lethal to all excreted pathogens (with the possible exception of hepatitis A virus-- not included in the enteric viruses in the figure--at short retention times). Indicated time-temperature requirements are at least: 1 hour at ≥62°C, 1 day at ≥50°C, and 1 week at ≥46°C.

Source: Feachem and others, Sanitation and Disease.

Survival of excreted pathogens on crop surfaces may be as follows: [1]

| Pathogen | Survival time |
|---|---|
| Viruses | less than or equal 2 months, but generally 1 month |
| Bacteria | less than or equal 6 months, but generally 1 month |
| Protozoa | less than or equal 5 days, but generally 2 days |
| Helminths | less than equal 5 months, but generally 1 month |

Stabilization ponds can provide adequate low-cost treatment for sewage. They are particularly effective in warm climates where a series of five to seven ponds, each with a retention time of 5 days, will remove all helminths and protozoa and reduce the concentrations of other enteric organisms to safe levels for irrigation.

Health hazards of night-soil and sewage-reclamation systems have been well documented.[2] The reclamation systems considered here include methane production at household and community levels, irrigation of gardens or crops, fertilization of fields or ponds for agriculture or aquaculture, and pig feeding. Areas of potential health hazard include exposure of the workers and contamination of foods.

Data on the health effects of night soil or sewage upon sanitation or agricultural workers are inconclusive, although the risk is self-evident. Although there is unquestionably a hazard, most surveys made to date reveal no greater susceptibility to disease than that of the general population in industrial countries.[3] An exception is a 1971 survey in India of workers in farms fertilized with raw sewage that revealed significantly higher levels of intestinal parasites, anemia, skin disorders, and diseases of the respiratory and intestinal tracts.[4]

Risk to the general population is better known. Recent developments in China include night-soil treatment along with snail eradication programs prior to use of night soil as fertilizer, to reduce

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1. Suggested criteria for reduction of the health risks associated with the agricultural reuse of excreta and sewage are presented in Feachem and others, Sanitation and Disease, and in standard works on irrigation.

2. Ibid.

3. Ibid. See also C. Scott Clark and others, "Disease Risks of Occupational Exposure to Sewage," Journal of the Environmental Engineering Proceedings of the American Society of Civil Engineers, vol. 102, no. EE2(1976), pp. 375-388; and W. Anders, "The Berlin Sewer Workers," Zeitschrift fur Hygiene, vol. 1 (1954), pp. 341-371.

4. Central Public Health Engineering Research Institute, Health Status of Sewage Farm Workers, Technical Digest no. 17 (Nagpur, India, 1971).

prevalence of schistosomiasis with concurrent reductions of ascariasis.[1] Other reports of infection due to aerosols from spray irrigation in Israel, and to ridge and furrow irrigation of crops with poorly treated sewage in a number of places, reaffirm the need for careful selection and operation of waste treatment facilities that will adequately protect non-immune human populations.[2] Where excreta are fed to fish or pigs--as in South and Southeast Asia, West Africa, and Central America--waste treatment should be complemented by careful cooking of the meat. Methane from a household biogas unit or a community digester has no hazard of infection; the sludge or slurry will require the same treatment as that for night-soil or sewage treatment plant sludge.

Risks of infection from eating foods grown with water or fertilizer from raw or treated sewage, sludge, feces, or urine depend upon the kind of crop and whether it is eaten raw, upon handling of the food before and after cooking, and upon the time-temperature factors in the interior of the food during cooking. No attempt is made here to generalize on effects of different methods of preparing and cooking contaminated foods. Clearly, eating raw or partially cooked pork or whole fish from animals fed on feces is not safe. Nor is eating unsterilized watercress or other raw plants grown in contaminated water. If the meat, fish, or plant is cooked to the "well-done" stage, however, and no further contamination occurs during subsequent food handling, there will be no risk. The matter is a cultural and educational one whose influence on the design and operation of waste reclamation systems must be determined on a case-by-case basis.

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1. McGarry and Stainforth, Compost, Fertilizer, and Biogas; and M. G. McGarry, "Developing Country Sanitation," Report to International Development Research Centre (Ottawa, February 1975).

2. Hillel I. Shuval, "The Uses of Wastewater for Irrigation, with Special Reference to Enteric Pathogenic Protozoans and Helminths," Proceedings of the Conference on Sanitation in Developing Countries, Oxford, England, July 1977.

Chapter V

## Sociocultural Factors

Early all studies addressing the sanitation problems of the rural and urban poor in developing countries affirm the importance of social and cultural factors in the choice of appropriate technology. The operational recommendation generally made is to increase community motivation and participation in the planning and selection stages in hopes that community responsibility can be generated to use and sustain the system during the operating and maintenance stages. The widespread failure of community water supply and latrine programs, when measured by long-term successful operation or usage, points to the need for a more careful analysis of the sociocultural aspects of the choice of technology and for more specific operational guidelines.

This chapter summarizes the results of sociocultural surveys and case studies of social factors affecting the selection of sanitation technology that were carried out as part of the World Bank research project that preceded this report.1/ These detailed case studies were limited to Latin America; thus, their results must be interpreted with caution by those working in other parts of the world. Many of the Latin American findings were supported by surveys conducted in Asian and African communities, but constraints of time prevented verification of these surveys through additional case studies.

The questionnaire used in all communities was designed to provide community input during the design stage of project implementation; it generally followed the form used by White, Bradley, and White in East Africa.2/ Such a questionnaire is one of the behavioral scientist's tools for carrying out stage 1 in figure 1-1. Its purpose was to find out what community members thought about their present methods of water supply and excreta disposal and how they would respond to an opportunity to change those methods.

The survey first attempted to determine how people perceived their environment. Second, the survey investigated existing practices related to water use and excreta disposal and preferences for improvements. The survey also sought to identify incentives for change. To supplement the survey, the researchers used various anthropological techniques in the Latin America field studies, including direct observation of water-carrying tasks and water reuse practices, indirect observation of personal

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1. For a more complete analysis of the sociocultural case study results, see M. Elmendorf and P. Buckles, Appropriate Technology for Water Supply and Sanitation, vol. 5, Sociocultural Aspects of Water Supply and Excreta Disposal (Washington, D.C.: The World Bank, Transportation Water and Telecommunications Department, December 1980). Much of this chapter is taken from that work.

2. G.E. White, D. J. Bradley, and A. U. White, Drawers of Water: Domestic Water Use in East Africa, (Chicago: University of Chicago Press, 1972).

hygiene and habits of latrine use, interviews with local leaders and individuals involved in sanitation programs, and informal conversations with local store owners and craftsmen. One of the methodological conclusions from the case studies was that, without these "unstructured" information-gathering techniques to supplement the formal surveys, the responses obtained in the latter were often misleading or so incomplete as to be useless for guiding project design.

In addition to community-based data collection, pertinent information was assembled on the national and regional organizations involved in community water supply and waste disposal improvement. Both the successful and unsuccessful components of present and past programs were examined. This information on institutional issues has been incorporated in the program recommendations presented in chapter 7 of this report.

## Survey Results

Although each of the case studies provided many useful and original insights, the generalizations presented below represent the central and pervasive findings on environmental sanitation. These findings can also provide planners with some indication of the kind and quality of information that can be collected through a survey conducted prior to a project's initiation.

### Perceptions

If the majority of a population perceives their environment to be healthy, it is for reasons unrelated to sanitation. Many people believe their environment is healthy because it provides fresh and good air, good climate, or accessibility (for example, is "close to the highway in case anything goes wrong"). In crowded, concentrated settlements, a healthy environment is viewed as one that allows for privacy and is characterized by good relations with one's neighbors. Significantly, all of the reasons cited above are based on observations of the respondents' immediate surroundings. A healthy environment is certainly not associated, in residents' perceptions, with abstract theories on disease vectors or with contamination through contact with nonvisible pathogens in water or wastes.

In contrast, however, those who perceive their environment as unhealthy most frequently cite reasons related to poor sanitation. Individuals in this category are a small minority in rural communities and a significant majority only in some urban fringe communities. Again, visible contaminants--such as dead animals in the water source--are often included in explanations of why a water source was "bad". Most believe water quality is good if the water looks clean. Color, taste, and smell are important criteria. Where improved supplies exist, the water may be considered of good quality because it is piped or introduced by a government health institution. An understanding of the relation between water and health may occur when consumers are suddenly deprived of their utilities after an extended period of use.

Preference and practices

Abundance and proximity are the two primary qualities appreciated in a water supply. Two of the most objectionable factors associated with an improved water supply are cost (if the water is paid for) and the crowding, quarrels, and problems with neighbors that often accompany many households sharing the same public tap. In many cases, the opportunity for socializing while drawing water or washing clothes is not considered a benefit and may even have a negative value.

In communities where public taps have been introduced, most households desire greater accessibility through the installation of more taps at shorter distances or through the provision of private connections. Where public taps are close and a private connection involves additional cost, many prefer, as a cheaper alternative, the use of a hose to fill large drums placed next to the house.

An esthetically attractive facility for excreta disposal, with a shiny porcelain seat or a brightly painted cement floor, is preferred over cheaper, less attractive alternatives. Although people use a squatting position when defecating in the fields in Latin America, they prefer a latrine with a seat.

Where lack of space or rocky soil are constraints for the installation of household latrines, there is an expressed, and sometimes observed, willingness to use a public facility or to share one with the neighbors. People usually only share latrines with close friends, relatives, or good neighbors. Where sanitary facilities are maintained by attendants, however, the demand for use of public facilities is high.

Once latrines are filled, many households continue to use the superstructure by transferring it to a new site. Most people perceive, however, a need for technical assistance when initially installing latrines, and without continuous or at least periodic promotion--even in communities where initial acceptance is high--new families do not usually take the initiative to install a latrine.

Incentives

People can be successfully motivated to install excreta disposal facilities by: a desire to acquire the benefits of another service, such as a health clinic or an improved water supply; population pressures causing crowding and an increased need for privacy; interest in acquiring "modern" conveniences in the village or what are regarded as status symbols (either by definition of the village leaders or by the awareness of models from more developed countries created by the tourist industry); and social pressures to comply with a collective village decision arrived at through a consensus of leaders and household heads.

In almost all of the communities studied, the people offer some suggestions for improving the existing water supplies or sanitation facilities (or both). Though lack of economic resources is often given as a reason for not having implemented ideas for improvement, lack of leadership and lack of technical knowledge are cited almost as frequently in some communities and more often in others. People are more willing to give time in working to improve their sanitation facilities than to pay more than a very small amount of cash for improvements. Those unwilling to collaborate with others to improve water supplies are a small minority and cite as their reasons previous bad experiences, poverty, or that the present supply is good or close enough for their needs.

Motivation

The need for different or improved excreta disposal facilities is rarely given priority except when the community has become crowded, housing is concentrated, and the lack of privacy has become a problem. As a result of being linked with a need perceived to be of higher priority--such as health services, water supply improvements, or income-generating projects introduced through integrated community development programs--the installation of latrines or other means of excreta disposal can receive substantial community support and acceptance. In marginal squatter communities, a major constraint to investing in improved sanitation is the fear of eviction.

Community values of unity and progress may be considered more important benefits than cleanliness and sanitation in communally approved projects for the installation of excreta disposal facilities. The costs (in money and time) of installing a latrine may be perceived as minor when compared with the costs (in social pressure, loss of good will, and deterioration of solidarity) of not installing one.

The extent of community involvement in environmental sanitation projects is directly related to opportunities for frequent contact and the exchange of information with technically informed individuals. When the facilitators or promoters presenting a project are socially and culturally similar to the population with whom they are working, communication is more effective.

A general philosophy that nothing should be wasted was evident in most of the communities studied, particularly in the rural ones. Water from laundry is stored for later use to settle dust and clean floors. Water used to wash dishes, soak corn, or clean vegetables is saved and fed to chickens, pigs, and other small domestic animals along with food crops. Reuse of human excreta is an understood concept and is practiced traditionally in Latin America, albeit in a less advanced and systematic way than in Asia. Reuse is informal--often not spoken about because of the sociocultural taboo surrounding the subject--and it takes place primarily in individual households. Defecation in cornfields or on coffee plants is considered to serve a fertilizing function. Similarly, fruit trees are purposely planted over old, filled latrine pits. In some areas, human excreta deposited near the house are consumed by pigs. This last practice is sometimes formalized, when penned pigs are released periodically to clean areas that have been designated and used for the depositing of human waste. Native pigs are sometimes even preferred over bigger new stock because they carry out this important function and can be fed corn and scraps instead of commercial concentrates. Behavioral patterns incorporating excreta reuse as a principle can provide the basis for uneducated people to understand composting and biogas when these new technologies are adequately explained.

When there exists a credibility gap between external agencies and communities because of community experiences with abortive attempts to introduce innovations or compulsory programs, people are less willing to collaborate until materials or technical assistance are actually seen or made available. When communities are legally authorized to keep the fund for water supply maintenance in the community, or when economic resources for sanitation are made available through income-generating projects, local people take the initiative in defining as well as solving their own problems, and popular participation is more pervasive.

Behavioral Science and Sanitation Project Design

These highly specific findings from structured surveys are only a start in providing planners with an understanding of the social factors that influence the thinking that will determine whether potential users will accept, properly use, and maintain the services provided. A limitation of the use of questionnaires is the high cost, in time and trained personnel, needed to analyze a survey administered in every community to be served. The objective of incorporating the techniques of social science should not be to provide a few with custom-made latrines, but to provide many with acceptable sanitary facilities they are willing to use and maintain.

Another problem with surveys is the difficulty of obtaining reliable data on which to base decisions. When asked if they would be willing to contribute to projects, people must know how much, and of what, they are being asked to contribute. People are reluctant to respond when given a choice expressed in a hypothetical manner. Yet, when the technology suggested for a community is new to them, it is hard to pose concrete question that will be meaningful.

A survey preceding a proposed project also risks unintentionally misleading respondents into believing that an effort is being made to solve their particular and immediate sanitation problems. Raising false expectations has contributed greatly to the credibility gap that presently exists between communities and outsiders. People's past experiences with unfulfilled promises have created in them an unwillingness to become involved in self-help projects unless they can actually see materials or a similar demonstration of commitment on the part of agencies offering them assistance.

The limitations of surveys in predicting users preferences and willingness to pay have important implications for planning. The case studies suggested that surveys are most productive when complemented with unstructured information-gathering techniques at particular points in project design.

There are three components of project design that can be greatly strengthened by well-timed and planned inputs from the social sciences: selection of technology, its diffusion, and its adoption. These major components and the kind of input from social science recommended for each, are discussed below.

Selection of technology

Insights into the reactions of users--for use in areas selected for improved sanitation--must be found in the study of communities in which technologies have already been introduced and accepted (or rejected). The communities should be as culturally and environmentally similar as possible to those in the area or region selected for sanitation improvement. Through a preliminary analysis of agency records, researching can find out how much consumers have promised to contribute and how much they are actually contributing to maintenance of sanitation systems. The research will indicate the willingness of future beneficiaries to support such maintenance through monetary contributions.

Means for the diffusion of technology

Because of the low priority given to sanitation needs in many communities, planning at the national level should link the disposal of human waste with other services given higher priority by the communities (for example, water supply or health clinics). In the rural areas, community involvement in planning water supply and sanitation projects usually requires the creation of a branch office of the responsible agency that will be accessible to consumers and that has decisionmaking power for project selection and development in line with the policies and priorities established by the agency's central office (see chapter 7).

For purposes of liaison with the community, the agency responsible for water supply and sanitation should rely on facilitators or promotors assigned to an existing local agency such as a health clinic. If this kind of personnel does not exist, teachers or agricultural extension workers should be requested to assist in technical tasks, community organization, and health education activities. The facilitators should be natives of the region; they should have had experience working in the area, and they should share the cultural perspectives of the people with whom they will be working. An effort should be made to recruit women as well as men so that information on improved hygiene practices related to water supply and sanitation can be more effectively communicated to local women and their children. The facilitators should receive intensive training in the technical aspects of the technology and its promotion, and they should be provided with adequate transport and visual aid materials if they are responsible for promoting the technology in a number of communities.

When an appropriate organizational structure does not already exist at the community level, project participants should be expected to organize a locally selected committee or cooperative to coordinate and oversee the community's contributions to the project. The case studies suggest that such committees are capable of assuming a wide range of responsibilities when provided proper authority and guidance.

When the promotion of a project at the community level is the responsibility of an individual or institution involved in other activities, initial participation may be high. Continued promotion, however, often is not given because energies must be dedicated to competing activities that may also have the incentive of producing an income (for example, selling medicines, giving injections, and other related health activities). For this reason, promotion should continue on a periodic (campaigns by promoters) or continuous (campaigns by radio) basis long after projects are initially constructed.

Motivation for the adoption of technology

Because urban and concentrated rural settlements consider sanitation more of a problem than do dispersed communities, initial efforts to introduce sanitation technologies are likely to be more effective in urban and rural areas. The existence of conflicting factions and the fear of evictions (in squatter communities) may, however, mean that monetary or labor contributions will be more difficult to obtain. In the rural areas, sanitation can sometimes be linked with a request for an improved water supply, which is more often the community's priority. If the projects are implemented simultaneously, they will be viewed as related, and the need for maintaining both will be clearer.

When the technology is understood by the population, there is no need to build demonstration models to promote it. If it is not understood, the use of slides or other visual media and visits to prototypes may be a more rapid means of gaining the support of community leaders than the building of demonstration models in each community. When adequate examples are not available, however, demonstration models will usually be necessary. With any project, once the agency and the community have come to an agreement to undertake the project, expected contributions and responsibilities should be formally committed before its initiation.

For the most efficient planning, communities should have some input into scheduling installation and construction activities according to seasonal migration patterns, planting and harvesting seasons, and climate cycles. Decisions about the location of water distribution outlets, colors for the sanitation facilities (if latrines are to be painted), when maintenance fees should be collected (monthly, bimonthly, or by some other schedule), and options for levels of service should be allocated to consumers so that community initiative in decisions affecting the care and maintenance of the facilities will be encouraged. Community leaders and project participants should also be encouraged to establish criteria by which individuals not participating in the original project may later be included.

To ensure adequate maintenance of facilities, local residents should be trained in simple procedures and in the reporting of major malfunctions to responsible authorities. Fees are more likely to be collected if they are maintained by an appropriately authorized community organization, such as a "Water Supply Improvement Committee." The local group should be required to maintain records and file periodic reports on its collections and expenditures, and it should have authority to impose sanctions against those who fail in their committed payments.

A system for periodic project monitoring should be established. A monthly visit by the local sanitary inspector or some other authority from the responsible agency can be an effective tool for motivation when it is carried out in a culturally sensitive manner. Any problems that have arisen with use of the facilties can be discussed with local leaders in a nonthreatening manner, and joint solutions can be negotiated. The visits will not only motivate communities to care for the facilities, but they will also provide agencies with client contact and important feedback on changes in water use and sanitation practices that have occurred after the introduction of new technologies.

Findings

For many of these sociocultural aspects of the case studies, findings seem self-evident. It was very difficult, however, to find examples in the field of the widespread diffusion of new technologies, or the sustained, successful operation of community water supply and sanitation facilities. In some cases failures were from poor technical design or the lack of institutional support. But, in many cases, the major problem was that the social and cultural factors discussed above had been ignored by planners. These "software" components of appropriate sanitation technology are crucial to its successful introduction and diffusion.

Unfortunately, research into the design and delivery of these project components is scarce, and what is available tends to be extremely site specific. Perhaps this is a reflection of the nature of the inputs themselves. Because these sociocultural components constitute the link between a technology and a particular community, it is obvious that they must be adapted to suit the local context. Yet, at the least, an analysis of which techniques of social science and which delivery methods have and have not been successful in the implementation of sanitation projects needs to be attempted on a wider scale. If such an effort fails to reveal any common characteristics of successful or unsuccessful strategies, then a cumbersome and expensive site-by-site approach, such as that used in this study, may have to be adopted.

Woman washing clothes at outdoor sluice in Colombia
WORLD BANK PHOTO by Edwin G. Huffman. 1974

# PART TWO

# PROGRAM PLANNING AND DEVELOPMENT

# CHAPTER VI

## The Implementation of Appropriate Sanitation Technology

In designing a program for the implementation of appropriate sanitation technology, an important question to answer is why have inappropriate technologies been chosen in the past? This is really, several questions in one. Are alternatives to those technologies chosen available? If so, what is the appropriate procedure for selecting among the alternatives? Given that selection process, why has the result in the past been different from the one expected from what now appear to be more appropriate choices? Finally, how can those factors responsible for the difference be altered or overcome to ensure that appropriate choices are made in the future? This chapter attempts to answer such questions as they relate to sanitation alternatives.

### Obstacles

There are many points on the course toward implementing an appropriate sanitation technology where the planner can encounter an obstacle and be sidetracked. The first and most obvious problem found in the case studies, which form the basis of this analysis, is the information gap. As described in chapter 2, many nonconventional sanitation technologies are being utilized around the world, but there is a real dearth of detailed information on them. At the outset of this study, the World Bank contracted the International Development Research Centre (Ottawa, Canada) to carry out a detailed bibliographic search for information on sanitation technologies. The final bibliography contained summaries of 528 articles, of which nearly half were previously unpublished.1/ Efforts such as this can help bridge the information gap directly.

With few engineers aware of the range of sanitation technology available, it is not surprising that even fewer planners and administrators know about the present variety of technological alternatives. This lack of knowledge has often meant that requests for sanitation studies have called only for the examination of different configurations of sewerage systems. The least-cost evaluation has usually been limited to pipe sizes and different treatment alternatives. Once a least-cost sewerage system has been designed, its financial implications have been derived and compared with the city's capacity to raise funds. In most cases, this comparison has led to a recommended staging of sewer construction to serve downtown and wealthier residential areas (often the only ones with piped water) in early years and to do nothing for those living in the rest of the city.

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1. See Witold Rybczynski, Chongrak Polprasert, and Michael McGarry, Low-Cost Technology Options for Sanitation: A State-of-the-Art Review and Annotated Bibliography [a joint effort by the International Development Research Centre and the World Bank: IDRC-102e/Appropriate Technology for Water Supply and Sanitation, vol. 4] (Ottawa: IDRC, 1978).

Even if terms of reference have included the evaluation of nonconventional options, there have been biases in the process of technology selection that have favored sewerage systems. The background and training of the bulk of consulting sanitary engineers certainly has constituted one bias. With very few exceptions, this orientation is heavily directed toward sewerage modeled on systems in developed countries. Thus, most sanitary engineers generally are good at designing a workable sewerage system as one of several alternatives, but they rarely have the knowledge or experience to "preselect" the best, and likely more appropriate, alternative technology to compare with sewerage. If problems are encountered in designing a sewerage system to fit the site, they can usually devise ways to overcome them. But if problems arise in the design of an alternative technology, it is often abandoned, rather than adapted, because of the engineers' lack of design experience. Only time and increased exposure to nonconventional solutions can overcome this difficulty.

Concurrently with the design of alternatives, the feasibility team prepares estimates of the demand for the service to be provided. This is another area in which existing practice has favored sewerage. If economics is "the dismal science" (as Thomas Carlyle called it in 1849), engineering is the optimistic one. Linear demand projections made from tiny bases persist despite historical evidence that, over the long run, demand growth is S-shaped and asymptotic. The supplies of complementary inputs, such as piped water and additional housing, have been assumed to be perfectly elastic. The influence of price on consumption has been ignored. The intricacies of urban growth patterns have rarely been explored, although they often are based upon an influx of population that is much poorer and less able to afford service amenities than present populations. Thus, when historical rates of growth in demand have been projected into the future, the lower consumption patterns of the new migrants are grossly overestimated. Because sewerage master plans often cover periods of more than 20 years, these errors have been compounded over time until a highly unrealistic picture of demand is created and used as the frame for testing alternative technologies. The reason that the assumption of rapid growth in demand has favored sewerage over most nonconventional systems is that those technologies with large economies of scale are more economical under conditions of rapid growth. As pointed out in chapter 3, however, the financial consequences of investing in such large-scale technologies can be very serious should demand turn out to be lower than projected.

There is one aspect of demand projection that deserves special emphasis because it has been ignored for so long. This is the social, or micro-level, basis of any demand analysis. Behind any set of such numbers are the consumers whose individual needs and resources form the boundaries of consumption patterns. When working in a familiar and homogenous social environment, such as a Western European country, an engineer incorporates social factors into the demand analysis almost automatically because the engineer himself, generally, is a part of that same social fabric. But, in developing countries, it is necessary for the engineer to make a real effort to discover the user' practices and preferences in order to satisfy them at the least cost. Habits and ideas regarding human waste disposal are highly variable across cultures and are not easily discerned by the casual visitor. There are many examples in which cultural misunderstandings have led to nonuse or misuse of new sanitation technologies. Factors such as the color or location of a latrine may have little technical import and yet be crucial to the acceptance and use of a facility.

Even when demand analysis has been properly done and consumers' preferences and financial constraints are known, it is possible to choose the wrong technology by applying an inappropriate selection test. The most common fault has been the use of financial rather than economic costs in the least-cost analysis. The reasons why sewerage benefits from financial rather than economic costing are that it is relatively capital intensive (and financial interest rates are generally below the opportunity cost of capital); it is relatively import intensive (and foreign exchange is often officially undervalued); its cost to the householder in needed plumbing and internal facilities is very high; it has relatively high water requirements (which are usually omitted from the cost comparison or included at a market price below long-run production cost); and it possesses larger economies of scale than most nonconventional systems for waste disposal that are not properly valued where design populations are used for costing.

## Incentives

Given the diversity of the obstacles to the selection of appropriate sanitation alternatives, a variety of incentives or policy changes is likely needed if the conventional practices of engineers and their clients in developing countries are to be revised. For example, it is necessary to ensure that terms of reference for sanitation master plans include the examination of alternatives to sewerage. The international lending agencies can have an important influence here because they are often called upon to review terms of reference for studies of projects they will be asked to finance. The information gap can be closed by the widespread dissemination of information such as that collected during this study. There are two areas, however, where concerted efforts will have to be made to permit a more equitable consideration of nonconventional solutions for sanitation.

The first is the revision of the methods that have been used by consulting engineers and planners in selecting among technologies. The socioeconomic base for feasibility planning must be improved. This probably means that multidisciplinary teams--including an economist/planner and behavioral scientist as well as an engineer and financial analyst--should be used in the first phase of planning and demand analysis. The amount of direct interaction with, and information gathering within, the community to be served should be increased to provide better data for estimating future demands for different kinds of sanitation service. The demand analysis should be disaggregated according to income, social status, housing, or other groupings that are likely to affect demand. In some cases, it will be appropriate to look for the critical constraints to demand growth. For example, the growth of the water supply system, and the rapidity with which new connections can be made, may be a constraint to the growth of a sewerage system that requires house connections for water to function properly. Similarly, if the local housing market is tight and the city is densifying rather than spreading as population increases, the demand for new facilities (rather than the intensified use of original facilities) is likely to be constrained. Income generally imposes another constraint on the demand for sanitation services. Especially in areas where the behavioral scientist finds that improved sanitation is not a high priority of the inhabitants, the willingness of potential users to pay for any new system is probably low.1/ In poor areas, unless the residents have secure tenure on their property, they may be unwilling to pay anything for sanitation improvements they cannot take along with them if they are forced to move. If the estimation of demand does not take into account factors such as these, it cannot provide a sound basis for the selection of technology.

The contribution of the economist and behavioral scientist to the feasibility study should not stop with the demand analysis. The economist's involvement in the preparation of appropriate least-cost estimates for the various feasible alternatives has been discussed in chapter 3. The behavioral scientist's work in eliminating socially infeasible possibilities--and in acting as liaison between the community and the design engineer in preparing the final project designs--is covered in chapter 5. In addition, the behavioral scientist must plan the method by which the community makes its choice among the final alternatives and associated costs. Both economist and behavioral scientists should be involved in the monitoring and evaluating phase of project development.

The second area in which new incentives will be required for the promotion and adoption of appropriate sanitation technologies is that of financing. In many developed countries the central government provides large subsidies or grants for the construction of interceptors and sewage treatment plants.2/ This obviously makes it very difficult for a community to choose any other waste disposal system, since it would have to bear the alternative system's full financial cost.

An additional financial disincentive in some cases has been the use of consultant fee schedules that have been tied to a percentage of the construction costs of the project the consultants design. Because it often takes more time and ingenuity to make a low-cost sanitation technology such as vacuum cartage function at optimal efficiency than it does to use tried and tested rules for sewerage design, it would be unfair to expect consultants to design effective alternative systems for less money. Yet this would be the result if their fees continue to be based on project costs.

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1. Willingness to pay, of course, is a broader concept than ability to pay, and thus applies to high-income areas as well as low-income ones. If households already have well-functioning (and probably expensive) septic tanks to dispose of household wastes, householders are unlikely to be willing to discontinue use of the septic tanks for connection to a sewerage system even if they can afford to do so.

2. In the United States, for example, the government finances 75 percent of total construction costs, and states (such as California) provide another 12 percent.

International and bilateral lending agencies have also exerted a financial bias toward sewerage systems in the past. Many made loans only to cover the foreign exchange cost of projects. This meant that those technologies that were relatively intensive in imported equipment (and consultants) generated interest and support from the agencies, whereas those that used mostly local materials, and perhaps even self-help construction, had too small a foreign exchange cost for the agencies to be interested. Fortunately, most aid organizations, including the World Bank, have now changed their policies to permit financing of projects' local cost components. There has also been increased interest in financing projects whose benefits are directed to the poorer groups in society. These two changes should promote the continuing, increased interest of aid organizations in low-cost sanitation packages.

Along with such changes in the financial policies of aid organizations will have to come changes in the kinds of institutional structures these agencies work through. Where household systems such as improved pit latrines are the appropriate technology, much of the construction work can probably be undertaken by the individual households with supervision and technical assistance from a local organization. The best local organization to provide this assistance may well be the health clinic or agricultural cooperative, which may already have local personnel and knowledge of the community, rather than the centralized water or sewerage authority. Channeling funds through an organization whose primary function is different from the activity being funded will certainly present unusual challenges in promoting traditional cost recovery and management objectives while retaining the independence of the organization to pursue its primary responsibilities.

As is emphasized elsewhere in this report, the preparation of sanitation projects is likely to require more time and local involvement than has been devoted in the past to sewerage projects. Weak or nonexistent local institutions will present a more serious constraint to project preparation, since much of the selection process depends on local manufacturing of the beneficiaries' needs and preferences. It is difficult to substitute foreign consultants for this, although it may be possible to use local university or municipal personnel.

In sum, the obstacles that have created a bias in favor of sewerage in the past are gradually being overcome. Much of the necessary technical research into appropriate technologies for sanitation has been accomplished, and a widespread effort of dissemination must now be made to close the information gap. Terms of reference for sewerage projects are beginning to include the development of alternative sanitation components. The importance of economic and social analysis to supplement technical and financial evaluations is now widely accepted and is beginning to find its way into feasibility studies. In addition, changes in the policies and objectives of international and bilateral lending agencies have created incentives to promote the selection of more appropriate technologies.

The success record of individual government policies that could encourage better sanitation programs is mixed, with much room for innovation. Governments in developing countries need to consider carefully what they hope to achieve through subsidizing costs for waste disposal. If the objective is improved community health, then they should make funds available for packages designed to achieve this goal at the least cost. These might include immunization and educational components along with low-cost methods of waste disposal. Even the most sophisticated sanitation technology will not bring health improvements unless properly used and combined with good habits of personal hygiene. If a government's objective is the long-run protection of the environment, then it should subsidize those technologies that promote this goal through dispersed recycling of treated waste. In general, sewerage systems are not the least-cost way of achieving either better health or environmental protection. To subsidize them exclusively may preempt the appropriate solution.

Overall, the climate for a major breakthrough in providing sanitation services to the large majority of people in developing countries who currently lack them is probably better now than it has been in the past 30 years. A continued effort to improve incentives and remove constraints to the choice of appropriate sanitation technologies can provide the needed groundwork for such extended, global efforts as the United Nations International Drinking Water Supply and Sanitation Decade of the 1980s.

# CHAPTER VII

## Institutional Requirements

For their successful development and implementation, water supply and sanitation projects require an institutional framework that allocates authority and responsibility for each phase of the project. Policies, organizational management, and financial resources must be legally established to ensure continuity of efforts in the sector. The institutional and policy requirements for a successful water supply and waste disposal program will be examined in the following section;

### Essential Components

Domestic water supply and excreta disposal are part of the larger water supply and waste disposal sector, which itself may be part of a much larger sector such as water resources. In any case, specific sectoral policies and organizational arrangements should cover domestic water supply and excreta disposal. In addition, actions and policies of the health and education sectors can have significant effects on water supply and sanitation. The health ministry, for example, is frequently responsible for rural water supply and sanitation.

Sanitation projects often fail to achieve the objectives they are designed to meet because the sector itself is neglected, disorganized, or does not receive the necessary support from government. Neglect is usually greatest in rural areas, villages, small towns, urban fringe areas, and slums. One reason for such neglect is the high visibility of projects for major urban areas and the ability of the middle-class, urban consumer to preempt both government attention and funds. Factors contributing to disorganization are the lack of a comprehensive policy for the sector, a lack of understanding of the benefits the sector provides (because they cannot be easily quantified), and a lack of knowledge about the low-cost technologies appropriate for service levels affordable by the urban and rural poor.

Government support on a steady, long-term basis is essential to avoid the destructive stop-and-go of program preparation and implementation. Neither agencies nor communities nor users will make commitments and undertake construction if clear evidence of consistent government support is not forthcoming. The sudden withdrawal of support--or failure to follow through once a project has been prepared--may permanently discourage a community from undertaking a scheduled project or supporting future ones.

The reassessment of technology at frequent intervals is necessary because of a natural tendency of designers to base their selection on past, successful experiences without necessarily considering present local conditions in sufficient detail. This tendency is particularly relevant to the transfer of technologies from industrialized to developing countries: the requisite trained manpower and access to equipment, spare parts, or repair facilities frequently are not available in the developing world. Furthermore, the particular sociocultural environment can preclude the acceptance of some technologies without major educational efforts directed toward the intended beneficiary, and indigenous religious beliefs can prevent the use of others. Periodic monitoring of past projects, when coupled with analysis of specific, current conditions, can enable an institution to learn from its own experience.

Stable, autonomous institutions offer career opportunities that attract competent staff and can establish financial and tariff policies that can enable the institution to undertake long-term development programs without interruptions and excessive political interference. The two most important ingredients for the success of a water and sanitation agency are competent employees and sufficient funds. Staff subject to dismissal with each political change loses motivation and effectiveness. Funds that can be easily diverted to other sectors to satisfy needs of other constituencies delay implementation of sanitation projects and, when they are required as matching funds for borrowings, may postpone projects indefinitely.

In addition to simply attracting competent staff, an organization should offer salary increases and related benefits to minimize staff turnover, including the provision of training programs to increase staff capacities. Because public institutions are often unable to offer staff compensation equal to that prevailing in the private sector, trained staff often leave public service after relatively short periods of employment. Such training still provides an overall economic benefit to the country, but it follows for the public institution that training programs must be continuous to ensure the availability of qualified candidates and to minimize institutional disruptions.

Tariffs for services rendered provide not only for the financial viability of the executing agency, but enable it to cross-subsidize a minimal standard of service at prices affordable to the poor and to encourage efficiency by charging the real cost of facilities to those who can afford it.1/

A sound tariff policy developed and supported at the national level is usually necessary to ensure that needed increases in tariffs will not be delayed by local political pressures. In addition, departments responsible for planning or financing can develop guidelines to aid communities in determining the economic cost of the services received for purposes of tariff setting and in designing tariff structures to provide cross-subsidies for poorer consumers. As is true of technology selection, the basic tariff policy should be set at the national level, and the application of the policy in a particular community should be left to the community organization.

## Policy Implementation

For water supply and excreta disposal projects incorporating other than conventional technologies, further institutional and policy strategies should provide for:

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1. For a discussion of water tariff design based on principles of marginal cost pricing, see J. J. Warford and D. S. Julius, "Water Rates in Developing Countries," Journal of the American Water Works Association (April 1979), pp. 199-203.

- Government commitment to the program evidenced by clear objectives, policies, and reliable allocation of adequate staff and funds;

- Community participation in evaluation and selection of standards for service levels and appropriate technology;

- Community participation in the construction and selection of operating and maintenance arrangements in communities too small for an independent water and wastes agency. An efficient, well-staffed and well-managed agency for technical support that, for communities too small for independent agencies, will: (1) plan programs, provide guidelines and design assistance to local agencies and communities, monitor ongoing programs, evaluate completed projects, and ensure that lessons learned are reflected in new designs; (2) maintain close liaison among design, operating, and maintenance activities; (3) establish clear criteria for selection of materials and equipment; (4) actively promote programs and assist communities in their implementation; and (5) be sufficiently decentralized to assist communities effectively.

Organizational Issues

One of the fundamental decisions to be made in organizing the water supply and sanitation sector is whether the sector should be independent or combined with other municipal or social sectors. Successes and failures have been reported for both organizational approaches, and there are advantages and disadvantages to both solutions. In urban areas there is usually an established organization that is responsible for municipal water supply and waste disposal. In large cities, this is often an autonomous agency whereas, in smaller cities, it is frequently a department of the municipality or a part of a multisectoral agency. Quite often, municipal agencies or departments are assisted by a regional organization or a government agency that is responsible for overall planning and that allocates funds to support sectoral institutions. Occasionally, however, a regional or state agency is responsible not only for the planning but also for the implementation and subsequent operation and maintenance of water and sewer systems in the area of its jurisdiction.

In contrast to urban water supply and sewage disposal, small towns and rural areas are less able to take care of their own needs because their inhabitants are generally not as well off and, therefore, are less able to financially support the institutions capable of providing adequate services. One solution to this problem that has often achieved notable results is the combination of various productive and social components in rural development projects. In such integrated development projects, the water supply and sanitation component benefits from the organization, management, and (possibly) the income of the project's productive components. Nevertheless, these projects often suffer from the same problem encountered with rural water supply and sanitation systems in general: inadequate operation and maintenance that leads to a rapid deterioration of the facilities. As a general rule, a single, sectoral agency that has been organized to provide support to small community organizations is preferable to a multisectoral institution because the organizational, managerial, and personnel needs of the former are likely to be known and more easily met than those of the latter.

Another critical decision to be made in organizing the water and sanitation sector is the extent of centralization or decentralization of control. Whatever the organizational arrangement, there should be a national policy and planning body; national (in small countries), state, or municipal operating agencies for project planning, implementation, operation, and maintenance; and local community units with responsibility for final technology selection, operation, and maintenance. There obviously are many solutions, with the allocation of responsibility dependent on local conditions. Often the reasons for the choice of an organization are historical. Both the costs and benefits of any suitable organizational set-up should be evaluated before the structure is adopted.

A good organizational structure provides for maximum participation by communities, particularly in the rural areas where social and cultural considerations are important in selecting standards of service and, thus, the sanitation system's construction and operating costs. There appear to be fewer cultural constraints in urban areas, probably because immigrants to the city have already accepted the need to adapt to a different life style. There is no standard form such community participation should take, but chapter 5 of this report provides some guidelines for its design.

Division of Responsibilities

Whether urban or rural, single- or multisectoral, the institutions and agencies involved in water supply and excreta disposal must have a clear division of responsibilities. It is not as important to decide which functions are assigned to each as it is to avoid overlaps and gaps in responsibilities. A generalized example of the various agencies and accompanying functions likely to be involved in water and sanitation program planning an execution is shown in table 7-1.

In practice, the organizational arrangements will probably never be as simple, and responsibilities so clearly defined, as indicated in the table. For example, in many countries the responsibility for urban and rural areas is allocated to different ministries. Even within urban and rural areas, there may be different responsible ministries or various agencies within ministries. Furthermore, communities naturally grow and develop and, thus, can move from one jurisdiction to another.

Ideally, the sector should be properly organized before projects are designed and implemented. It is rarely possible, however, to achieve this objective in practice within a short period of time. The

Table 7-1. Institutional Responsibilities in Sanitation Program Planning

| Level of Institutional Responsibility | Function |
| --- | --- |
| National | |
| Legislature | Review and approval of policies; establishment of enabling legislation |
| Ministry of Economic Planning; Hydraulic Resources; Public Works and the like | Long-term planning; allocation of national and foreign financial resources |
| Public Utility Commission (or Planning Unit) | Planning of policies and sectoral priorities; review of tariffs; (development of sectoral manpower) |
| Sectoral finance agency | Financing and financial policies |
| Ministry of Health | Establishment and monitoring of quality standards |
| State or province | |
| Public Utility Department or Planning Unit | Detailed planning; allocation of state resources |
| Water supply and sanitation agency or multisectoral development agency | Implementation of national policies; design and construction; monitoring, supervision and support of local authrities; manpower training; operational and maintenance backup for small systems |
| Local | |
| Municipal Authority or Municipal Department | Design; a/ construction; a/ operation and maintenance; on-the-job training |
| Water and Sanitation Committee of small community or cooperative | Construction; operation and maintenance |

a. Unless performed by the state agency.

overall organizational objectives of the sector should therefore be considered as long-range goals, with the institutional arrangements that will eventually lead to their attainment (or that, at least, will not prevent their clarification and development) being designed for specific projects and programs.

In sum, it is the finding of this study that the irreducible minimum institutional requirements for the successful implementation of community water supply and sanitation projects are: a government (national or state) policy that supports the project; a sectoral agency at the regional (for rural areas) or community (for large cities or metropolitan areas) level to provide the project with technical support; and a community organization's committee, or leader to provide the link between users and agency. Although not interchangeable, these required levels of institutional organization are interdependent and reciprocal. Projects and programs can be initiated at any of the three levels as long as they fulfill the requirements of the other two.

# CHAPTER VIII

## Community Participation and Organization

Conventional water supply and sewerage projects are usually designed without community participation; that is, the beneficiaries are not directly consulted or involved in the design, implementation, or operation of the facilities. In fact, public involvement is often considered of little value at best and a hindrance to progress at worst. Few members of a community to be served by a new sanitation system ask the question whether the conventional sanitation technology is the best or the only feasible method of providing the intended service.

In the urban areas of developing countries, the lack of community participation has resulted in water and sewerage systems being constructed according to the models of those built in industrialized countries. This simple adoption of advanced technology has provided reasonable water service to the middle- and upper-income populations and sewerage to those in very dense and high-income areas. The high cost of conventional sewerage, however, has inevitably meant that scanty or no facilities could be provided for the poor. The situation is even worse outside major cities. In rural areas, the lack of funds is aggravated by the absence of sectoral institutions capable of operating and maintaining conventional facilities.

Increasing the present low levels of sanitation service will require either a massive infusion of funds and the creation of large service organizations or the use of technologies that are less expensive than sewerage and easier to operate and maintain by users and smaller communities. With funds limited, the use of alternative sanitation technologies clearly offers a greater possibility for realization, but it will also require greater involvement by the beneficiaries in smaller towns and rural areas to compensate for the absence of a strong centralized institution.

### Objectives

The objectives of community participation in sanitation are the selection of:

- Technologies that are acceptable to the community and that offer benefits the community considers important at a cost it can afford;

- The most effective materials and methods of constructing the appropriate facilities;

- Technologies that can be operated and maintained by the local population with minimal assistance from outside agencies.

To achieve a successful project, the community's participation should extend from the initial collection of data and identification of user preferences through the design and construction stage to the permanent operation and maintenance of the facilities. The form of participation and the extent of community involvement will vary.

Scope

To achieve the objectives of community participation in sanitation, the organizational program must include:1/

- Identification of formal or informal channels for community leadership and communication;
- Determination of the community's existing practices for water use and excreta disposal and its attitudes toward them;
- Determination of the community's willingness to pay for desired improvements through cash contributions, labor, or materials;
- Organization and execution of any self-help construction agreed upon
- Operation and maintenance of communal facilities, assistance to users in maintaining individual facilities, and collection of funds.

There are many methods and models for initiating the process of community participation that may be suitable for different communities. Obviously, the approach must fit the particular community, and what is suitable in one culture may not be appropriate in another. Regardless of the agency or organization responsible for initiating sanitation projects, a team including behavioral scientists, community extension workers, and engineers is probably most suitable for implementing a program for community participation. At the least, the team should consist of a technician familiar with low-cost water and sanitation technology and a person (preferably female) with expertise in public health education, personal hygiene, and nutrition. Both should be employees of the agency responsible for providing the community with technical support and should have access to agency specialists such as hydrogeologists, well drillers, engineers, economists, behavioral scientists, health specialists, and so forth. The involvement of the community leadership is important for the success of the program regardless of the method used to implement the program.

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1. This list has been developed in part from work by A. U. White and G. F. White, "Behavioral Factors in Selection of Technologies," in Appropriate Technology in Water Supply and Waste Disposal (New York: American Society of Civil Engineers, 1979).

Implementation

The following tasks can be identified as the minimum for a community participation program that will lead to a successful project. Each will be discussed in turn in this section.

- Unstructured interviews with community leadership and a limited number of users to identify users' attitudes and preferences;
- Design and testing of a questionnaire for structured interviews;
- Structured interviews conducted with a representative sample of households;
- Presentation of feasible technologies and their costs to the community or its leaders to determine willingness to pay;
- Organization of the construction and execution of the work;
- Continued activities of operating, maintenance, and monitoring, including the assessment and collection of fees;

The first three tasks should be undertaken at the very beginning of project development (they are, incidentally, part of stage 1 in figure 1-1), the fourth toward the end of the selection phase (stage 6 of figure 1-1), and the final two must be scheduled to meet technical requirements and community work patterns.

Among the factors to be considered in the first task here are preferences for private or communal facilities; importance of the facilities' location, capacity, reliability, and privacy; the importance of aesthetic features such as the design of the superstructure or color of the interior; local traditions concerning conservation, reuse, or reclamation of water and waste; the importance of local autonomy versus confidence in regional or national authorities; and the existence of cooperative arrangements, either formal or informal. Other factors about which information is essential for design or implementation include land tenure; the customary manner in which local committees are formed and contributions in time, money, or materials are made to community projects; and the means by which a community majority or consensus can be obtained. The second task consists of the preparation and testing of a questionnaire for structured interviews; the type of questionnaire used in the World Bank case studies was described in chapter 5 and it can serve as a basis for developing locally relevant questions. The third is the formal interviewing of a representative sample of the community. Household interviews should include women, since they are both knowledgeable about water use and responsible for training children in personal hygiene and sanitation. The interviewer should always remember that the most reliable answers to questions on sanitation will come from those who are most concerned about sanitation, and these responses will be given most candidly to an interviewer who is perceived to understand and emphasize with the respondents. After the formal interviews, the responses should be evaluated by the behavioral scientist and engineer component of the project team.

The information on community preferences and attitudes should be used by the engineer to design acceptable sanitation alternatives. Once these have been costed, a meeting should be held between the project teams and the community or its representatives, at which the alternative technologies and their costs should be discussed (the fourth task). Photographs and working models should be presented and explained, and the benefits of each level of service and the manner in which each alternative can be upgraded should be discussed. If necessary, limited demonstration projects may be built. In any event, the community's choice of technologies and willingness to pay should be determined at or following this meeting.

If an interested majority within the community does not develop in about a month after the meeting, it will ordinarily be better to shift the project and resources to another community. Important differences between community preference and design or between levels of service (whether higher or lower) are seldom resolved by more education or information, and voluntary schemes in which wealthier individuals are asked to support sanitation services for others usually do not work. Either in parallel with the selection of technology or as a result of it, the community will have to organize the implementation and subsequent operation and maintenance of the facilities to be constructed (the fifth and sixth tasks).

The fifth task follows on the selection of technology and is the time when the choice of implementing procedures (for example, self-help labor, contracting, or a mix of the two) and organization is made and the construction is undertaken. Construction work should be performed with the assistance of the technician from the technical support agency (but under local leadership, if possible). For continuity, it is important that the technician train at least one person in the community for this task as the participatory process proceeds.

If there is a formal organizational structure in the community, it may be used to facilitate project implementation and operation. If no structure exists, special organizational arrangements will have to be made for the project. Just as in the selection of the technology, the type of organizational arrangement should be a community decision.

The sixth task encompasses the regular operation, maintenance, and monitoring of the facilities. The monitoring program should include the dissemination of the information collected for the project to other communities, so that lessons learned from the success or failure in one location can be used in the design and implementation of programs in others. The monitoring should also include the exchange of visits by those responsible for the operation and maintenance of similar facilities in various other communities and, if systems are large or sophisticated enough, any training not accomplished under the fourth and fifth tasks above. The relation between the operators and the technician should be established; the technician should make periodic visits to the community to help solve minor problems, provide routine technical assistance, order spare parts, and mobilize additional support if major problems arise. These visits should be regular and made at short intervals in the beginning of operation and at least once a month after the community has become familiar with the tasks of operating the facilities. Provision also should be made for rapid contact in cases of emergency (such as the failure of equipment, suspected water contamination, and the like).

Institution-Community Linkage

As the preceding description of tasks suggests, many aspects of the community's participation in sanitation program development depend upon and influence institutional structures. The institutional policies required to facilitate and support community involvement these policies should include measures to:

- Establish a support unit for water supply and sanitation in existing regional agencies or form an independent support unit (the specialists likely to be involved include engineers, hydrogeologists, a behavioral scientist, an economist, an accountant, a plumber, a mechanic, an electrician, a well driller, a purchasing agent, and a health educator);

- Organize and staff a central support unit; establish design and operating standards and select the villages or the criteria by which priority is assigned; conduct specialized tasks such as hydrogeological surveys, management training, or operating assistance;

- Train community workers in low-cost technologies for water supply and sanitation and in community organization;

- Train community workers in health care and nutrition;

- Canvass and organize selected communities; plan, design, and implement prototype projects to complete the training of community workers;

- Assign community workers or teams to designated areas to canvass and organize communities;

- Assist communities in constructing facilities;

- Maintain a limited number of community workers as itinerant maintenance and operations advisers and monitors for completed projectgs; assign all other extension workers to new areas to replicate successful projects;

- Provide technical assistance and support; maintain the stock of spare parts;

- Monitor the operation and quality of service; disseminate information; and provide continuous training programs for community workers and local staff.

# CHAPTER IX

## Project Development

Within the framework for institutional and community involvement in the planning of sanitation programs discussed in previous chapters, the development of individual sanitation projects will be accomplished by different approaches in different settings. This chapter considers three of the most probable settings for project development and presents a method for the selection and upgrading of technology.

### Types of Sanitation Projects

The urban and rural setting for a sanitation project, as well as the particularities of the site, will influence the choice of appropriate technology (see chapters 1 and 2). Similarly, the institutional structure through which an urban sanitation project is developed and implemented will be different for a project designed specifically for water supply and sanitation and for one designed for general urban development. These differences will be examined in the following subsections.

#### Urban water supply and sewerage

Conventional sanitation projects are usually developed through well-defined stages, beginning with a master plan for an urban community or region that a plan generally defines stages of implementation and is followed by feasibility studies for individual stages or projects, which are followed in turn by detailed design and construction. All these studies and designs can be done by the sanitation institution, although the work is more often contracted to consulting engineers. Construction of small projects is often performed by the sectoral agency, whereas major projects are generally constructed by contract with only the supervision of construction provided by agency staff.

Community participation in conventional water supply and sewerage projects is minimal. Projects are generally designed to satisfy existing or forecasted demands, and the solution employed is usually so well known and universally accepted that any discussion of alterantive technology is not considered necessary. The major drawback of conventional projects has been their cost, which effectively has prevented the extension of water supply and sewerage services to all inhabitants of a community. Usually the downtown areas and middle-class districts of cities are the first recipients of water supply and sewerage services. Water supply at a lower level of service (for example, public standpipes) is often extended to other areas of a city, but sewerage is rarely, if ever, constructed in districts other than the high-density areas during the first stages of a master plan's implementation. To serve the entire population of a community at a price it can afford, a change is required in the development of master plans for sanitation. Terms of reference should specifically require that consultants evaluate not only the potential development of sewerage for some areas but also the provision of sanitation services for the entire community, including the identification of areas for which sewerage is the correct solution and areas for which other methods of sanitation are appropriate. These latter alternative sanitation services should be designed to be gradually upgraded as water consumption increases and the incomes of the users grow. Similarly, the water supply component should provide for a mix of service levels that can be gradually improved as the demand from, and the financial resources of, consumers increases.[1]

A major departure from the traditional approach to the development of urban water supply and sewerage systems is the requirement that the master plan considers several technologies and that the subsequent feasibility, design, construction, and operating stages reflect the progress over time of each of the alternative technologies to be used. Another, additional revision of previous practice is that, in the selection of alternative sanitation technologies, the community to be served be included in the choice of a technology that will match its preferences and needs. Organizing the community for operation and maintenance of the chosen technology will ordinarily not be required because the existing municipal organization should be capable of providing the necessary services.

Preparation of such a master plan obviously requires additional and different skills, and consultants should be selected and compensated accordingly. Consultants need to have on their staff specialists in the behavioral sciences, community organization, economics, sanitation, public health, low-cost construction, and personnel training. This last specialist will have to devise and implement training programs for local staff, so that they acquire the skills necessary to undertake similar projects elsewhere in the region. Most consultants will initially have to train their own staff in the design of nonconventional sanitation projects.

Urban development projects

Urban water supply and sewerage are provided not only by agencies directly responsible for these sectors but also by a variety of organizations responsible for the design and implementation of multisectoral projects--such as urban development, slum upgrading, development of satellite communities, and the like. Responsibility for the provision of water supply and sewerage for such projects may rest with a municipal water and sewerage agency, which will likely follow its established procedures for project development and implementation. Alternatively, a development agency may design and implement the project independently or work under various cooperative arrangements with a water supply and sewerage institution.

Whatever the institutional arrangements, a multidisciplinary project would, ideally, implement already defined sectoral plans. But very often sectoral plans do not exist (see chapter 7) or do not cover all the areas involved. Some ad hoc sectoral planning must then be done so that future integration of the facilities into a municipal network can be accomplished at least cost. It is best that the municipal water and sewerage agency be responsible for operation and maintenance after the system is put into service.

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1. See Donald T. Lauria, Peter J. Kolsky, and Richard Middleton, Appropriate Technology for Water Supply and Sanitation, vol. 9, Design of Low-Cost Water Distribution Systems, (Washington, D.C.: The World Bank, Transportation, Water, and Telecommunications Department, 1980).

One of the distinguishing features of urban development projects--and particularly of "sites-and-services"1/ and slum-grading projects--is the active participation of the community. This participatory process can easily be extended to include water supply and sanitation. As in previously described projects, community participation would be primarily in the selection of technology rather than in the organization of operation and maintenance. An exception is the case in which a new community must provide its own infrastructural services. In this case, of course, the process of community participation will have to include the establishment of the necessary organization for operating and maintaining communal facilities.

Rural water supply and sanitation

The provision of water supply and sanitation to rural areas has traditionally been the most intractable problem in the sector, basically because rural communities are too small to support their own viable infrastructural agencies. Rural areas also have often been neglected in national or regional planning for water supply and sanitation. An additional reason for the neglect has been that the technologies for water supply and sanitation have been developed primarily for the benefit of urban populations. Because urban communities contain a mix of income levels more often than do rural ones, the potential for cross-subsidizing poorer residents is lower in rural communities.

For lasting success, projects for rural water supply and sanitation require the government's commitment, an agency to provide technical support, and community participation. It takes time, of course, to translate governmental support into effective policies and direction, and it also takes time to establish an effective organization for technical support at the regional level. A judgment has to be made in each case on how far the process of translating the government's commitment into substantive action and of implementing an organization for technical support must proceed before communities can be helped in their desire to improve their water supply and sanitation services. Great care has to be taken not to raise expectations that may not be fulfilled.

Rural water supply and sanitation projects require a comprehensive governmental policy on how the needs for infrastructure are to be met and financed. Criteria for the selection of communities and for standard project design should be established by the technical support agency responsible for the area in question. Based on these policies and criteria, the technical support agency should train community workers in appropriate water supply and sanitation technology, health education (particularly personal hygiene), nutrition, and ways to generate community participation and to organize a community in the implementation and subsequent operation and maintenance of the facilities.

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1. Sites-and-services projects generally provide streets, water supply, sanitation, and other basic infrastructure for an urban area; loan funds are made available to potential residents who build their own houses.

Technology Selection

In the foregoing section, three standard settings for sanitation projects were described. In the sections that follow, information presented in preceding chapters will be used to develop an analytical method for the design of sanitation projects in a particular setting and sequences for modifying appropriate technology to accommodate users' changing needs for improved service.

Once a community has been selected for sanitation improvements, the planner of sanitation projects must select from those technologies ones appropriate to the needs and resources of the community. This selection should be based on a combination of economic, technical, and social criteria, and these issues often reduce, --particularly in low-income areas-- to the single question: what is the cheapest, technically feasible technology that the users will accept and can maintain and that the local authority is institutionally capable of operating? The cheapest technology may not always be the one that should be chosen, but it certainly must be determined if the full range of alternatives is to be explored.

An algorithm, which can be used as a step-by-step guide to the selection of the most appropriate sanitation technology for any given community in the developing countries, is presented (in stages) throughout figures 9-1 through 9-3. The algorithm is intended only as a guide to the decisionmaking process. Its main virtue is that it can stimulate engineers and planners to ask the right kinds of questions, the sort they may not ask otherwise. Some of the answers to these questions can only be obtained from the intended beneficiaries (see chapter 8). Although it is believed that the algorithm is directly applicable to most situations encountered in developing countries, there will always be the occasional combination of circumstances for which the most appropriate option is not the one the algorithm suggests. This analytical device should not, therefore, be used blindly in the place of engineering judgement but, rather, as a tool for facilitating the critical appraisal of various sanitation options, especially those for the urban and rural poor.

The algorithm is most useful when there is no existing (formal) sanitation in the community under consideration. In general, any existing household sanitation systems, except perhaps unimproved pit and bucket latrines, will influence the technology chosen to improve excreta and sullage disposal in ways the algorithm cannot fully capture. In addition, it is important to consider the sanitation facilities existing or planned in neighboring areas because these facilities may enable the community to reduce its costs below what they would otherwise be, thereby providing additional affordable alternatives. Here and in the algorithm, affordability is taken to embrace both economic and financial affordability at the household, municipal, and national levels--including the question of subsidies--as discussed in chapter 3.

**Figure 9-1 First-stage Algorithm for Selection of Sanitation Technology**

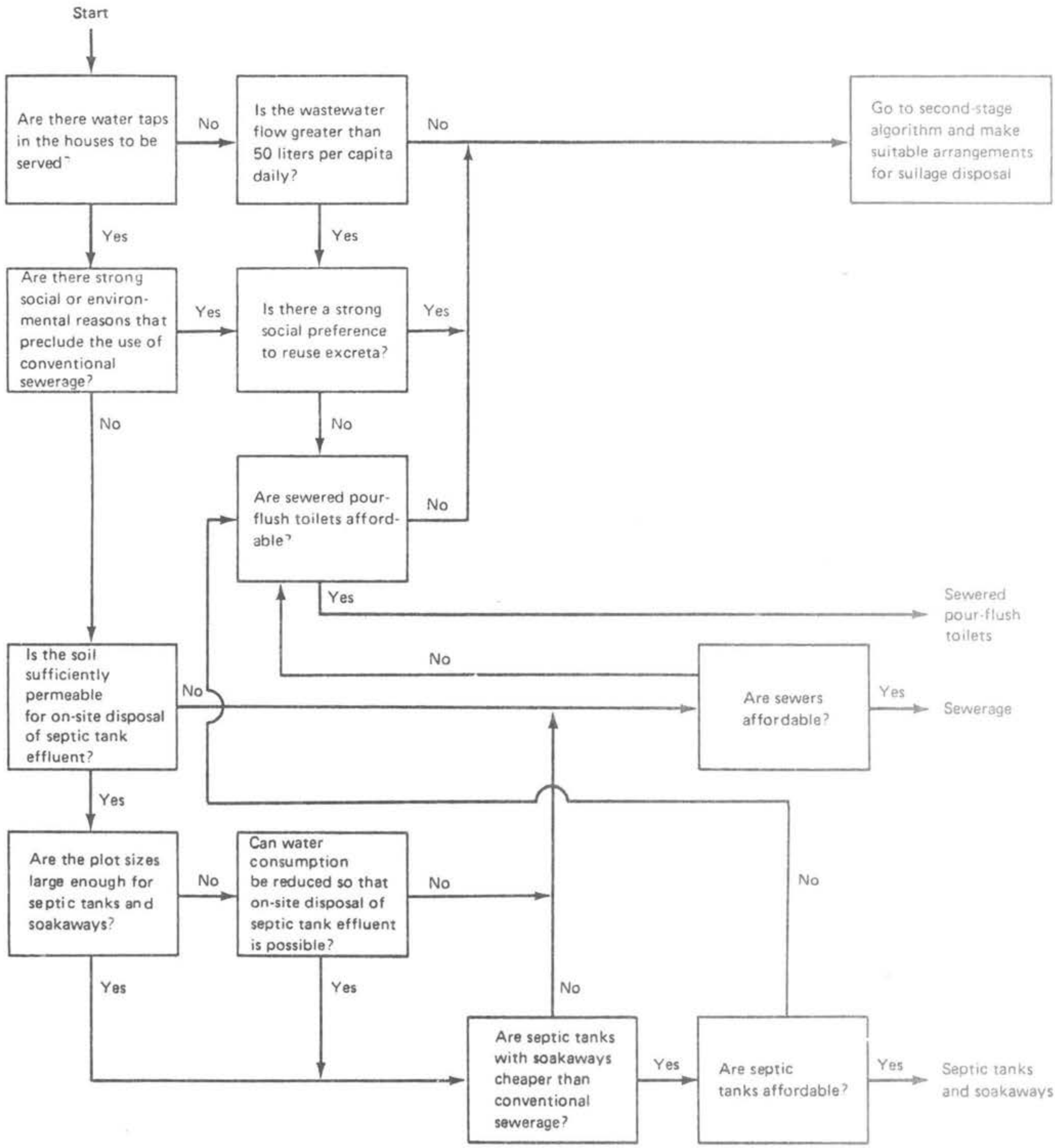


Figure 9–2 Second-stage Algorithm for Selection of Sanitation Technology

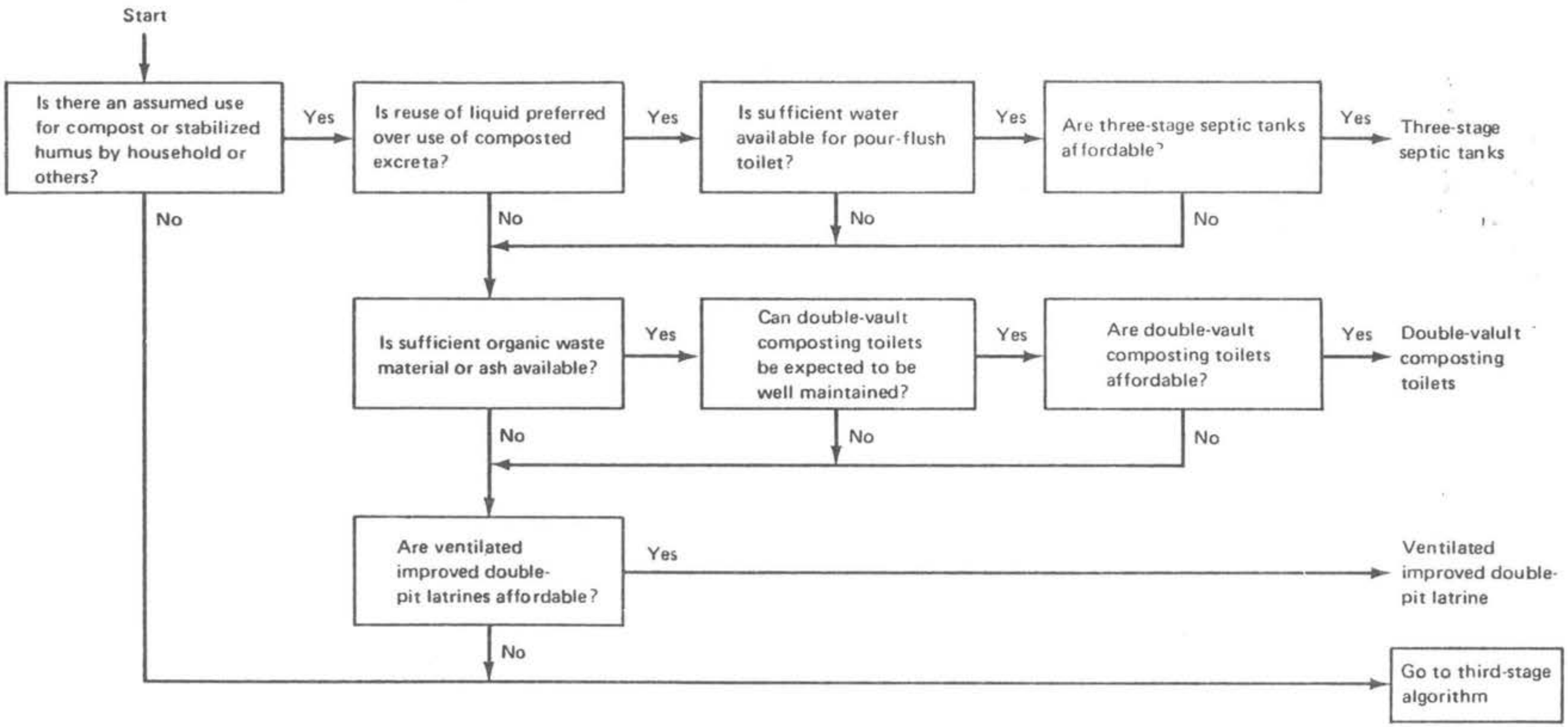
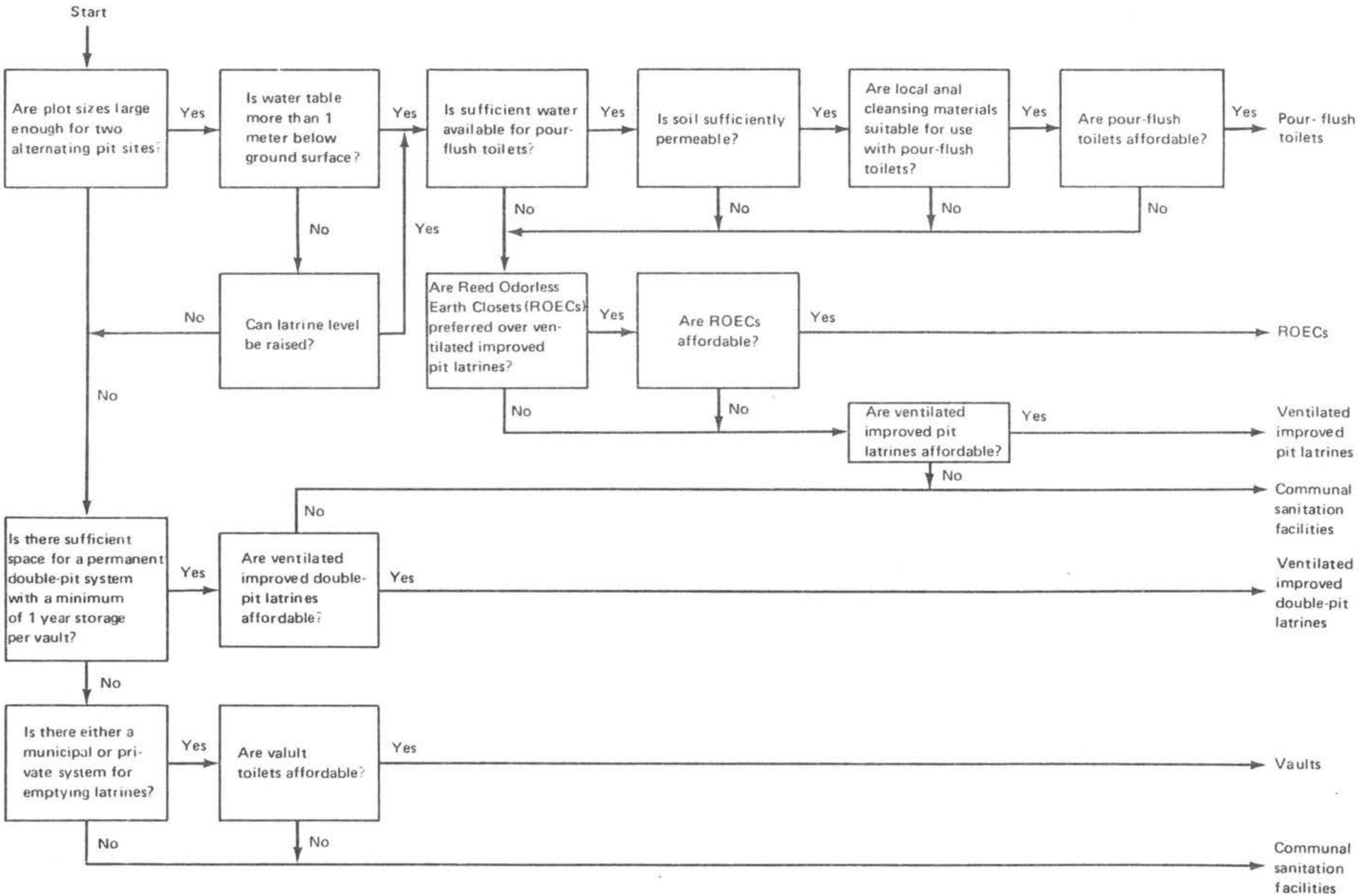


Figure 9-3 Third-stage Algorithm for Selection of Sanitation Technology



Once the most appropriate technology has been selected by using the algorithm, several questions should be asked as checks. These are:

1. Can the existing sanitation system (if any) be upgraded in any better way than that suggested by the algorithm?

2. Is the proposed technology socially acceptable? Is it compatible with cultural and religious requirements? Can it be maintained by the user and, if appropriate, by the municipality? Are municipal support services (for example, education and inspection) required? Can they be made available?

3. Is the technology politically acceptable?

4. Are the consumers willing to pay the full cost of the proposed technology? If not, are user subsidies (direct grants or "soft" loans) available? Is foreign exchange required?

5. What is the expected upgrading sequence? What period of time is involved? Is it compatible with current housing and water development plans? Are most costly technologies in the upgrading sequence affordable and desired now?

6. What facilities exist to produce the hardware required for the technology? If lacking, can they be developed? Are the necessary raw materials locally available? Can self-help labor be used? Are training programs required?

7. If the technology cannot dispose of sullage, can adequate facilities for sullage disposal be installed? Is the amount of sullage low enough (or could it be reduced) to avoid the need for sullage disposal facilities?

## Sanitation Sequences

The selection of the technology best suited to effect initial improvements in sanitation for a particular area should also reflect the future need for improvements as the users' aspirations and socioeconomic status rise. The following subsections examine the feasibility of upgrading sanitation in stages that take into account incremental improvements in the level of water supply service (improvements that are themselves, of course, measures of socioeconomic status). Such feasible sequences or stages for upgrading are summarized in figure 2-4.

### Toilets and three-stage septic tanks

These toilets, functioning well and with a continuing demand for compost or fertilizer, need no upgrading. Upgrading of the water supply from hand-carried to household service, increased housing density, or decreased demand for compost would, however, require modifications in these facilities. The toilets could be easily modified to a PF vault toilet or to a vault with vacuum-truck.

VIP latrines and ROECs

Many rural and suburban water and sanitation projects provide pit latrines and communal hand pumps or public standpipes as the initial improvement. The pit latrine should be either a ventilated improved pit (VIP) latrine or Reed Odorless Earth Closet (ROEC). The subsequent priority for improvement would most likely be upgrading the water supply to yard taps (or household hand pumps where applicable). Both the VIP latrines and ROECs could then be upgraded to PF toilets. The conversion of a ROEC to a PF toilet is very simple and inexpensive: a water-seal squatting plate or pedestal seat is installed in place of the ROEC chute, and the existing displaced pit is used to receive the flush water. Depending on soil conditions, it may be necessary to enlarge the pit to provide more infiltration area for the flush water. Alternatively, a second pit or infiltration trench could be provided to receive the settled flush water from the original pit.

A VIP latrine can also be converted to a PF toilet by filling in the pit with soil and installing a water-seal unit that is connected to a newly dug pit. Clearly, this is best done when the pit is close to the end of its life, and it is most advantageous when the superstructure cannot easily be dismantled (for example, the superstructure is constructed in concrete block or adobe brick).

PF toilets

When the water supply is upgraded to house connections, it is possible to install a low-volume, cistern-flush toilet. This is not essential and may not be considered a priority by the users, to whom upgrading of the water supply from a single yard tap to multiple house connections usually first means plumbing for kitchens and bathing areas. The main improvement required is better sullage disposal that does not have to be via sewers.

Vault toilets

The system of vault toilets and vacuum trucks is used most commonly in urban areas. Because the vault satisfactorily stores the excreta and PF water and has a water seal, no upgrading is necessary for excreta disposal. As the water supply service improves to a house connection, however, sewers (or other suitable arrangements) for sullage disposal may be desirable. If sewers are installed, the vault toilet may be readily converted to a sewered PF toilet by connecting the vault to the sewer system as described above.

Sample Staged Solutions

To demonstrate the feasibility of using a staged sanitation system, four possible schemes or variations are illustrated in figure 9-4, and comparative economic costs are presented for each. The last scheme, installation of a sewerage system with no preceding stages, is obviously not a sequence but is included in the figure as a reference. Schemes 1-3 can be started with any stage and terminated at any point, depending on the desires of the users. For simplicity, it is assumed that each stage within a scheme will remain in service for 10 years, after which either the next stage will be added or the existing facility will be replaced or repaired. In addition, the schemes described can be varied substantially without adding greatly to the cost. For example, to a standard pit privy with a PF, a vault could be added if housing density increases or the soil becomes clogged. Similarly, a composting toilet that already has a watertight vault could be converted into an aquaprivy or PF with a vault.

As shown in figure 9-4, the initial sanitation facility (a) would consist of a VIP latrine with a concrete squatting slab and concrete block superstructure. An actual facility of this kind in an East African city was used as the basis for the costs shown. Its (unlined) pit is about 5-1/2 meters deep and 1-meter square, and the normal filling time is 10 years. Its initial construction cost is $108, of which the superstructure accounts for $53.

In year 11 the community water system is upgraded from wells or standposts to yard hydrants, and the dry latrine is converted to a PF latrine (b) by digging a new soakage pit near the superstructure and replacing the old squatting plate with a bowl and inverted siphon. The old pit is filled in prior to placement of the new squatting plate. For costing purposes, it is assumed that the accumulated sludge would be removed from the new pit at 5-year intervals and composted.[1] The costs of truck, land, and equipment for the composting facility are therefore included in year 15, and the trucks are replaced at 5-year intervals thereafter. The operating and maintenance costs incurred in years 11-20 also included the costs of water for flushing for the PF latrine, which was calculated as 10 liters per capita daily for six persons at $0.35 per cubic meter.

In year 21 the third stage of Scheme 1 would begin, when the water service is upgraded to house connections and a large volume of sullage water has to be disposed of. At this point a new (lined) pit would be dug and the existing bowl and siphon would be connected to it. An overflow pipe would connect the pit to a newly constructed small-bore sewer system (c). This upgrading would permit the use of cistern-flush toilets if desired by the users. Annual collection of sludge would be required from the smaller vault, and a trickling filter plant would be constructed for treatment of the effluent.[2] The combined flushing water and sullage flow from year 21 onwards is taken to be 175 liters per capita daily.

Comparative total economic costs,[3] on a household basis, were prepared for this scheme and for the three variations--including the

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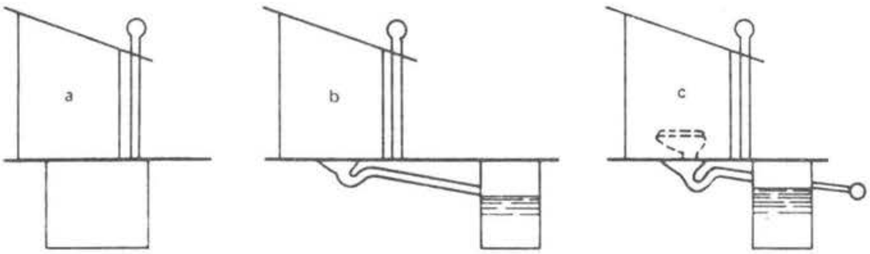
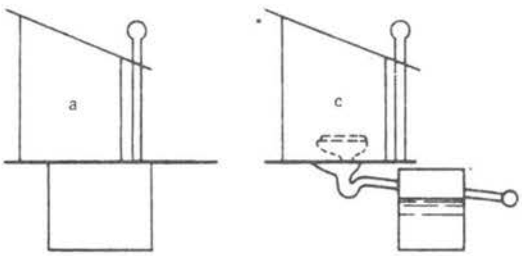
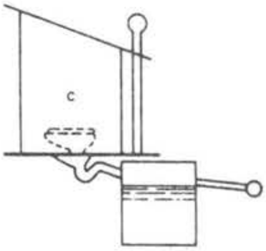
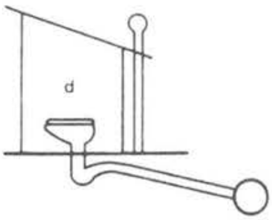
1. In small communities, sludge would probably be buried rather than composed.

2. This option is chosen for illustrative purposes because of available cost data from the same East African city.

3. This is the present value (assuming an opportunity cost of capital of 10 percent) of the 30-year investment and maintenance cost streams.

**Figure 9 - 4. Sample Sanitation Sequences (cost data in 1978 U.S. dollars)**

| Item | Year 1 | Year 10 | Year 20 | Year 30 | Total economic cost per household 30-year period |
|---|---|---|---|---|---|
| Scheme 1 |  | | | | |
| Construction cost | 108 | 65 | 905 | | 354 |
| Scheme 2 |  | | | | |
| Construction cost | 108 | 915 | | | 1,111 |
| Scheme 3 |  | | | | |
| Construction cost | 960 | | | | 1,519 |
| Scheme 4 |  | | | | |
| Construction cost | 978 | | | | 3,000 |

a, Ventilated improved pit latrine; b, pour-flush toilet with soakaway; c, pour-flush toilet with small-bore sewer (with optional bowl and seat); d, conventional sewerage.

alternative of proceeding immediately with the construction of a sewerage system (Scheme 4). The total economic cost per household of the three-stages of Scheme 1 over a 30-year period (in 1978 prices) is $354, which includes the salvage value of the sewerage system (assumed to have a 40-year life). The second scheme shown in figure 9-4 moves directly from the VIP latrine (installed in year 1) to small-bore sewers in year 11. The total cost per household over 30 years for Scheme 2 is $1,111, or more than three times that of the preceding, three-stage alternative. The third alternative (Scheme 3) is simply the installation of a small-bore sewerage system in year 1. This would have a total cost of $1,519 per household over 30 years. The final alternative (Scheme 4), calculated in the same way and with data from the same city as the small-bore sewerage system for purposes of comparison, is the immediate construction of a conventional sewerage system. A construction period of 5 years is assumed and the facility is assumed to be two-thirds utilized upon completion and fully utilized 10 years after completion. Based on these assumptions, the total cost per household over 30 years is $3,000, which includes the cost of water for flushing and all regular operating and maintenance costs (as do the costs of the other alternatives). It is nearly ten times as high as the cost of the three-stage Scheme 1 and almost twice that of the one-stage sewered PF alternative shown as Scheme 3.

As is shown in figure 9-4, none of the upgrading sequences discussed above leads to conventional sewerage. This is not because conventional sewerage systems should not be built (they are an excellent form of sanitation for those who can afford them and have plenty of water), but because they are not necessary to provide a high standard of sanitation. The sewered PF system (which can include a low-volume, cistern-flush toilet for user convenience) yields an equally high standard of service and has two big advantages over conventional sewerage: it is substantially cheaper, and it can be reached by the staged improvement of several different sanitation technologies. Thus, planners of sanitation programs can confidently select one of the low-cost technologies in the knowledge that, as socioeconomic status and sullage flows increase, it can be upgraded in a predetermined sequence of incremental improvements to an ultimate level of convenience. The important fact for concerned planners to remember is that sewers are required to dispose of sullage, not excreta, and that the elimination or reduction of nonessential water use is thus the crucial element of an economic solution to sanitation problems. This is particularly significant in developing countries, where the increasing competition for investment funds often limits the amount of resources that can be allocated to the water and irrigation sector.

# CHAPTER X

## Concluding Note

In a special session on November 10, 1980, The United Nations General Assembly declared the 1980s to be the International Drinking Water Supply and Sanitation Decade. The objectives of the Decade--as promulgated by the nations participating in the United Nations Water Conference in Mar del Plata, Argentina, in April 1977-- are to provide an adequate supply of safe water and facilities for the sanitary disposal of waste for all by 1990, if possible, or to reach such goals as governments consider feasible. At the General Assembly meeting, governments also submitted national plans for the Decade that indicated targets to be reached and described actions to be taken during the Decade.

This study has identified and evaluated traditional technologies found in a variety of communities and countries around the world. Costs and benefits have been assessed and improvements suggested. A method of sequential improvement of sanitation has been developed to permit a gradual increase in the level of convenience from the pit privy to a flush toilet in steps that keep pace with the users´ability to pay for them. Incremental costs are low because each step in the sequence makes use of previously built facilities. The report further examines institutional and engineering aspects of sanitation systems and has provided detailed recommendations on how to evaluate sanitation needs, design and implement projects, and organize the necessary institutional and community support.

In demonstrating the feasibility of using low-cost technologies appropriate for the conditions in large and small communities of developing countries, the report can play a significant role in the implementation of the International Drinking Water Supply and Sanitation Decade. Similarly, companion volumes addressing specific topics or reporting case studies provide the planner, engineer, and community worker with detailed information on the design, implementation, and implications for health of sanitation projects.1/ Nevertheless, these publications are but a beginning in the process of designing appropriate solutions to the pressing needs of the world´s part for water supply and sanitation. The next steps are equally important:

- Economic planners and officials responsible for the allocation of international funds must be informed of the availibility of appropriate technologies that permit the provision of services to many more people for the same cost as conventional technologies provide for fewer users.

- Engineers must learn to use these technologies and seek the participation of behavorial scientists and health educators to help in the design of projects fully responsive to the needs of the user and to assist in the implementation of such projects with the affected communities´ participation.

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1/ See the list of publications in the series World Bank Studies in Water Supply and Sanitation and Appropriate Technology for Water Supply and Sanitation (given in the preface).

- Master plans for water supply and sanitation should provide service standards (and technologies) that the different groups in the community can afford without precluding the possibility of adding future sequential improvements. Professionnals developing water plans and projects should be recompensed for the work to be done rather than on the basis of the cost of their proposed solutions.

- Work must continue on the improvement of traditional technologies, the adaptation of advanced technologies and the development of health education techniques so that water supply and sanitation services may be extended at lowest possible cost.

The list above is, of course, incomplete. But given imagination and the courage to examine and recommend the unconventional, low-cost solutions to problems of water supply and sanitation will be found. This book represents an initial step in this creative process.

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