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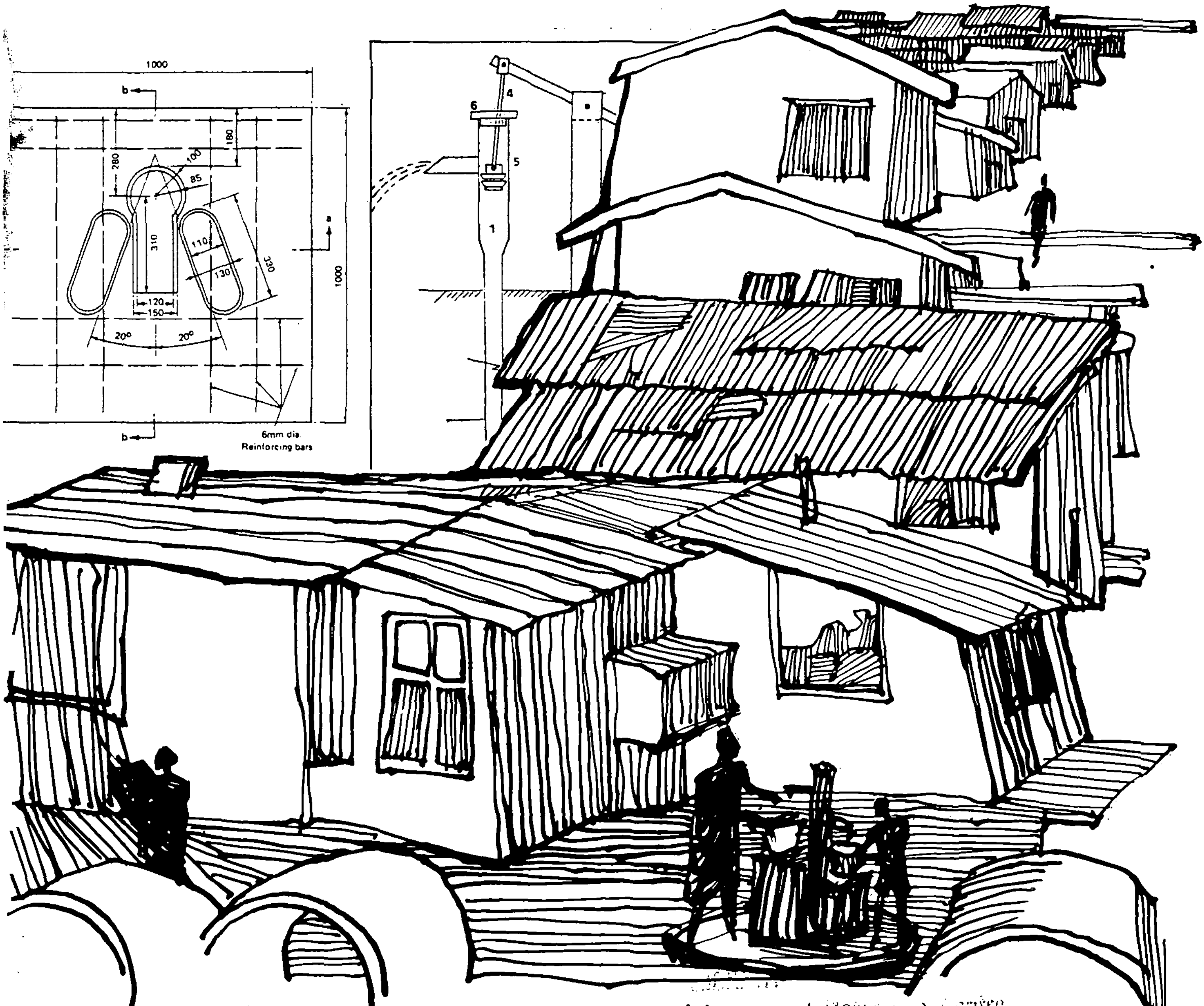
A Summary of Technical and Economic Options

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 1a

APPROPRIATE TECHNOLOGY FOR WATER SUPPLY AND SANITATION

A SUMMARY OF TECHNICAL AND ECONOMIC OPTIONS

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Abstract

This paper is a summarized version of the final report on appropriate technology for water supply and waste disposal in developing countries, a World Bank research project (RPO 671-46) undertaken by the Energy, Water and Telecommunications Department in 1976-1978. It reports the broad technical, economic, health, and social findings of the research and discusses the aspects of program planning necessary for their implementation.

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PREFACE

Over the past decade the focus of development planners has broadened from an overriding concern with economic growth to 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 1978 Annual Meeting, Mr. McNamara stated that, in order to achieve the twin objectives of growth and equity, countries must modify the pattern of growth so as to raise the productivity of the poor, and also improve the access of the poor to essential public services.

Among these essential public services are water supply and waste disposal. Few other services contribute as much to an improvement in health and living standards as the provision of an adequate supply of safe water and the sanitary disposal of waste. It has become apparent, however, that projects have to be specifically designed to reach the urban and rural poor in order to provide them with services that they can afford and that meet their needs.

In particular, sewerage, the conventional method of human waste disposal, requires massive investments of both foreign and local capital that are generally not available in developing countries. Where sewerage systems have been built they have often resulted in charges to the consumers that were beyond their ability to pay. As a consequence, in 1976 the World Bank launched a two-year research project on appropriate technology for water supply and waste disposal in developing countries. The emphasis of the project was directed toward identifying and evaluating sanitation technologies, particularly as they are affected by water supply service levels and the needs and resources of project beneficiaries. The project assessed public health and social objectives as well as technical, economic, environmental, and institutional constraints. The findings of the research project and other parallel research activities in the field of low-cost water supply and sanitation are presented in the series of publications entitled: Appropriate Technologies for Water Supply and Sanitation, of which this report is a summarized version of volume I. Publications in this series include:

(Vol 1) Technical and Economic Options, by John M. Kalbermatten, DeAnne S. Julius, and Charles G. Gunnerson [a condensation of Appropriate Sanitation Alternatives: A Technical and Economic Appraisal, forthcoming from Johns Hopkins University Press]

(Vol 2) A Planner's Guide, by John M. Kalbermatten, DeAnne 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 Johns Hopkins University Press]

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

(Vol 5) <u>Sociocultural Aspects of Water Supply and Excreta Disposal</u>, by Mary Elmendorf and Patricia K. Buckles

(Vol 6) <u>Country Studies in Sanitation Alternatives</u>, by Richard A. Kuhlthau (ed.)

(Vol 7) <u>Alternative Sanitation Technologies for Urban Areas in Africa</u>, by Richard G. Feachem, D. Duncan Mara, and Kenneth O. Iwugo

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

(Vol 9) <u>Design of Low-Cost Water Distribution Systems</u>, 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) <u>Nigh-soil Composting</u>, by H. I. Shuval, Charles G. Gunnerson, and DeAnne S. Julius.

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

(Vol 12) <u>Low-Cost Water Distribution--A Field Manual</u>, by Charles Spangler

Additional volumes and occasional papers will be published as ongoing research is completed. With the exception of volume IV, all publications may be obtained from the Transportation, Water and Telecommunications Department, World Bank (and, for volumes 1-3, from the Johns Hopkins University Press, Baltimore, Maryland, USA, upon their publication).

It is the purpose of this report to summarize the broad technical, economic, health, and social findings of the research and to discuss the aspects of program planning necessary to actualize the findings. Thus it is directed primarily to planning officials and sector policy advisors in and for developing countries. Although the focus is primarily on sanitation options (because water supply technology is better known and understood), information on water service levels is included because water use is a determining factor in waste disposal. Details and technical recommendations on technologies, potential improvements, applications, project design, and implementation are presented in volume 2, which has been written primarily for engineers and field workers.

The findings and recommendations of this report are based on surveys of relevant literature (volumes 3 and 4), an evaluation of sociocultural aspects (volume 5), detailed field studies (volumes 6 and 7), 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 few can be mentioned. We wish to acknowledge, in particular, the support given to this project by Mr. Yves Rovani, Director, Energy, Water and Telecommunications Department; and the valuable review and direction provided by the Bank staff serving on the Steering Committee for the Project: Messrs. E. Jaycox, A. Bruestle, W. Cosgrove, F. Hotes, D. Keare, J. Linn, R. Middleton, R. Overby, A. Stone, and C. Weiss. In addition, Messrs. R. Feachem, D. Mara, and J. Warford provided us with useful advice on specific issues. The contributions of consultants conducting field studies and providing specialized reports are acknowledged in the volumes to which they have contributed. The reports could not have been produced without the dedication and cooperation of the secretarial staff: Margaret Koilpillai, Julia Ben Ezra, and Susan Purcell.

EXECUTIVE SUMMARY

The member countries of the United Nations have declared 1981-1990 to be the International Drinking Water Supply and Sanitation Decade. Their goal is to provide two of the most fundamental human needs--safe water and the sanitary disposal of human wastes--to all people. The World Bank and many other international and bilateral development agencies are equally committed to enhancing the health and well-being of the urban and rural poor by improving their access to essential public services. The magnitude of the task is enormous. Today 1.1 billion people in developing countries lack adequate sanitation, and an almost equal number have no access to safe water. If to this number the predicted population growth to 1990 is added, over 2 billion people will have to be served.

During preparation for the International Drinking Water Supply and Sanitation Decade, constraints to meeting the Decade's goals must be identified and programs developed for overcoming them. In the field of water supply, such work is already well advanced. New designs for hand pumps have been prepared and tested for rural areas, although much work remains to be done to overcome the chronically high failure rates of hand pumps. Designs for low-cost water distribution networks providing a mix of house connection and standpipe service to urban slum and squatter communities are already being implemented. The institutional infrastructure needed to efficiently expand service at a rapid rate and the tariff policies necessary to cross-subsidize it have already been developed in many countries. Achievement of Decade targets for water will depend more on mobilizing funding and the training of sufficient staff to expand present programs than on the need to develop new ones. For sanitation, however, few attempts have been made to develop or implement technical options for a developing country other than waterborne sewerage. What is becoming very clear, however, is that waterborne sewerage, the conventional developed country solution, has proven to be technically, economically, and culturally unsuitable for many cities and communities in the developing world when it has been tried. Even in industrial countries, the enormous water requirements and very high environmental cost of the point discharge of treated waste necessitated by sewerage are leading to a re-examination of its desirability. Thus the first step toward the rapid expansion of sanitation services is a thorough and critical examination of the technological options available.

This report presents the results of two years of field studies undertaken by the World Bank in thirty-nine communities in fourteen countries around the world to identify appropriate technologies for sanitation in developing countries. Initially a bibliographic search was conducted for information on nonconventional options, but only about 1 percent of the published technical literature on wastewater was found to relate to technologies other than sewerage. Case studies conducted by local engineers, economists, and social workers thus formed the backbone of the research effort. Its results are both encouraging and challenging.

The first and most important finding was that there are many technologies between the unimproved pit privy and sewerage that can be recommended for widescale replication. In all, five types of household (on-site) systems and four types of community systems were identified, and many variations of each type were observed. Improved designs were prepared for several of these, and for only one technology (bucket latrines) was it concluded that introduction into new sites should be avoided. Two of the other technologies, aquaprivies and communal facilities, are limited in their applicability by social factors. All of the remaining technologies (improved pit latrines, pour-flush toilets, composting toilets, modified septic tanks, vault and cartage, small-bore sewerage, and conventional sewerage) can be recommended for adoption subject to the physical conditions of the site and the social preferences and economic resources of the beneficiaries. Except in unusual circumstances, both scattered rural and densely populated urban communities should find themselves with two or more technically feasible options, each with a range of design alternatives.

One of the most important technical contributions of this research is the design of "sanitation sequences," step-by-step improvements leading from one option to another and designed from the outset to minimize costs over the long run. Thus the community can initially select one of the low-cost technologies in the knowledge that, as their socioeconomic status improves, it can be upgraded in a known series of improvements to a sophisticated "final" solution. This is something that is not possible with conventional sewerage; for it to function properly, large investments and large waterflows are needed from the outset. It is noteworthy that none of the sanitation sequences developed results in conventional sewerage. In urban areas the final upgrading is generally to a low-volume cistern flush toilet connected to a vault that overflows into a small-diameter sewer. From the user's viewpoint, the only difference between this system and conventional sewerage is the size of the toilet tank in his bathroom. But the cost savings, particularly if it is installed by utilizing an existing facility, are significant. The installation and use of such a system over a thirty-year period cost about one-half the present value cost of conventional sewerage. Its environmental cost is also significantly lower than that of sewerage since its eventual waste discharge is less. As this example makes clear, sewers are required to dispose of sullage water (laundry and kitchen wastes plus flushing water), not excreta; therefore the key element in an economic solution to sanitation is the reduction of nonessential water use. Toward this end, work is underway to adapt water-saving showerheads and other appliances for use in developing countries. This also leads to the conclusion that water supply schemes, even when the sanitation component is not included, should consider in their design and in the establishment of service standards the requirement to dispose of the water being supplied to the community and the costs (even in the future) associated with its disposal.

In addition to these technical findings, the research has produced a new approach to the problem of linking health benefits to environmental sanitation improvements. It was recognized that quantifying health benefits is not the primary objective of better sanitation: achieving them is. If funds are inadequate to build and maintain the elaborate sewerage system known to provide all these benefits, it is essential to choose the technology that will maximize the health benefits achieved with the funds available. This requires a more precise analysis of the relations between disease and sanitation than has been attempted in the past. Thus, the Ross Institute of Tropical Hygiene (London School of Hygiene and Tropical Medicine) was contracted as part of this study to focus directly on the transmission process of excreta-related disease and to relate that process to the various types of sanitation interventions (i.e., technologies). They have developed an environmental classification of excreta-related infections that, together with a basic understanding of the factors important in disease transmission, enables the planner and engineer to maximize the health benefits of whichever technology is chosen. The means of doing so include both incorporating specific design features and supplementing the "hardware" with precisely targeted user education campaigns.

That alternative technologies exist and that they can be designed to maximize health benefits still leaves the planner with two important questions: what do they cost and what complimentary inputs do they require for successful implementation? The costs collected from a statistically based, case study approach such as this one are bound to vary widely from one community to another, even for identical technologies. When that problem is compounded by the fact that no two observed pit privies, for example, were exactly alike in their design or construction, it is obvious that precise measures of cost sensitivities cannot be obtained. Nevertheless, by applying a consistent methodology to all case study calculations and by deriving economic rather than financial costs, a broad cross-technology cost comparison was possible.

The nine technologies studied broke clearly into three cost groupings. Five of them cost less than $100 1/ per household per year (the range was from $19 to $65) when all input costs are shadow valued and both capital and recurrent costs are included. Two technologies (aquaprivies and Japanese-type vacuum cartage) cost between $150 and $200 per household per year. Septic tanks and sewerage costs averaged $370 and $400 per household per year, respectively. Thus the ratio of lowest to highest cost system was 1:20.

The two most important influences on total household costs were factors that have often been ignored in engineering analyses: on-site household costs (e.g., internal plumbing) and the cost of flushing water for water-carried systems. The former was important for all technologies and never accounted for less than 45 percent of total household costs on an annual basis. The latter is most important for sewerage and septic tank systems. Where the economic cost of water is high, the payoff from designing systems with low requirements for flushing water is large.

Since technological alternatives to sewerage do exist and can provide full health benefits at a substantial cost saving, why have they not been adopted in the past? What are the obstacles to their selection that

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1. All dollar figures in this report are in 1978 U.S. dollars.

need to be overcome, and what new incentives need to be provided? One important obstacle has been the information gap. Results such as those of this study need to be disseminated as widely and as quickly as possible. A second obstacle is the retraining of most professionals in the field required to cope with the nonconventional solutions being proposed. The technology selection process will have to be redefined to be based on an economic rather than financial comparison of alternatives. An even bigger change is needed in the way project feasibility studies are carried out; the amount of interaction with the eventual users (the community or its direct representatives) must be greatly increased. This probably means that multidisciplinary teams including sociologists should be used from the first phase of planning and demand analysis through the final phases of technology selection and detailed design. Since many of these technologies will be partially built and often maintained by the users, it is crucial that they be involved in the entire selection process.

In addition to increased community involvement, the successful implementation of many of the nonconventional technologies will require different institutional arrangements than those appropriate for sewerage. More decentralization and better coordination with health, housing, and other agencies are the main factors involved.

The final area in which new incentives will be required to promote the adoption of appropriate sanitation technologies is in their financing. In many developing (and industrial) countries the central government provides large subsidies or grants for the construction of interceptors and sewage treatment plants. Obviously this makes it very difficult for a community to choose any other waste disposal system, since it would have to bear the full financial cost of it. Governments in developing countries need to consider carefully what they hope to achieve through subsidizing waste disposal costs. If it is improved community health, then they should make funds available for packages designed to achieve that objective at the least cost. These might include immunization and education components along with a low-cost method of waste disposal. Even the most sophisticated sanitation technology will not bring health improvements unless properly used and combined with good personal hygiene habits. If a government's objective is the long-term protection of the environment, then it should subsidize those technologies that promote that 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 except in high-density, high-water-consumption areas. To subsidize them exclusively may preempt the appropriate solution.

International and bilateral lending agencies have also exerted in the past a financial bias in favor of sewerage. 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, while those that used mostly local materials and perhaps even self-help construction had too small a foreign exchange cost to concern the agencies. Fortunately, most aid organizations have now changed their policies to permit financing of local cost components. There has also been increased interest in financing projects with benefits directed to the poorer groups in society. These two changes should promote increased interest by aid organizations in low-cost sanitation packages.

The obstacles that in the past have created a bias in favor of sewerage are gradually being overcome. 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 record on individual government policies that could encourage better sanitation programs is mixed, with a lot of room for innovation. 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 thirty years. A continued effort to improve incentives and remove constraints toward the choice of appropriate technologies can provide the needed groundwork for the International Drinking Water Supply and Sanitation Decade of the 1980s.

WORLD BANK PHOTO by Edwin G. Huffman

INTRODUCTION

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 by 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. Coupled with malnutrition, these excreta-related diseases take a dreadful toll in developing countries, especially among children. Invariably, it is the poor who suffer the most from the absence of water and sanitation, because they lack not only the means to provide for the necessary facilities but also 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.

Today some 1.1 billion people in developing countries lack sewerage, and an almost equal number do not have any access to safe water. If to this number the predicted growth in population to 1990 is added, over 2 billion people have to be provided with water and sewerage during the 1980s to meet the goals of the Drinking Water and Sanitation Decade.

One of the fundamental problems in meeting these goals is the high cost of conventional sanitation services. Very general estimates based on existing 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. Per capita investment costs for sewerage alone range from $150 to $650, which is totally beyond the ability of the beneficiaries to pay.

In industrialized countries, the standard solution for the sanitary disposal of human excreta is waterborne sewerage. 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. Yet sewerage was not designed (and is not required) to maximize health benefits. It is also far from an optimal environmental solution (as developed countries today are discovering).

An examination of how sewerage came about reveals three facts very clearly. First, waste disposal went through many stages before sewerage. Second, existing systems were improved and new solutions invented whenever the old solution was no longer satisfactory. Third, improvements have been implemented over a long period of time and at substantial cost. 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. With the benefit of hindsight it should be possible not only to correct some of the shortcomings of past solutions, but also to develop a sequence of planned sanitation improvements, designed from the outset to provide maximum health benefits while minimizing costs over the long run. In short, there is a need to reopen the question of appropriate sanitation technologies for developing countries.

There is no concise and universally correct definition of technological appropriateness. 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 product at the least economic cost.

The process begins by identifying all of the technological alternatives available for providing the good or service desired (in this case, sanitation). Within that set there will usually be some technologies that can be readily excluded for technical or social reasons. For example, some technologies may require institutional support that is infeasible given the social environment. Once these exclusions have been made, one is left with the range of technically and socially feasible alternatives. For those technologies, cost estimates are prepared that reflect their real resource cost to the economy. Least-cost solutions for each technology are selected. On the basis of these economic costs and discussions with government planners, financial costs are prepared for all least-cost solutions. The final step in identifying the appropriate sanitation technology must rest with the eventual beneficiaries. Those alternatives that have survived technical, social, and economic tests are presented to the community with their attached financial price tags, and the users decide what service level they are willing to pay for.

This selection process, or operational definition, immediately provokes questions. How does one judge social or environmental acceptability? What is the economic cost of a process? The case studies upon which this report is based were undertaken both to test approaches to these methodological questions and to accumulate factual information on the technical, economic, social, and health aspects of existing sanitation technologies.

ANALYSIS OF FIELD STUDY RESULTS

Technical Assessment

Service levels in water supply and sanitation vary widely in the developing world. They are interrelated in that: (1) health and environmental benefits of a safe water supply can be realized only when appropriate attention is paid to excreta and wastewater disposal, and (2) the larger the amount of water supplied, the fewer the options and the higher the costs for excreta and sullage disposal.

Site investigations of sanitation systems in thirty-nine communities around the world provided a wealth of practical design and operating data upon which to base a technical assessment of the various sanitation service levels. While many variations of similar systems were observed, they have been broadly classified into five types of household systems and four community systems, as listed below.

Household sanitation technologies

1. Pit latrines
2. Pour-flush toilets
3. Composting toilets
4. Aquaprivies
5. Septic tanks

Community sanitation technologies

1. Bucket latrines
2. Vault toilets with vacuum-cart collection
3. Communal facilities
4. Sewerage

Conventional designs, potential improvements, and the technical advantages and limitations of each were studied. The main technical and environmental factors that are important in choosing among them are discussed below.

Water Supply Service Levels

Hand-carried supplies from a public hydrant restrict feasible technologies to those not requiring water, such as latrines, composting toilets and their various adaptations. Pour-flush (PF) toilets may be feasible in a sociocultural environment where anal cleansing with water requires the carrying of water to the toilet in any event. 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. It should be noted that the above-mentioned facilities can be converted to water-seal units if desired when the water supply service is improved to a yard or house connection.

Yard connections permit PF and vault toilets, but not cistern-flush toilets. If sullage generation exceeds 50 liters per capita daily (lcd), sewered PF toilets also become technically feasible. The choice between these additional possibilities and pit or composting latrines, which are also still technically feasible, depends on other factors such as soil conditions and housing density. House connections make cistern-flush toilets with conventional sewerage or septic tanks and soakaways technically feasible, but the decision whether to install them or not is financial and economic. Sewered PF toilets are possible; but they have high capital costs and, as an interim measure, alternative improvements in sullage disposal may be economically more attractive.

Soil Conditions

Soil conditions are important for all sanitation technologies except those that can be completely contained above ground level. The only technologies that fall into this category are bucket latrines, composting toilets, and vault toilets, although in principle septic tanks with a raised evapotranspiration bed for effluent disposal could also be classified as "above ground" technologies.

Housing Density

In densely populated urban areas, pit latrines, PF toilets, and septic tanks with soakaways may be infeasible. Conventional sewerage is feasible if gradients are steep enough to provide self-cleansing velocities. PF toilets with soakaways will be feasible at flatter gradients, and vault toilets with vacuum-cart collection are feasible if minimal access is available. The choice among these possibilities is decided 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 what population density on-site systems such as pit latrines, PF toilets, and composting toilets become infeasible. The figure is probably around 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 population densities as high as 1,000 persons per hectare in North Africa. 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.

Complementary Investments

Off-site night-soil or sewage treatment works are required for vault toilets, sewered PF, 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, composting latrines may be provided where there is a demand for reuse. Other technologies that require off-site treatment facilities have high potential for 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 pit latrines, composting toilets, 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.

User Hygiene Habits

The choice of anal cleansing materials, in particular, can affect the choice of technology. PF and cistern-flush toilets cannot easily process anal cleaning materials such as rocks, mud balls, maize cobs, stones, or cement bag paper where a traditional practice of disposing of them in the toilet exists. Aquaprivies can accept such materials without blockage, although the frequency of desludging must be increased. The practice of using water for anal cleansing may present problems for pit latrines in soil with limited permeability or for composting toilets, which may as a result 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 of lack of adequate maintenance (at the user and/or municipal levels); the users and some municipal officials may not be fully aware of the need for such maintenance. Thus, user education programs and programs for institutional development will generally form an essential part of sanitation program planning. Changes, especially those in social attitudes, can be accomplished only slowly, which emphasizes the value of a planned series of incremental sanitation improvements over time.

Technical Evaluation

From the foregoing factors and others, the technical suitability of various technologies for application in a specific community can be assessed. In this project, judgments were also made about the global potential for upgrading and/or widespread replication of each technology type.

Of the household systems, the pit latrine is, and will likely remain, the most common technology, particularly in rural areas. Two improved versions have been developed and field tested and are ready to be widely used. The first is the ventilated improved pit (VIP) latrine, which incorporates a specially designed vent pipe topped with a gauze screen, and is essentially odor and insect free. The second is the Reed Odorless Earth Closet (ROEC), which has a displaced pit for longer life and greater social acceptability in some cultures since the excreta cannot be seen.

PF toilets are also ready for replication. They can satisfy the desire for an indoor toilet at low cost and can be upgraded to handle increased sullage flows. In practice their more severe limitations are that users do not use enough flushing water, or that they are blocked by solid anal cleansing materials such as stones or corncobs. Thus, a user education program should accompany their introdution into a new area.

There are two basic types of composting toilets: continuous and batch. Continuous composters are extremely sensitive to the degree of user care; the humus must be removed at the correct rate, supplemental organic matter must be added in the correct quantities, and only a minimum of water can be added. Even if all these conditions are met, fresh excreta may occassionally slide into the humus pile and limit the potential for reuse. For this reason, the conclusion of this study is that continuous composting toilets are not suitable for use in either the urban or the rural tropics.

Double-vault composting (DVC) toilets are the most common type of batch composting toilet. They have two adjacent vaults, one of which is used until it is about three-fourths full, when 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 safe for use as a soil fertilizer or conditioner.

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

The conventional aquaprivy consists of a squatting plate above a small septic tank that discharges its effluent to an adjacent soakaway. The squatting plate has an integral drop pipe that is submerged into the water in the tank to form a simple water seal. As long as the water level in the tank is properly maintained, odor and insect nuisance are avoided.

In practice, maintenance of the water seal has usually been a problem, either because users are unaware of its importance, 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. One African country banned the building of aquaprivies because of such problems. A variation on the conventional design, called the self-topping or sullage aquaprivy, was developed to overcome the problem of losing the water seal. The additional water it receives, however, necessitates a larger soakage pit, so it cannot be used in urban areas where the soil is not suitable for soakaways or where the housing density or water usage is too high to permit subsurface infiltration for effluent disposal.

If properly maintained, the conventional aquaprivy is a sound technical solution. It has no technical advantage, however, 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. The only comparative advantage of the aquaprivy is that it is less easily blocked if users utilize solid cleansing materials or throw stones or corncobs into the tank. Thus, except in cases where users are unwilling to change such habits, the PF toilet should be preferred to the aquaprivy.

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 since they can provide a very high service level to those who can afford it in a given community, without the commitment of community funds for the construction of a sewerage system. Thus, as a part of a sanitation package that can meet the needs and resources 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.

Of the community systems, only the bucket latrine is judged to be unsuitable for replication. Problems of odor, insects, spillage, and generally unsanitary conditions at all collection and transfer points were ubiquitous in all of the cases surveyed. 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, and so forth), it is still difficult in practice to ensure that the system is operated satisfactorily. 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 or communal facilities.

Vault toilets, 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 two to six weeks. The vault toilet, emptied by a 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 collection tanker routes. Vaults are suitable for medium-rise buildings where excreta can be flushed down a vertical pipe into a communal vault at or below ground level. From the user's point of view, 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 lcd) 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 becomes necessary to provide for sullage disposal. Their main disadvantage is one shared by all community facilities: the need for an institution capable of organizing the collection service and operating the treatment facilities. Vault toilet systems observed in this study in East Asian and North African countries were found to work well where municipal institutions were well developed. The vault toilet system is technically very promising, although it may require prototype testing in some areas to ensure adequate institutional development.

There are no unusual technical requirements for a communal toilet. It may be a PF bowl, an aquaprivy, a low-volume cistern-flush, 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. 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 technical viewpoint, communal facilities may be the only low-cost alternative for providing sanitation to people living in very dense cities with no room for individual facilities. The social and institutional commitment to provide for their proper use and maintenance, however, can be a serious constraint.

Conventional sewerage is the final community system studied. Its main advantage is the high user convenience it provides. The main technical constraints are its large water requirement, the difficulty of excavation in very dense areas or 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 its construction when it is underutilized. A further problem of conventional sewerage 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 harm.

Over the past three decades numerous attempts have been made to design and build sewerage systems around the world. The success rate has not been high. The majority have not gotten past the master plan stage because of the failure to take into account financial constraints. Many of those that have been built in developing countries have had very serious problems with consumer acceptance. Connection rates, even where mandated by law, have been very low. Of the eight sewerage systems included in this study, three were operating close to capacity. One of those was in a Japanese city, and the other two were African systems built in the 1950s. On the other hand, many cities have a central commercial area with high-rise buildings where sewerage may be the only feasible solution. The lesson seems to be that the "economies of scale" in sewerage are illusory in areas where consumer acceptance is not assured, and in developing a sanitation package for a city, sewerage should be planned only for those areas where it is clearly the most appropriate for social and economic as well as technical reasons.

The general conclusion from this technical assessment is that there are many proven technologies available that provide satisfactory service levels and the potential for full health benefits (see below). Waterborne sewerage is not likely to be the most cost-effective solution to human waste disposal for most situations in developing countries. Given the present state of the art, it is the only feasible solution in the high density, westernized areas of some cities. But less expensive, equally effective technologies exist for application in many urban and almost all rural areas.

The Economic Comparison

Comparative costing lies at the heart of the analysis of alternative sanitation technologies. The scoring measure commonly used in project evaluation is some variation of the benefit-cost ratio. Unfortunately, the impossibility of meaningful benefit measurement for sanitation projects precludes its use in this case. There are also unquantifiable costs associated with alternative sanitation technologies. While 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 them with the environmental situation that would develop without the project in order to determine net benefit or net cost figures.

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 one apply a cost minimization rule. 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. While most properly selected systems can be designed to provide the potential for full health benefits (i.e., to assure pathogen destruction), the user convenience offered by an indoor toilet with sewer connection is hard to match with a pit privy. 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 solution will not provide sufficient information to select among sanitation alternatives. Nonetheless, if properly applied, it will provide an objective common denominator that reflects the cost trade-offs 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 service standards. Thus the economic evaluation of alternative sanitation technologies comprises three components: comparable economic costing, maximizing the health benefit from each alternative through proper design, and allowing the user to make the final benefit-cost determination.

The methods used in this study for economic costing are essentially those developed over the past two decades for project appraisal and recently elaborated upon by Squire and Van der Tak. 1/ Because benefit quantification was not possible, distributional weights could not be explicitly taken into account. This was not a serious limitation for this study, however, since its major focus was on identifying technologies that could meet the needs of the rural and urban poor. Thus the case studies themselves were chosen to incorporate that objective, and a wide range of socioeconomic levels among project beneficiaries was rare.

One of the most important principles of economic costing 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 are considered in a cost comparison. The costs borne by the household are often ignored. In addition to internal plumbing and toilet facilities, these costs include that of the water necessary to properly operate a PF or sewerage system. As shown below, these householder costs account for a significant part of total system costs.

Field Results

The single most useful figure for cross-technology cost comparison is the total annual cost per household (TACH). It includes both investment and recurrent costs, properly adjusted to reflect real opportunity costs, and averaged over time by the average incremental cost method. The use of per household rather than per capita costs is appropriate for those systems with on-site facilities designed for use by a single household. TACH, however, would be misleading if applied to communal facilities or cases where several households share one toilet. In those instances as adjusted, TACH has been calculated by scaling up per capita costs by the average number of persons per household.

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1. L. Squire and H. van der Tak, Economic Analysis of Projects, (Baltimore: Johns Hopkins University Press, 1975).

Table 1 below summarizes the TACH obtained for the ten technologies studied. It also shows the functional breakdown of costs into on-site, collection, and treatment components.

Table 1. Average Annual On-site, Collection, and Treatment Costs per Household (1978 U.S. dollars)

Facility	Mean TACH	On-site costs	Collection costs	Treatment costs
Low Cost				
PF toilet	18.7	18.7	-	-
Pit privy	28.5	28.5	-	-
Communal toilet	34.0	34.0	-	-
Vacuum-truck cartage	37.5	16.8	14.0	6.6
Low-cost septic tanks	51.6	51.6	-	-
Composting toilets	55.0	47.0	-	8.0
Bucket cartage a/	64.9	32.9	26.0	6.0
Medium Cost				
Sewered aquaprivy a/	159.2	89.8	39.2	30.2
Aquaprivy	168.0	168.0	-	-
Japanese vacuum truck	187.7	128.0	34.0	26.0
High cost				
Septic tanks	369.2	332.3	25.6	11.3
Sewerage	400.3	201.6	82.8	115.9

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

Contrary to expectation, when ranked according to cost the technologies do not divide cleanly into community and individual systems. The most expensive group (that with TACH greater than $300) includes sewerage and Japanese and Taiwanese septic tanks. The middle-range technologies (those with TACHs between $150 and $200) are aquaprivies, sewered aquaprivies, and Japanese cartage. The low-cost technologies (those with TACHs less than $100) include both community systems such as buckets and most other individual systems. The decision between high-, medium-, and low-cost technologies is fairly sharp, with large buffer areas available for system upgrading. The fact that variations of 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 as development proceeds.

The separation of TACH into its functional components is useful in determining where to focus the design effort in attempting 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 cost reduction potential for them must center on the on-site system components and the materials and methods used to produce and install them. Even among the six community systems, on-site costs account for at least 45 percent of the total. Japanese and Taiwanese septic tanks have the highest on-site costs of over $300 per household annually. The large role that the costs incurred by the household play in total system costs shows the importance of finding ways for funding on-site facilities. The very low connection rates of many sewer systems in developing countries (often in the face of legal requirements to connect) probably is at least partly due to the large household expenditure involved.

Two of the systems, sewerage and vacuum cartage, exhibit an interesting variety of cost patterns across the case studies. There is a wide difference in on-site costs of sewerage, ranging from an average of about $300 per household yearly for the Japanese systems to an average of just over $130 per household yearly for the five systems in developing countries. This variation is due both to the more elaborate internal plumbing facilities that are found in middle-class Japanese homes and to the high cost and relatively large amount of flushing water required by the Japanese systems. 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 average treatment costs of the former are $175 per household yearly, whereas those of the latter are less than $20 per household yearly.

For cartage systems, also, the major difference between the Japanese systems and the others is the household investment cost. The collection vehicles used in Japan are more expensive than those used elsewhere, and labor costs for operation, levels of vehicle maintenance, and the accompanying labor costs are much higher. These factors, however, are far outweighed by the very large differential in household facility costs. This has important implications for system upgrading. 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.

The two most outstanding influences upon total household costs are factors that have often been ignored in engineering analyses: on-site household costs and the cost of flushing water for water-carried systems. The former is important in all systems and never accounted for less than 45 percent of TACH. The latter is most important for sewerage and septic tank systems. Where the economic cost of water is high, the payoff from designing systems with low requirements for flushing water is large.

The Economics of Reclamation

A fourth functional cost component is reclamation. If reuse benefits can be produced, they could offset some of the other costs. One of the original aims of this study was to determine the technical and economic potential for reuse technologies.

Unfortunately, it has been very difficult to locate working examples of human waste disposal systems in developing countries with a sizeable reuse component. A few of the sewage treatment systems produce small amounts of methane from their digestors, which 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, while there is much experimental and theoretical data on the economic potential of reuse technologies, there is a dearth of empirical data derived from actual experience. 1/

All of the significant reuse technologies found in this study were located in the far eastern countries. 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 modern marketing analyses or optimal pricing strategies. Thus it is probably not surprising that none showed significant economic benefits. The optimistic claims that have been made for reuse technologies were not supported, but neither have they been refuted. The economic potential for reuse technologies remains to be explored.

Financial Costs

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--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 the like), and therefore are quite objective, financial costs are entirely subject to interest rate policy, loan maturities, the availability of central government subsidies, and so forth. Therefore, it is not possible to present comparable financial costs of the various technologies in the same way

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1. The obvious exception to this statement is the experience of China, but scientifically documented information on it is rare, and it was not possible to include first-hand observation in this study. Much data are available on biogas production in India, but most units use animal rather than human excreta.

present comparable financial costs of the various technologies in the same way that economic costs could be developed. It is possible, however, to use the economic costs to derive total investment costs per household, which will provide a basis for financial comparison of alternatives. The other useful figure that can be extracted from economic costs is the annual recurrent cost (with water costs shown separately), which will give an indication of periodic financial requirements.

One possible set of financial requirements for the various systems is tabulated below based on assumptions for loan terms and interest rates. The first column in Table 2 is the total investment cost (including on-site, collection, and treatment facilities) divided by the number of households to be served. For the individual household systems, such as pit latrines, it is simply the total cost of constructing the facility. For the community systems, it is the total cost divided by the design population (in households). Thus, for those facilities that exhibit economies of scale such as sewage treatment plants, this figure will understate the real financial requirements during most of the early years of operation. Note that since investment costs do not reveal anything about the lifetime of facilities, they should not be used to make judgments about least-cost alternatives. They are presented only to indicate an order of magnitude of initial financial expenditure necessary for the various systems. The monthly recurrent cost per household is the sum of recurrent costs for on-site, collection, and treatment facilities.

Table 2. Financial Requirements for Investment and Recurrent Cost per Household (1978 U.S. dollars)

Facility	Total investment cost	Monthly recurrent cost	Hypothetical total monthly cost a/	Percent of income of average low-income household b/
Low cost				
PF toilet	70.7	0.5	2.0	2
Pit latrine	123.0	-	2.6	3
Communal facility a/	355.2	0.9	8.3	9
Vacuum truck cartage	107.3	1.6	3.8	4
Low-cost septic tanks	204.5	0.9	5.2	6
Composting latrine	397.7	0.4	8.7	10
Bucket cartage b/	192.2	2.3	6.3	7
Medium cost				
Sewered aquaprivy	570.4	2.9	10.0	11
Aquaprivy	1,100.4	0.5	14.2	16
Japanese cartage	709.9	5.0	13.8	15
High cost				
Septic tanks	1,645.0	11.8	25.8	29
Sewerage (design population)	1,478.6	10.8	23.4	26

a. Assuming investment cost is financed by loans at 8 percent over five years for the low-cost systems, ten years for the medium-cost systems, and twenty years for the high-cost systems.

b. Assuming average annual income per capita of $180 and six persons per household.

Financial affordability can be roughly tested by comparing financial costs with the income. Average income per capita in the low-income countries (where the bulk of the water and sanitation deficiencies exist) was about $180 in 1978. With an average of six persons per household, this yields a monthly household income of $90. All of the medium- and high-cost systems have monthly costs that amount to over 10 percent of income and thus are probably outside the range of affordability without further subsidy. Sewerage and the Japanese and Taiwanese septic tanks have recurrent costs that alone are over 10 percent of income even if initial facilities could be completely subsidized. For most of the other systems, affordability would hinge on the arrangements that could be made to subsidize investment costs from other revenue sources. Average per capita income figures, however, should not be relied upon without realizing their limitations in countries where much of the economy is nonmonetized. In addition, over fifteen countries have per capita incomes that are less than the average of the low-income group, and in all of the countries more than half of the population earns less than the country average.

Public Health Aspects

Improved community health is generally considered the major benefit of improved sanitation. As the discussion above 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. Even for those man-days of illness incurred by the employed population, some (perhaps all) of their work is probably made up by them during the days following the 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 effect of environmental changes on community disease profiles, and of economics in quantifying benefits that 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* them is. In particular, if funds are inadequate to build and maintain the elaborate sewerage systems known to provide all these benefits, it is essential to choose the technology that will maximize the health benefits achieved with the funds available. This requires a more precise analysis of the relations between disease and sanitation than has usually been attempted. Toward this end, the Ross Institute of Tropical Hygiene was contracted as part of this study to focus directly on the disease transmission process of excreta-related diseases and relate that process to the various types of sanitation technologies. They have developed an environmental classification of excreta-related infections that, together with a basic understanding of the factors important in disease transmission, should enable the planner and engineer to maximize the health benefits of whatever technology is chosen. The means of doing so include both incorporating specific design features and supplementing the "hardware" with precisely targeted educational campaigns.

Although the primary focus of this study is sanitation, the relation between water and health should be kept in mind. Water is important for 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 or greywater can theoretically serve as a transmission vehicle for some types of disease. In this sense, not only poor water quality, but also too little and too much water consumption, present problems.

Available evidence indicates that most of the health benefits of safe water are attainable at service levels of 30 to 40 lcd on site; this will provide for protection against the range of water-related diseases and is adequate for the personal hygiene that (with health education) will lead to less diarrheal disease, skin and eye infections, and parasites on the skin. For the latter, access to water is more important than its microbiological or chemical quality.

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 lcd of sullage--indicate that per capita discharges of the bacterial pollution indicators, fecal coli and fecal streptococci, in sullage are 10^6 and 10^5 bacteria per day, respectively. If these indicator values are generally representative of the concentrations of pathogenic bacteria, they would constitute approximately one median infective dose per capita contribution of sullage. Corresponding per capita discharges in feces are approximately 5×10^{10} for fecal coli and 10^9 for fecal streptococci, some four or five orders of magnitude greater than those for the 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 than from sullage.

In sum, while 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 and/or lower population density, the potential problem of sullage is one of low priority. Nonetheless, further research should be undertaken on the health effects of sullage under actual conditions in developing countries, particularly at the level of the residents' health, rather than only microbial concentrations.

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. The second way in which excreta relate to human disease is where their disposal 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 tracts (cockroaches and flies), or they may be vectors for pathogens that circulate in the blood (mosquitoes).

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, how these numbers change during the particular transmission route or life cycle, and 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 infective dose for another. These are latency, persistence, and multiplication. Diagramatically the concepts can be represented thus:

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

From an examination of the properties (i.e., of these five parameters) of the various excreta-related diseases and the types of intervention needed to break their transmission, an environmental classification of excreted infections has been developed. Such a classification, which groups excreted pathogens according to common transmission characteristics rather than their biological origin, is much more helpful than medical classifications in predicting the differing health impacts of diverse sanitation improvements and in understanding the health effects of excreta and sewage treatment and reuse processes. The environmental classification presented below distinguishes six categories of excreted pathogens. They are shown in Table 3.

<u>Category I</u>

These are the infections that have a low infective dose (less than a hundred organisms) and that are infective immediately on excretion. These infections are spread very easily from person to person wherever personal and domestic hygiene are low. Therefore, it is likely that changes in excreta disposal technology will have little, if any, effect on the incidence of these infections <u>if</u> they are unaccompanied by sweeping changes in hygiene that may well require major improvements in water supply and housing, as well as major efforts in health education. The most important facet of excreta disposal for the control of these infections is the provision of a hygienic toilet of any kind in the home so that people have somewhere to deposit their excreta. What subsequently happens to the excreta (how it is transported, treated, and reused) is of less importance because most transmission will occur in the home. Categories I and II, however, merge into each other and actually form a continuum.

Table 3. Environmental Classification of Excreted Infections

Category	Epidemiological feature	Infection	Dominant transmission focus	Major control measure
I	Nonlatent, low infectious dose	Enterobiasis Enterovirol viral infections Hymenolepiasis Amoebiasis Giardiasis Balantidiasis	Personal Domestic	Domestic water supply Health education Improved housing Provision of toilets
II	Non-latent medium or high infectious dose, moderately persistent and able to multiply	Typhoid Salmonellosis Shigellosis Cholera Path Escherichia coli Yersiniosis Campylobacter infection	Personal Domestic Water Crop	Domestic water supply Health education Improved housing Provision of toilets Treatment prior to discharge or reuse
III	Latent and persistent with no intermediate host	Ascariasis Trichuriasis Hookworm	Yard Field Crop	Provision of toilets Treatment of excreta prior to land application
IV	Latent and persistent with cow or pig intermediate host	Taeniasis	Yard Field Fodder	Provision of toilets Treatment of excreta prior to land application Cooking, meat inspection
V	Latent and persistent with aquatic intermediate host (s)	Clonorchiasis Diphyllobothriasis Fascioliasis Fasciolopsiasis Gastrodiscoidiasis Heterophyiasis Metagonimiasis Paragonimiasis Schistosomiasis	Water	Provision of toilets Treatment of excreta prior to discharge Control of animal reservoirs 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 (forthcoming).

a. Includes polio–, echo– , and coxsackieviral infections: poliomyelitis; viral meningitis; diarrheal, respiratory, and other diseases (see Feachem and others 1981, chapter 1).

b. Ancylostoma duodenale and Necator americanus.

c. Culex pipiens is a complex of mosquito species and subspecies. The principal tropical species, and the vector of filariasis in those tripical areas where the infection is transmitted by Culex, is Culex quinquefasciatus (previously also known as Culex pipiens fatigans, C. p. quinquefasciatus, or C. fatigans).

Category II

The infections in this category are all bacterial. They have medium or high infective doses ($>10^4$) and hence are less than likely category I infections to be transmitted by direct person-to-person contact. They are persistent and can multiply, so that even the small numbers remaining a few weeks after excretion can, if they find a suitable substrate (such as food), multiply to form an infective dose. Person-to-person routes are important, but so are other routes with longer environmental cycles, such as the contamination of water sources or crops with fecal material.

The control measures listed under category I are important -- namely, water supply, housing, health, education, and the provision of hygienic latrines -- but so are waste treatment and reuse practices. Changes in excreta disposal and treatment practices alone may reduce the incidence of some infections such as cholera and typhoid, but such changes are unlikely to be as effective against intestinal virus infections, salmonelloses (other than typhoid), and infections due to Shigella sonnei, Giardia, Enterobius, and enteropathogenic Escherichia coli, since these pathogens are still commonly transmitted within affluent communities in industrialized countries.

Category III

This category contains the soil-transmitted helminths. They are both latent and persistent. Their transmission has little or nothing to do with personal hygiene since the helminth eggs are not immediately infective to man. Unlike categories I and II, there is no risk to those involved in cartage of excreta. Domestic hygiene is relevant only insofar as food preparation must be adequate to destroy any infective stages present on food, and latrines must be maintained in a tolerable state so that eggs do not remain on the surrounds for the days or weeks of their latent period. Therefore, any kind of latrine that contains or removes excreta and does not permit the contamination of the floor, yard, or fields will limit transmission. Because persistence is so long, however, it is not sufficient to stop fresh feces from reaching the yard or fields. Any fecal product that has not been adequately treated must not reach the soil. Therefore, in societies that reuse their excreta on the land, effective treatment is vital prior to reuse.

Category IV

This category contains only the beef and pork tapeworms (Taeria saginata and T. solium). Any system that prevents untreated excreta from being eaten by pigs and cattle will control transmission of these infections. Therefore, the provision of toilets of any kind to which pigs and cattle do not have access, and the treatment of all wastes prior to land application are the necessary control methods. It is also necessary to prevent birds, especially gulls, from feeding on trickling filters and sludge drying beds and subsequently depositing tapeworm ova in their droppings on pastures. Personal and domestic cleanliness are irrelevant, so long as toilets are used.

Category V

These are the water-based helminths, which need an aquatic host or hosts to complete their life cycles, of which schistosomes are the most important. Control is achieved by preventing untreated night soil or sewage from reaching water in which these intermediate hosts live. Thus, any land application system or any dry composting system will reduce transmission.

Category VI

This category is reserved for excreted infections that are, or can be, spread by excreta-related insect vectors. The most important and ubiquitous of these vectors are certain mosquitoes and flies and cockroaches. The implied control measure is to prevent access of the insects to excreta, and this can be achieved by many sanitation improvements of differing sophistication. In general, the simpler the facility, the more care is needed to maintain it insect-free. Cockroaches and flies have numerous breeding places other than those connected with excreta disposal and, thus, can never be controlled by sanitation improvements alone, but in some instances Culex mosquito populations may depend heavily on flooded latrines, so that sanitation improvements may greatly alter the spread of filariasis.

These descriptions of the various categories of excreta-related disease clearly show that sanitation improvements are necessary but, in themselves, not sufficient for the control of excreted infections. Without them, excreted infections can never be controlled. Other complementary features, such as improved water supplies and sustained health education programs, are essential for success. The theoretical potential for control of excreta-related disease by environmental sanitation improvements alone and by personal hygiene improvements alone is summarized below in Table 4.

Table 4. Potential Health Improvement

Category	Sanitation alone	Personal hygiene alone	Other important inputs
I	Negligible	Great	None
II	Slight-moderate	Moderate	Proper treatment
III	Great	Negligible	Proper treatment
IV	Great	Negligible	Proper treatment, animal control, or cooking of meat
V	Moderate	Negligible	Proper treatment
VI	Slight-moderate	Negligible	Insect control

The outstanding difference is between categories I and II, which depend so strongly on personal and domestic hygiene, and the other categories, which do not. Category I and II infections are thus much more likely to be controlled if 20-40 lcd of safe water is made readily available concurrently with sanitation improvements and if an effective and sustained program of health education is organized.

The changes necessary to control categories III and IV are relatively straightforward: the provision of toilets that people of all ages will use and keep clean and the effective treatment of excreta and sewage prior to discharge or reuse. The reason why the literature on the impact of latrine programs often does not show a marked decrease in the incidence of category III through VI infections is because, although latrines were built, they were typically not kept clean, often not used at all by children, nor by adults when working in the fields. This again points to the importance of social and educational factors in the design and delivery of appropriate sanitation technology.

Sociocultural Factors

Nearly all studies that address 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 participation in the planning and selection stages in hopes that community responsibility can be generated to sustain the system during the operation 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 technology choice and for more specific operational guidelines.

There are three aspects of project design that can be greatly enhanced by well-timed and planned social science inputs: the technology selection, its diffusion, and its adoption. The discussion below elaborates on the integration of the social science inputs into these three aspects of project design.

Technology Selection

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

Observations of how facilities are being used or misused will suggest how designs can be modified to meet the needs of users. Whether users will share facilities or how close facilities must be situated to be used can be ascertained through such observations. Interviews with involved personnel at the community level and at the agency level can be used to pinpoint problems encountered during project implementation (delays in materials delivery, insufficient supervision of construction, and so forth). The information will provide some indication of methodologies for service delivery that can be adapted or that should be avoided.

On the basis of findings from this preliminary research, technical and administrative packages can be developed for communities environmentally and culturally similar to those studied. In this way, when the range of alternative technologies is made available to consumers in the target area, promoters can be as specific as possible about expected community contributions and responsibilities.

Means for Diffusion

Because of the low priority given to sanitation needs in many communities, planning at the national level should link human waste disposal with other services given higher priority by the communities (for example, water supply, health clinics). In the rural areas, community involvement in planning water supply and sanitation projects usually requires the creation of an agency branch office accessible to consumers and with decision-making power in project selection and development in line with policies and priorities established at the central office level.

For community liaison purposes, 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 type of personnel does not exist, teachers or agricultural extensionists should be requested to assist in technical tasks, community organization, and health education activities at least until promotors, or facilitators, can be trained. The facilitators should be natives of the areas; they should have experience working in the area, and they should share the cultural perspectives of the people with whom they are 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. The facilitators should receive intensive training in the technical aspects of the technology and its promotion, and they should be provided with adequate transportation 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 in the project. The social case studies suggest that local committees are capable of assuming a wide range of responsibilities when given proper authority and guidance, including providing liaison between the agency and the community, organizing and maintaining records of the voluntary labor force, selecting community members to be trained in facility maintenance, collecting the maintenance fee, keeping accounting ledgers, and filing periodic reports to the responsible authority concerning the results of these activities.

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 have the incentive of producing an income (selling medicines, giving injections, and the like). For this reason, promotion should continue on a periodic (promoter campaign) or continuous (radio) basis long after projects are completed.

Motivation for Adoption

Since 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 than rural areas. The existence of conflicting factions and the fear of eviction (in squatter communities), however, may mean that monetary or labor contributions would 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 is 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 project initiation.

For 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 location of water distribution outlets, colors (if latrines are painted), when maintenance fees should be collected (monthly, bimonthly, and so forth), 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 is 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 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 motivation tool when carried out in a culturally sensitive manner. Any problems that have arisen with use of the facilities can be discussed with local leaders and joint solutions provided. The visits will not only motivate communities to care for the facilities, but they will also provide agencies with important feedback on changes in water use and sanitation practices resulting from the introduction of new technologies.

PROGRAM PLANNING AND DEVELOPMENT

Obstacles and Incentives

In designing an implementation program for appropriate technology, an important question to answer is why inappropriate technologies have been chosen in the past. The first and most obvious problem found in the case studies was the information gap. As described above, many nonconventional technologies are being utilized around the world, but there is a real dearth of detailed information about them. At the outset of this study, the World Bank contracted the International Development Research Centre (IDRC) to carry out a detailed bibliographic search for information on sanitation technologies. Of 18,000 titles that were produced by a key-word computer search only 188 articles were found that directly related to nonconventional sanitation technologies. The final bibliography contains summaries of over 500 articles, of which more than half were previously unpublished.

With few engineers aware of the range of sanitation technologies available, it is not surprising that even fewer planners and administrators had knowledge of them. This lack of knowledge often resulted in terms of reference for sanitation studies that called only for the examination of various configurations of sewerage systems. Even if terms of reference did include the evaluation of nonconventional options, there are biases in the technology selection process that favor sewerage. One is the background and training of the bulk of consulting sanitary engineers. With very few exceptions it is heavily weighted toward developed country sewerage. Thus, they are generally good at designing a workable sewerage system as one of the alternatives, but they rarely have the knowledge or experience to "preselect" the best alternative technologies to compare with it. If problems are encountered in designing the 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 a lack of design experience. Only time and increased exposure to nonconventional solutions can overcome this problem.

Concurrent 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 works in favor of sewerage. If economics is the dismal science, engineering is the optimistic one. Linear demand projections 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 are assumed to be perfectly elastic. The influence of price on consumption is ignored. The intricacies of urban growth patterns are rarely explored, although they often are based on a population influx that is much poorer and less able to afford service amenities than the present average population. Thus, when historical growth rates in demand are projected into the future, the lower consumption patterns of the new migrants are grossly overestimated. Since sewerage master plans often cover periods of more than twenty years, these errors are compounded over time until a highly unrealistic demand picture is built up and used to test alternative technologies. The reason that rapid demand growth favors sewerage over most nonconventional systems is that those technologies with large economies of scale are more economical under conditions of rapid growth. They cause institutional and financial headaches, however, when demand assumptions turn out to be optimistic or the city grows in a different direction from that anticipated. Because of the inflexibility of such large scale 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 on which to base forecasts it is extremely risky to recommend a system with large economies of scale with a design period that is correspondingly long.

Even when demand analysis has been properly done and consumer preferences and financial constraints are known, it is possible to choose the wrong technology by applying an inappropriate selection test. The most common fault is using financial rather than economic costs in the least-cost analysis. The reasons that 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), it has a very high cost to the householder in terms of the plumbing and internal facilities needed, it has relatively high water requirements (which are usually omitted from the comparison or included at its market price, which is below its long-run production cost), and it possesses larger economies of scale than most nonconventional waste disposal systems.

Given the diversity of the problems, a variety of incentives or policy changes is likely to be necessary to revise the conventional practices of engineers and their clients in developing countries. Some of these are obvious from the description of the problems. For example, it is necessary to ensure that terms of reference for master plans include the examination of alternatives in addition to sewerage. The international lending agencies can play an important role in this, since they are often called upon to review terms of reference for studies that they will be asked to finance. The information gap can be closed by 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 more equitable consideration of nonconventional sanitation solutions.

The first is a revision of the methods used by consulting engineers and planners in selecting among technologies. The economic and social base for feasibility planning must be improved. This probably means that multidisciplinary teams, including an economist/planner and sociologist 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 in, the community to be served should be increased to provide better data for estimating future demands for different types of sanitation service.

The second area in which new incentives will be required to promote the adoption of appropriate technologies is in their financing. In many developing countries the central government provides large subsidies or grants for the construction in interceptors and sewage treatment plants. Obviously this is prejudicial to a community's choice of technology. If governments wish to improve a community's health, they should make funds available for a combination of technologies designed to achieve that objective. In general, sewerage is not the least-cost method of achieving health benefits, and to subsidize this method alone may preempt the appropriate solution.

International and bilateral agencies have contributed to this bias in favor of sewerage by financing the foreign exchange cost of projects. This policy favors projects with sophisticated technologies and expatriate engineering requirements. In some cases consultants' fee schedules are tied to the construction costs of the projects they design. Since it often takes more time and ingenuity to optimize a low-cost sanitation technology, such as vacuum cartage, than it does to use tried and tested rules for sewerage design, it would be unfair to expect consultants to do the former for less money.

The preparation of appropriate sanitation projects, with its emphasis on community participation, training of local staff, and improvement or creation of institutions, will often require more time than that of conventional sewerage projects. They do, however, offer the opportunity to substantially expand sanitation service levels at modest cost.

Institutional Requirements

Water supply and sanitation projects require an institutional framework that allocates authority and responsibility for each phase of a project for their successful development and implementation. 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 are:

- A sector strategy supported by government;

- frequent reassessment of technologies;

- a stable, autonomous institution with clear responsibilities;

- a tariff policy that insures financial viability and encourages efficiency and equity; and

- manpower development programs and career opportunities in the sector.

For water supply and excreta disposal projects incorporating other than conventional technologies, further institutional and policy strategy should provide for community participation in the selection of service level standards. For communities too small for independent water and wastes agencies, regional support offices should be established. Their functions should be to provide guidelines and design assistance to local communities, monitor ongoing programs, and evaluate completed projects to ensure that lessons learned are reflected in new designs. They should maintain close liaison among design, operation, and maintenance activities, and establish clear criteria for selection of materials and equipment.

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 in both approaches, and there are advantages and disadvantages in 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. In either case, the organization has staff competent in conventional water supply and waste disposal technology, although the degree of expertise and the availability of financial resources to develop and implement projects differ from municipality to municipality. 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 sector institutions. Occasionally 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 responsibility.

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 less able to financially support institutions capable of providing adequate services. One solution that has often achieved notable results is the combination of various productive and social project components in rural development projects. In such projects the water supply and sanitation component benefits from the organization, management, and possibly the income of the productive components of the development projects.

Whether urban or rural, single or multisector, the institutions and agencies involved in water and excreta disposal must have a clear division of responsibilities. Often it is not as important to decide which functions are assigned to each group as it is to avoid overlapping responsibilities and gaps.

Table 5 presents a generalized example of the various agencies and accompanying functions likely to be involved in water and sanitation program planning.

Table 5. Institutional Responsibilities in Sanitation Program Planning

Level	Responsible body	Function
National	Legislature	Review and approval of policies, establishing 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 sector priorities; review of tariffs; sector manpower development
	Sector Finance Agency	Financing and financial policies
	Ministry of Health	Establishment and monitoring of quality standards
State/Province	Public Utility Department or Planning Unit	Detailed planning; allocation of state resources
	Water Supply and Sanitation Agency or Multisector Development Agency	Implementation of national policies, design and construction; monitoring, supervision and support of local authorities; 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.

In practice, the organizational arrangements will probably never be as simple and responsibilities so clearly defined. For example, in many countries responsibility for urban and rural areas is allocated to different ministries. Even within urban and rural areas, there might be different ministries or various agencies within ministries. Furthermore, communities are dynamic; they 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. In practice, it is only rarely possible to achieve this objective within a short period of time. The overall organizational objectives should therefore be considered as long-term targets and institutional arrangements that would eventually lead to the overall sector organization -- or at least not prevent it -- should be designed for individual projects and programs.

Community Participation and Organization

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

To result in a successful project, the community's participation should extend from the initial collection of baseline data and identification of user preferences, through the design and construction stage, to the continued operation and maintenance of the facilities. The format of participation and the extent of community involvement will vary. A community on the urban fringe, or a slum upgrading project, can probably count on the organization providing municipal water and sewerage services to implement and operate communal facilities. The community participation will be concerned primarily with the selection of service levels that reflect community needs and ability to pay. Rural communities, on the other hand, need to develop a system they can operate and maintain with a minimum of external inputs. Usually this means local part-time management and operation with advice and assistance from a regional technical support organization. The program described below reflects the conditions of a rural community and would be simplified for projects in an urban environment.

Six tasks can be identified as the minimum for a community participation program that leads to a successful project:

1. Unstructured interviews with community leaders and a limited number of users to identify user attitudes and preferences;

2. design and testing of a questionnaire for structured interviews;

3. structured interviews with a representative sample of households;

4. presentation of feasible technologies with their costs to the community or its leaders to determine willingness to pay;

5. organization of construction and the execution of the work; and

6. continued operating, maintenance, and monitoring activities including the assessment and collection of fees.

The first three tasks should be undertaken at the very beginning of project development, the fourth toward the end of the selection phase, and the final two must be scheduled to meet technical requirements and community work patterns.

Many of the aspects of community participation in sanitation program development depend upon and influence institutional structures. A simplified description of the institutional steps required to facilitate and support community involvement is as follows:

1. Establish a support unit for water supply and sanitation in existing regional agencies, or form an independent support unit. The likely personnel required include engineers, hydrogeologists, a sociologist, an economist, an accountant, a plumber, a mechanic, an electrician, a well driller, a purchasing agent, and a health educator.

2. Organize, staff, and train a central support unit. Establish design and operating standards and village selection/priority criteria, conduct specialized tasks such as hydrogeological surveys, management training, operating assistance, and the like.

3. Train community workers in low-cost water supply and sanitation technology, health care, nutrition, and community organization.

4. Canvass and organize selected communities. Plan, design, and implement prototype projects to complete the training of community workers.

5. Assign community workers or teams to designated areas to canvas and organize communities.

6. Assist communities in constructing facilities.

7. Maintain a limited number of community workers as roving maintenance and operations advisers and monitors for completed projects. Assign all other extension workers to new areas to replicate projects.

8. Provide technical assistance and support. Maintain the spare-parts stock.

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

Project Development

Within the institutional and community framework for sanitation program planning discussed above, the development of individual sanitation projects will require different approaches in different settings. In urban areas, sector institutions capable of undertaking water supply and sanitation projects usually exist, and the most important function of community participation is the selection of service level and technology. Providing water supply and sanitation to rural areas has traditionally been the most intractable problem in the sector. This is basically because rural communities are too small to create their own viable infrastructure agencies. They also have often been neglected in the national or regional planning for water supply and sanitation. An additional reason has been that water supply and sanitation technologies have been developed primarily for the benefit of the urban population. Particularly in sanitation technology, a gap exists today between what is affordable to a rural community and what is accepted as standard practice in the urban community. Because urban communities more often contain a mix of income levels than do rural, the potential for cross-subsidizing poorer residents is lower in rural communities.

Once the institutional framework has been established and different sanitation technologies have been preliminarily compared (excluded), the sanitation program planner must select from those available the ones most appropriate to the current needs and resources of the community. This selection should be based on a combination of economic, technical, and social criteria, which often reduce to the question: which is the cheapest, technically feasible technology that the users will accept and can maintain and that the local authority is institutionally capable of operating? In communities (or areas of cities) with higher income levels, consumers may prefer and be willing to pay for higher service standards, so that the cheapest technology is not always the one that should be chosen.

Algorithms have been developed as a guide to the kinds of questions to be asked in the selection of sanitation technology. Although they are directly applicable to many situations encountered in developing countries, there will always be the occasional combination of circumstances for which the most appropriate option is not that suggested by the algorithm. The one shown below (Figures 1-3) should not, therefore, be used blindly in place of judgment, but as a tool in the decision-making process.

Figure 1. First-stage Algorithm for Selection of Sanitation Technology

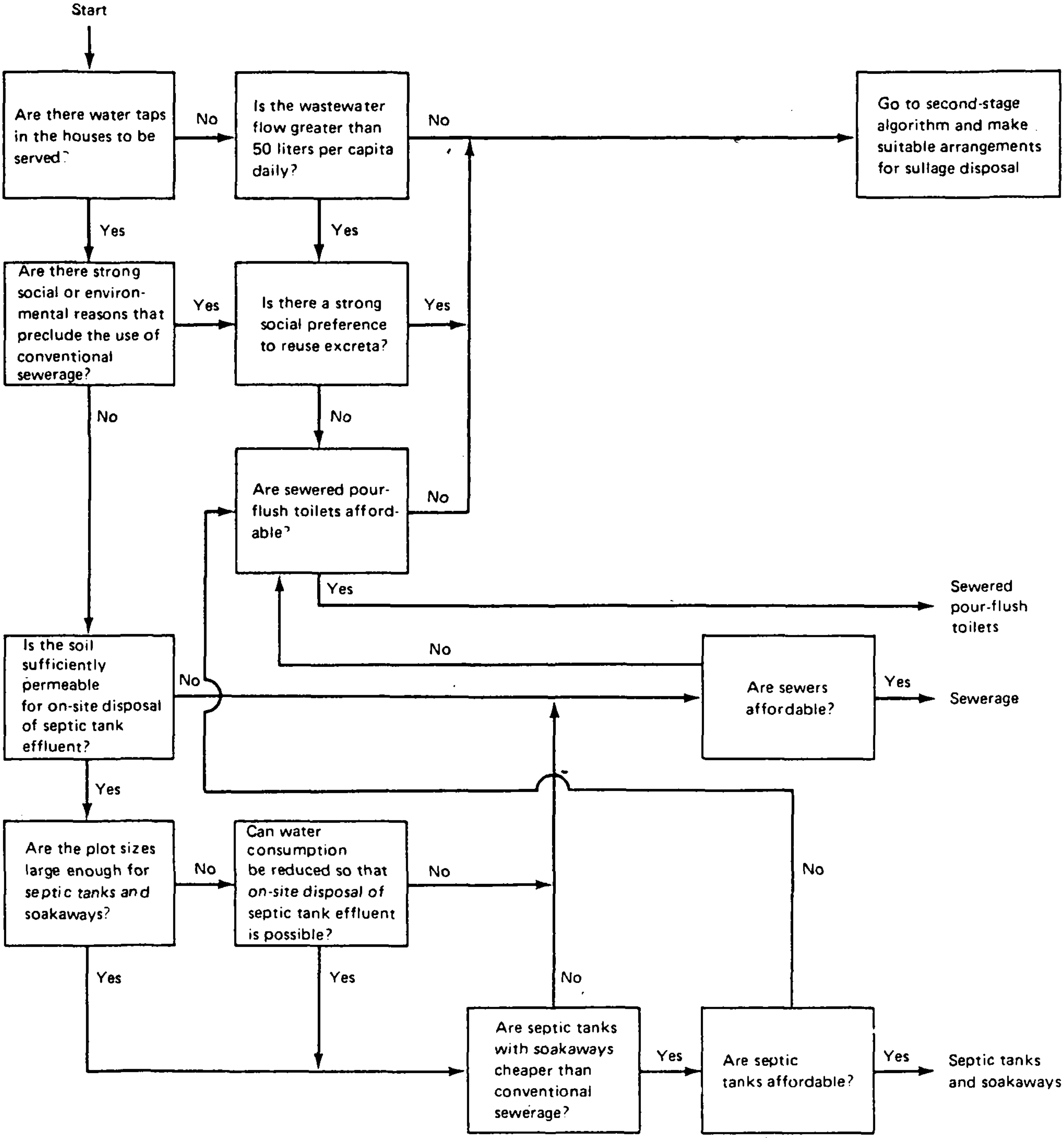


Figure 2. Second-stage Algorithm for Selection of Sanitation Technology

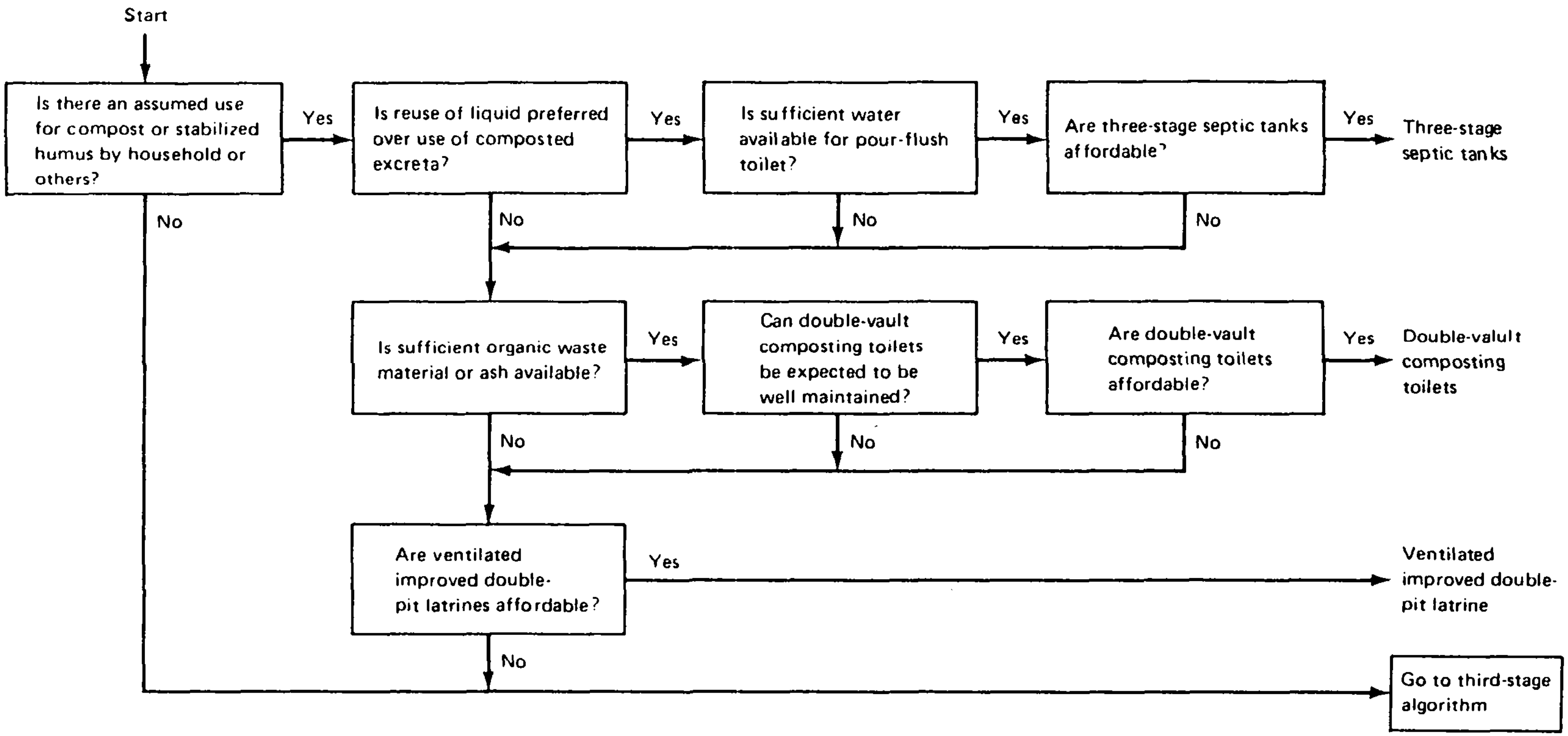
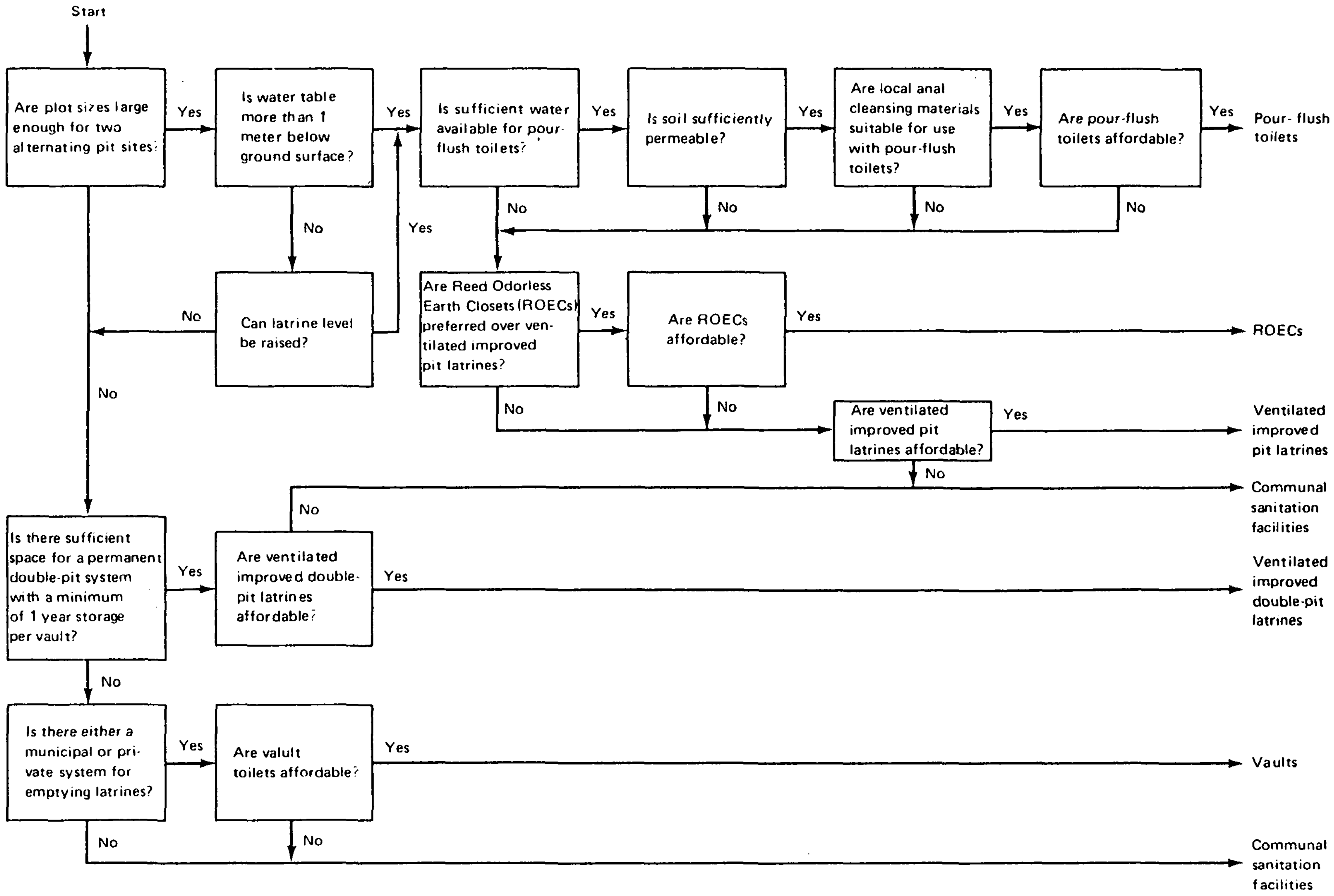


Figure 3. Third-stage Algorithm for Selection of Sanitation Technology



The selection of the technology best suited to effect initial improvements in sanitation should also reflect the future need for improvements as the users' aspirations and socioeconomic status rise. The feasibility of sanitation upgrading sequences depends very much on incremental improvements in the level of water supply service. Feasible upgrading sequences are summarized in Figure 5.

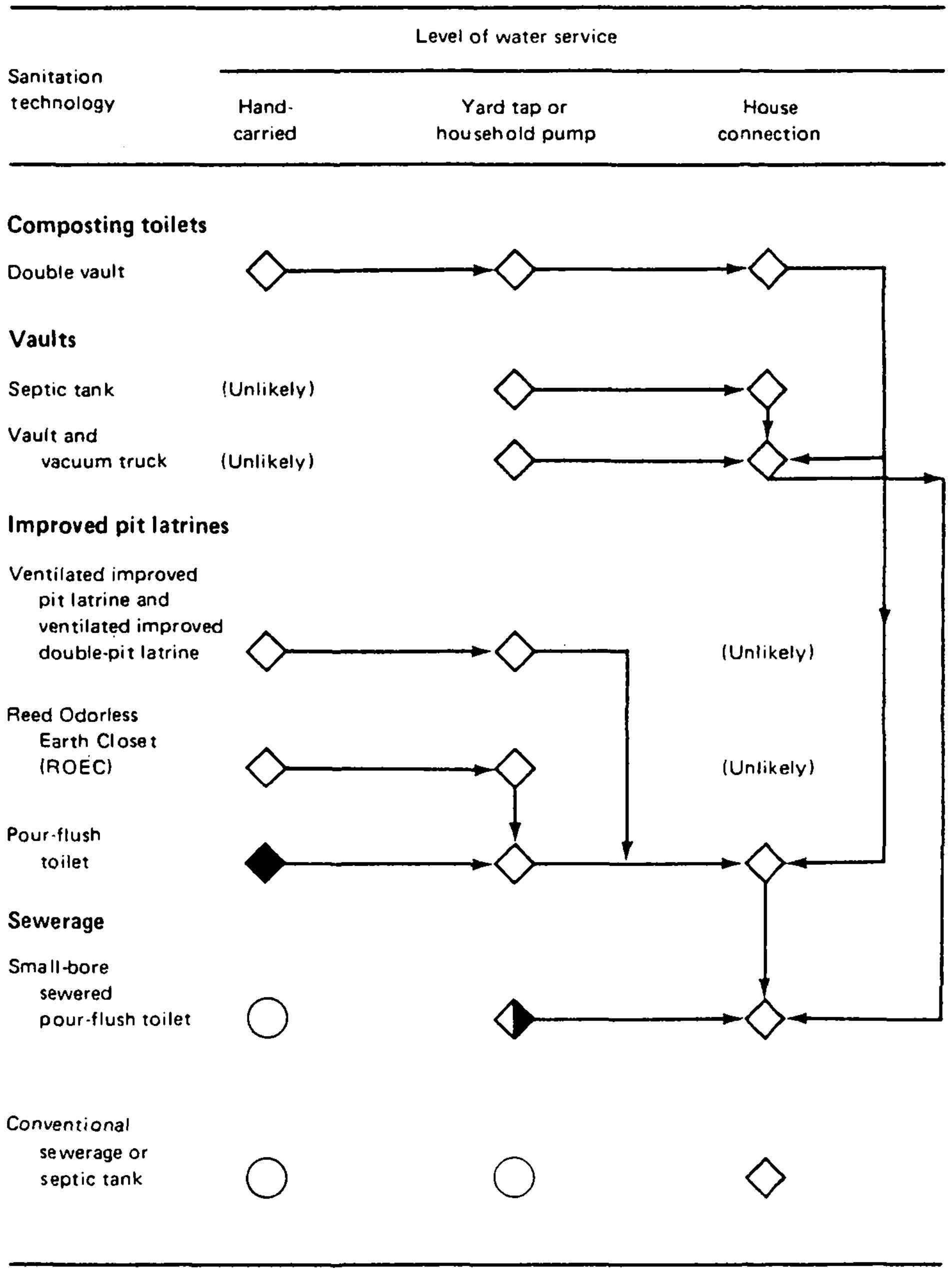
To demonstrate the feasibility of staging sanitation sequences, a possible scheme with three variations is described below, and comparative economic costs are presented. The scheme or its variations could be started at any stage and terminated at any stage, depending on the desires of the users. For simplicity, it is assumed that each stage would remain in service for ten years, after which either the next stage would be added or the existing facility would be replaced or repaired. The schemes described could be varied substantially without adding greatly to the cost.

The initial sanitation facility would consist of a ventilated improved pit (VIP) latrine (see Figure 5). In year 11 the community water system is upgraded to yard hydrants, and the dry latrine is converted to a pour-flush latrine by digging a new soakage pit near the superstructure and replacing the old squatplate with a bowl and an inverted siphon. In year 21 the water service is upgraded to house connections and a large volume of sullage water has then 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 (SBS). This upgrading would permit the use of cistern-flush toilets if desired by the users.

At a discount rate of 10 percent the present value of the cost stream of the three-stage scheme over a period of thirty years would be $354 per household. Alternatively, the present value of a two-stage scheme, which moves directly from the VIP (installed in year 1) to SBS in year 11 would be $1,111 per household over thirty years, or more than three times as much as the three-stage alternative. The present value of the costs over thirty years of a small-bore sewerage system installed in year one would be $1,519 per household. The present value of a conventional sewerage system would have been about $3,000.

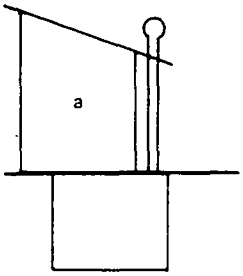
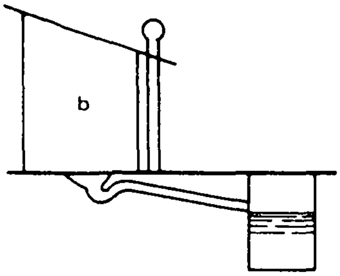
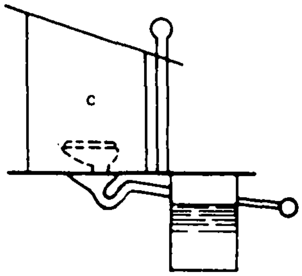
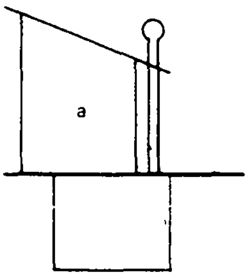
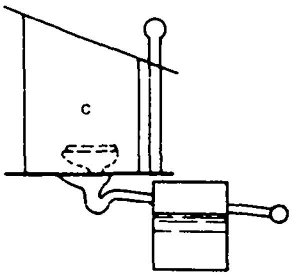
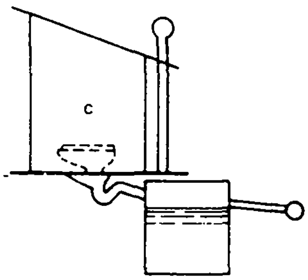
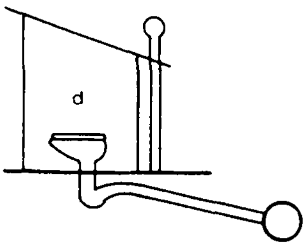
It is noteworthy that none of the upgrading sequences discussed above leads to conventional sewerage. This is not because conventional sewerage schemes should not be built (they are an excellent form of sanitation for those who can afford them and have plenty of water), but because they are not necessary to provide a high standard of health, environmental protection, or user convenience. The sewered PF system, which can accommodate a cistern-flush toilet, is an equally high standard sanitation system that has two big advantages over conventional sewerage: it is substantially cheaper and it can be reached by staged improvement of several different sanitation technologies. Thus sanitation program planners can confidently select one of these "base line" technologies in the knowledge that, as socioeconomic status and sullage flows increase, it can be upgraded in a known sequence of incremental improvements to a sophisticated "final" solution. The important fact to remember is that sewers are used to dispose of sullage, not excreta, and that elimination or reduction of nonessential water use is thus the key element in an economic solution to sanitation problems.

Figure 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.

Figure 5. 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.

Sanitation system

On site

Dry

1. Overhung latrine
2. Trench latrine
3. Pit latrine
4. Reed Odorless Earth Closet
5. Ventilated improved pit latrine
6. Batch-composting latrine
7. Continuous-composting latrine

Wet

8. Pour-flush latrine, soakaway
9. Pour-flush latrine, aquaprivy, soakaway
10. Pour-flush, septic tank, vault
11. Sullage-flush, aquaprivy, soakaway
12. Sullage-flush, septic tank, soakaway
13. Conventional septic tank

On-site or off-site

Wet

14. Low-volume cistern-flush, soakaway, or sewer
15. Low-volume cistern-flush, aquaprivy, soakaway, or sewer
16. Low-volume cistern-flush, septic tank, soakaway, or sewer

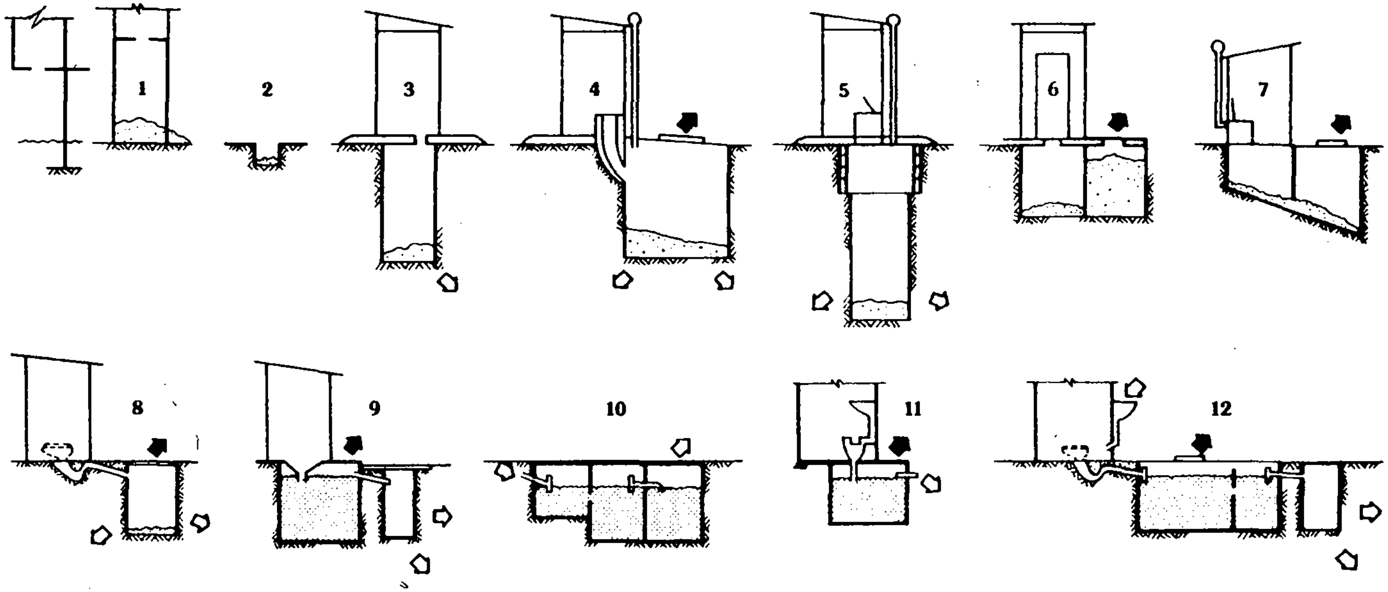
Off site

Wet

17. Conventional sewerage

Dry

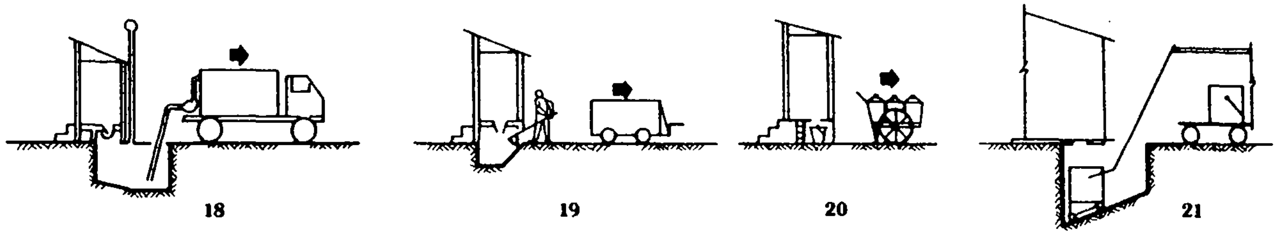
18. Vault and vacuum tank
19. Vault, manual removal, truck, or cart
20. Bucket latrine
21. Mechanical bucket latrine



13 Same as 12 except conventional cistern-flush.

14, 15, 16 Same as corresponding configuration in 8 to 12, except for elevated cistern with low volume-flush.

17 See standard manuals and texts.



⇨ Movement of liquids; ➡ movement of solids.

Source: The World Bank, Water Supply and Waste Disposal, Poverty and Basic Needs Series (Washington, D.C., September 1980).

Toilet Facility

WORLD BANK PHOTO by Jaime Martin