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INTERMEDIATE SERVICE LEVELS IN SANITATION SYSTEMS

by

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ABSTRACT

The major alternatives to sewerage are described and their potential for application in developing countries is explored. The reasons why conventional engineering practices have led to the selection of inappropriate technologies are examined. A least-cost comparison is made between sewerage and staged sanitation schemes, and recommendations for improved sanitation planning are presented.

INTRODUCTION

Sanitation is defined as the promotion of hygiene and prevention of disease by maintenance of sanitary conditions. For purposes of this discussion we limit sanitation to the adequate disposal of human waste in less developed countries (LDCs), although some brief references are made to water supply and sullage disposal insofar as they affect sanitary removal of human wastes.

It is clear that appropriate waste disposal by itself is not sufficient to provide adequate sanitation. Sufficient quantities of safe water are essential for human health, and other inputs such as medical care and health education are often required. The provision of water or waste

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disposal facilities to users who lack a clear understanding or knowledge of the importance of personal hygiene is, at best, partially effective and, in the worst case, useless. The emphasis of this paper is on human waste disposal, simply because that field has received insufficient attention in the past, and ideas and solutions have been stereotyped by experience in industrial countries which have little relevance to the needs and constraints of LDCs.

In the industrialized western countries, the standard solution for the sanitary disposal of human excreta is waterborne sewerage. The flush toilet is regarded as the ultimate and essential ingredient to an adequate solution to our waste disposal problems. Little thought is given to the fact that this method is designed not to maximize health benefits but to provide user convenience and environmental protection; two very important objectives in developed countries but with limited constituencies in LDCs. In fact, the flush toilet and associated sewer system is the result of slow progress over decades, even centuries. The cost of achieving the present standard of convenience is substantial.

The problem of LDCs is one familiar to most of us: high expectations coupled with limited resources. The decision-making elite would like to achieve the standards of convenience observed in industrialized countries. However, given the backlog in service and the massive size of sewerage investments, they do not have the funds to realize that goal. Sewerage could be provided for a few, but at the expense of the vast majority of their populations. Therefore, an investigation of other solutions to satisfy the health requirements of human waste disposal at a lower cost.

is urgently required. Any such solution, though of primary importance to LDCs, could also benefit inhabitants of industrialized countries not yet "blessed" with waterborne sewerage or those who find the ever increasing cost of cleaning up surface water polluted by sewage too great a burden.

HISTORICAL DEVELOPMENT

In Deuteronomy 23:12,13 the Lord instructed the Israelites to keep their camps clean: "You must have a latrine outside the camp, and go out to this; and you must have a mattock among your equipment and with this mattock, when you go outside to ease yourself, you must dig a hole and cover your excrement." Since Deuteronomy contains some of the oldest writings of the Bible, we can assume that appropriate waste disposal was of concern wherever people congregated, even in antiquity. It is interesting to note that there is no reference in the Bible to the need for clean water.

The latrine was probably the earliest attempt to increase user convenience associated with waste disposal, although not necessarily to reduce the health hazard 1/. The latrine provides privacy not available in the field; it reduces or eliminates the need to travel long distances to find privacy. If properly designed and maintained, is a perfectly acceptable method of human waste disposal. The majority of the people in rural areas of LDCs today use it in one form or another, and many people from industrialized countries still remember it from their childhood. In fact, in many rural areas the latrine presents the most cost-effective solution for the safe disposal of human waste.

As the population in the cities increased and land became more densely populated there was less room for backyard latrines. In addition, the development of municipal water systems required the disposal of increasing amounts of

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1/ When properly designed and fitted with a ventilation pipe the latrine can also fulfill stringent requirements for pathogen destruction. (Ref. 1) water. Latrines gave way to bucket cartage or public latrines with waste being collected and discharged into nearby water courses; sullage water was usually discharged to open drainage ditches or the street. Obviously, as more wastes were generated very unsanitary conditions resulted, leading eventually to water closets and the discharge from them to storm drains and nearby water courses. As population increased further and water consumption rose, treatment of the discharged waste had to be instituted in order to reduce the massive pollution of receiving waters which had arisen from indiscriminate discharge. This ultimately lead to the separate sanitary and storm water systems we know today. Now some professionals are beginning to consider treating storm water because even rain water receives enough pollution from roofs, streets and other paved surfaces to become a substantial source of contamination. Due to industrialization, there are demands for more and more sophisticated treatment processes to protect our water resources. 1/

It is clear that we have reached the present stage of sanitation technology by a process of devising a solution to a problem created by a previous solution which eliminated a previous problem. For example, the present concern about organic chlorine compounds in drinking water is a result of chlorination of waste water and industrial effluents in order to disinfect the discharge before it enters the receiving waters. The disinfection technology was the response to the problem of health hazards created by the discharge of effluents.

This cause and response relationship can be extended all the way back to the change from dry to waterborne waste disposal. Unfortunately, neither then nor at any time since was a thorough examination undertaken to determine

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1/ For more detailed discussion of the history of waste disposal technologies see Ref. 2.

whether waterborne waste disposal was the best solution. This may be because its consequences were not adequately foreseen. However, it is entirely possible that at some stage in the future we will find that we took the wrong fork in the road where the waterborne system and the dry system separated. It is clear that every time a new technology has been developed in order to solve the problems of another technology it has been the least-cost solution in the engineering sense. However, had a full economic evaluation been undertaken which included indirect as well as direct costs and which properly valued inputs at their opportunity costs rather than their market prices, the result might have been quite different 1/. Given the massive sewerage investments which now exist in the industrialized countries, it is probably too late for any major change in direction unless a definite correlation between some of the modern illnesses and sophisticated waste disposal and water treatment practices can be established, a development which is entirely within the realm of possibilities.

On the other hand, LDCs have waste disposal problems whose solution, in a majority of cases, has not yet been pre-empted by past commitments. They do not have the time it took the West to progress from the latrine to the present system. They also do not have the funds to do in one step what industrialized countries had decades, even centuries, to accomplish. In short, not only have the opportunity but the obligation exists to take another look at existing waste disposal practices, an opportunity which is of vital importance to the people in developing countries. For if a less expensive method to solve the waste disposal problem cannot be found, many people will be condemned to live their lives in unsatisfactory sanitary conditions.

1/ Since the basic tools of economic evaluation of projects have only been developed in the last 30 years, of course, it is unfair to criticize this aspect of engineering decisions made before that time.

LESS DEVELOPED COUNTRIES

To understand the magnitude of the problem, it is only necessary to look at some of the data collected by the World Health Organization in preparation for the United Nations Water Conference which took place in Mar del Plata in the Spring of 1977. Those figures show that at the present time only 32% of the population in LDCs have adequate sanitation services; that is, about 630 million out of 1.7 billion people. Population growth will add another 700 million people in the 1980s. In other words, between now and 1990 nearly two billion people will have to be provided with some means of sanitation if the goals of the Drinking Water Decade; i.e., adequate water supply and sanitation for all people; are to be achieved. A similar number of people will require water supply by the same date. It is at least of some consolation that water supply technology is better understood, and interest in water supply is substantially greater than in sanitation.

One of the fundamental problems in any attempt to provide the necessary sanitation services is the cost involved. Very general estimates based on existing per capita costs indicate that up to $60 million would be required to provide water supply for everyone and anywhere from $300 to $600 billion would be needed for sanitation services.1/ Per capita investment cost for sewerage ranges from $150 to $650, which is totally beyond the ability of the beneficiary to pay. It should be remembered that some one billion of these unserved people have per capita incomes of less than US$200 per year, with more than half of them below US$100 per year.

In addition to the technical task of developing or adapting lower cost technologies, the social and cultural aspects of waste disposal must be considered. Often there are strong social and religious taboos about

1/ The lower figure assumes technologies other than sewerage are used.

particular methods of waste disposal and personal hygiene which may preclude certain solutions. At the very least, education to enhance people's understanding of the value and the methods of waste disposal is necessary. In order to have the desired health impacts, sanitation technologies must not conflict with the natural preferences of the intended beneficiaries. For example, where water is a religious requirement for anal cleansing there is no sense in providing dry pit latrines. In some areas the feeling of being outdoors is desired; in other areas, privacy is of utmost importance. The construction of the privy or toilet enclosure will have to reflect these preferences.

The first question to be answered in evaluating sanitation technology for developing country application is whether feasible alternatives other than sewerage exist. Clearly, resources to serve all of the people of the developing world with sewer systems are not now available and probably will not be generated in the foreseeable future, as governments have other investment priorities. A look at alternatives in an attempt to improve the acceptability and the performance of some traditional but frequently abandoned technologies is therefore relevant.

ALTERNATIVES

On-Site Disposal

The latrine and its various modifications are probably the most widely used excreta disposal system in developing countries, especially in rural and semi-rural areas. They can be constructed by the user with very little outside help and few purchased materials. They are usually the least-cost method for the disposal of human waste.

In its simplest form the latrine is merely a hole in the ground into which excreta falls directly. It has been modified to improve convenience and eliminate some of the shortcomings of the open pit. One example of such an improvement is the pour flush squat plate or bowl, which not only increases user convenience but also prevents access by flies and insects and eliminates odors. Where the dry latrine is used, the design has been improved by including vent pipes which eliminate odor and substantially reduce fly breeding. Another improvement is to offset the seat or slab from the pit which permits the eventual removal of pit contents without disturbing the superstructure. The superstructure can be built to reflect the preferences of the owner and his ability to finance a simple or a more elaborate housing.

In rural areas it is the practice to abandon the latrine once the pit is about two thirds full, dig another one, place the existing superstructure on the new pit or build a new superstructure. In more densely populated areas where room for this multiple pit digging is not available, an offset pit latrine can be built. However, whenever this type of latrine is employed (often with pour flush squat plates or bowls) a community organization is required to empty the pit at intervals frequent enough to prevent filling up and possible spilling of the pit contents. Although no single design can be used universally, such latrines are adaptable to various conditions of environment, soil, and groundwater, by incorporating appropriate design modifications.

Composting toilets differ from the latrine in that they actively treat the excreta (i.e., kill pathogenic organisms) within the unit. Their operation requires considerable care because the composting process is sensitive to the amount of carbonaceous matter, such as kitchen wastes or grass cuttings, added. The process is also sensitive to moisture levels and thus water cannot be used for flushing. Composting toilets can be either continuous or batch process types; an example of the former is the well-known Swedish Clivus - Maltrum. The best known of the latter type is the Vietnamese double-vault latrine.

In the double-vault latrine one of the vaults is in use while the waste material in the other (which is sealed) undergoes composting. After a period of one year or so, the sealed vault is emptied while the first vault is sealed to allow the material to compost. The batch type latrines are more appropriate for use in LDCs because they are simpler to operate than the continuous type. The latter requires careful control of waste composition and frequent removal of the composted material in order to keep the process going. In addition, because the length of the composting period determines disease vector die-off, process control for the batch type composting latrine is less important than for the continuous process composting latrine with its shorter residence time.

Aquaprivies and flush toilets with septic tanks are another on-site disposal method. The aquaprivy is a vault on which either the pour or cistern type squat plate or bowl is placed with the water in the tank forming the water seal. The septic tank consists of a tank anywhere on the lot connected to a cistern flush or squat plate toilet with inverted siphon seal. As the description indicates, the aquaprivy can function with the very small amount of water needed to maintain the water seal. If the water consumption is elevated, as in the use of a cistern flush appliance, then the aquaprivy can be equipped with an overflow pipe to a soakage pit or drain field similar to the ones used to dispose of septic tank effluent. While the pit privy and the composting toilets can be adapted for use in almost any environment with or without water supply facilities, aquaprivies and flush toilets with septic tanks require water and depend on facilities to dispose of excess water. However, they do represent the increased convenience of a waterborne system without requiring the massive investments of off-site sewerage. They also represent improved insect and odor control; but in contrast to the pit privy and its various modifications, they require regular desludging, i.e., an institution to collect and dispose of the sludge.

Proprietary toilets are mentioned only for completeness as there seems to be little scope for their application to benefit the poorer population in LDCs. They might be of some use, however, in areas where public sewers are not available and home owners can afford to make the necessary investments to have the amenity of a more sophisticated system. Examples of proprietary toilets are recirculating toilets based on an oil-flush system with a separation of excreta and oil in an on-site separating unit and subsequent recirculating of oil to the system, and a toilet based on the destruction of feacal matter by the use of an electric burner or heating element.

Off-Site Disposal

The cartage system, which consists either of a bucket or vault latrine with collection at regular, short intervals and disposal by dumping or treatment, is in wide use in LDCs. The former is probably the oldest off-site disposal system known and is still used where the ability to maintain vacuum trucks and vehicles needed for the emptying of vaults is not available. There is no question that the bucket system is the least sanitary of the two cartage systems, and there is little possibility of improving the handling of buckets sufficiently to make this a satisfactory long term solution.

On the other hand, emptying of vaults by means of vacuum trucks is a satisfactory method, and possibly the least-cost off-site method of waste disposal for the near and medium term as long as local competence in maintaining and operating the necessary mobile equipment can be developed. The mobile equipment need not be sophisticated. A hand operated pump and donkey drawn wagon can be used as an intermediate step towards a vacuum truck.

Off-site disposal requires treatment of the disposed material to prevent public health hazards and pollution of the environment. The most commonly used method of treating nightoil is anaerobic digestion either in a conventional sewage treatment plant (where nightsoil collection exists in parallel with a sewer system) or by separate anaerobic digestors designed for nightsoil treatment. Digestors can be designed to recover the methane gas produced in the digestion process if the sale of this gas would contribute towards the cost of operation of the nightsoil collection and disposal system. Another promising treatment method is composting of nightsoil.

Pour flush latrines with small bore sewers combine the advantage of the pour flush latrine - the waterborne system with little water consumption - and the convenience of disposing of human waste through a sewerage system. Pour flush latrines with smallbore sewers represent an upgrading of the simple waterseal latrine with a soakaway. The addition of sewers usually is required when water consumption reaches a level which no longer permits the disposal of effluent through soakaways. Because no solids are discharged from the latrines to the sewers, the pipes can be much smaller and are therefore less costly

Because no solids are carried, the number of manholes can be reduced and the maintenance of grades is less critical. In general, the operation and maintenance of the small bore system is simpler than that of solids-carrying sewer system. On the other hand, latrine desludging program is necessary to avoid clogging problems if solids overflow into the sewers. Treatment of the effluent carried by the small sewer system is usually by stabilization ponds.

Communal toilets are an attempt to provide amenities to the low income population without constructing a large sewer system and individual house connections. Proper selection of communal toilet sites and the construction of a system to carry waste away from them can provide sanitation facilities for a large number of people. Unfortunately, in many societies communal facilities are not socially acceptable. Success with this type of waste disposal thus has been relatively rare. Nevertheless, where there are no low-cost alternatives due to environmental conditions, communal facilities combined with health education to overcome user resistance can constitute an important intermediate step in the development of a full sewerage system.

THE SELECTION PROCESS

Given the range of alternative waste disposal technologies available, the problem becomes one of selection. Evidently the method of selection which will yield the "right" solution is not an obvious one, however, since very few (if any) technologies other than conventional sewerage have been "selected" over the past 20 years. Yet the number of sewerage master plans gathering dust on shelves in citeis in LDCs with desperate waste disposal problems indicates that sewerage is not always appropriate. Even in a few of those cities where sewerage systems have been built, the number of house connections lags far behind the projected demand, and as a result both technical and financial problems abound. Apparently, the analysis which showed sewerage to be the least-cost solution omitted several important parameters.

In our experience there are four factors which, singly or in combination, account for the bias in conventional feasibility studies toward sewerage. The first, and probably most widespread, is that alternatives other than sewerage were not included in the investigation. Often this is not the fault of the engineering firm, but can be traced to the drafters of the terms of reference which specify that a sewerage system shall be designed for the city in question. The bias exists in the minds of planning officials and aid agencies, perhaps understandably since they are not expected to have a wide technical knowledge of the field. Due in part to the current fashion of searching for "appropriate technology" 1/ in the fields of agriculture and industry in LDCs, this bias is rapidly disappearing in the international aid community. Sewerage feasibility studies recently commissioned for two of the largest cities in Southeast Asia have included in the terms of reference the development of sanitation programs for those portions of the population who cannot afford to pay the full cost of sewerage.

A second factor which has led to the selection of wrong alternatives is that many least-cost analyses are based on financial rather than economic criteria. Thus they select the alternative which will be the cheapest (in present value terms) for the utility given prevailing interest rates and foreign exchange provisions, and often ignoring those costs borne by others, including the householder. An economic comparison would include all costs

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1/ The publication of E.F. Schumaker's book, Small is Beautiful, in 1973 was, perhaps, most responsible for promoting this idea and giving it widespread visibility.

necessary for the system's proper functioning, and would value all inputs at their opportunity cost to the economy rather than their financial cost to the utility. Thus, for example, the fact that sewerage systems require 20-40 liters of flushing water per person per day would be reflected by including the long-run cost of producing that water (including capacity expansion costs, properly discounted) in the cost of the sewerage system. The fact that sewerage systems are generally subject to economies of scale and therefore are not fully utilized until five to ten years after completion would be reflected by calculating the per capita cost of sewerage not on the basis of the design population but on the basis of the present value of the population actually served over time. Just as costs incurred in future years are less expensive than those incurred today, so benefits received in future years are less valuable.

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 (and even where this is included in an analysis water is almost always priced below its long-run production cost), and it possesses larger economies of scale than most non-conventional waste disposal systems. With more and more consulting firms incorporating economic analysis (in fact, rather than in name only) into their feasibility studies, one can hope these factors will be more fairly reflected in the future, and alternatives which are truly least-cost will be selected.

A third problem is the failure to incorporate social factors into the design and selection process. When working in a familiar and homogenous social environment such as the United States this is done almost automatically since the engineer himself is generally a part of that social fabric. However, in developing countries it is necessary to make a real effort to discover the users' current practices and preferences in order to satisfy them at the least cost. Habits and ideas regarding human waste disposal are highly variable across cultures and are not easily discerned by the casual visitor. There are many examples where cultural misunderstandings have led to non-use or misuse of new technologies, not only for waste disposal but also for agricultural innovations, birth control campaigns, etc. The social dimension of technology design should not be regarded as an appendage to the technical and economic analyses, but as an integral part. Factors such as the color or location of a latrine may have little technical import and yet be crucial to the acceptance and use of the facility. In one new African community, the engineer designed the bathroom to be in the front of the houses so that the connection to the sewer would be as short as possible. However, the people were unwilling to change their traditional practice of having the latrine in the back of the house, away from the view of passersby. Had this been discovered before the sewers were laid, they could have been placed between the adjoining backyards of the houses for little additional cost. However, the users were not consulted during the design process and by the time they discovered the plans and complained, the sewers were already in place, and the house connections had to be modified at extra expense. Thus the system which eventually was built was not the least-cost solution.

A final factor which creates a bias toward sewerage is the method of tying consultant fees to the cost of the system designed, for example, through percentage of construction cost payments. It probably takes much more engineering effort and ingenuity to design non-conventional solutions than to use the company's computer programs to optimize sewerage options. Yet, because non-conventional alternatives are much cheaper than sewerage, the engineer would get paid less. This is clearly an inequitable situation and one that is fortunately being changed as more and more countries are turning to contracts where fees reflect the engineers' actual costs.

The problems with the technology selection process which have created a bias in favor of sewerage are gradually being overcome. In addition, the increasing interest in appropriate technology in other fields has stimulated related work in sanitation. A technical bibliography has just been published to review the state-of-the-art in low-cost sanitation (Ref.3). An important new work on the health aspects of excreta and sullage management with special reference to non-conventional options is now under review and should bepublished next year (Ref.1). One of the interesting conclusions of that study is that a properly designed and located pit latrine is just as effective (and sometimes more so) in pathogen destruction as a sewerage system. In fact, most of the nonconventional options can be designed to provide the potential for full health benefits. As with sewerage, the realization of those benefits will hinge upon proper user education and maintenance.

THE DYNAMIC SOLUTION

Incremental Improvements

Asking people to forego the possibility of having the convenience of a sewer system, even if they do not expect to have one until far in the future, is clearly not realistic. Not providing for a reasonable degree of sanitation immediately is also unacceptable if we are serious about people's health needs and improvement in their living conditions. A solution must be found which eliminates this"either/or" proposition. Fortunately, a variety of such solutions already exist.

If we examine how waterborne sewerage came about, two facts stand out. 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. Whether or not waterborne sewerage is the best solution for human waste disposal problems is for the purposes of this discussion, irrelevant. What is important to remember is that sewerage was not a grand design implemented in one giant step but the end result of progressively more and more sophisticated solutions. Surely what took industrialized countries over a hundred years to achive in a close matching of needs and the economic capacity to take care of them cannot be expected of LDCs with limited resources in a short time. With the benefit of hindsight it should be possible to correct not only some of the shortcomings of more primitive waste disposal practices, as discussed in earlier paragraphs, but to develop a sanitation system which can be improved to reflect user requirements and the economic capacity to pay for improvements.

Staged sanitation systems should reflect not only the capacity of users to afford the facilities provided, but also their cultural environment and technical competence. Clearly, if sanitation facilities are to be used, consumer preferences and the customs of personal hygiene must be considered. In fact, staged sanitation might be more successful than the installation of sewerage since it can give the user a chance to progress as he sees fit, to whatever level of convenience he desires, and at his own speed. There is also no need for a commitment to reach a given stage at a given time.

A staged system can be chosen which reflects the user's growing level of technical experience as well as his cultural preferences. Construction of some sanitation facilities can be very simple and easily mastered by a homeowner. Operation and maintenance of on-site facilities may also be very simple; and off-site facilities, when they are needed, can be designed for operators with minimal technical expertise.

Sample Staged Solutions

To demonstrate the feasibility of using a staged sanitation system, three possible schemes are described, and costs are calculated for one of them and compared to those of sewerage. Each scheme could be started at any stage or 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. For example, to a standard pit privy with a pour flush a vault could be added if housing density increases or soil becomes clogged. Similarly, a composting toilet which already has a water tight vault, could be converted into an aquaprivy or pour flush privy with a vault.

I. The Waterless Latrine Scheme. The initial installation would consist of an offset pit or vault latrine with the vault extending outside the latrine housing to permit easy emptying. Emptying would be required every five years. This stage would last until the community water supply was upgraded from communal standpipes or wells to yard hydrants. With increased water availabili the dry latirne would be converted to a pour flush latrine by adding a squat plate or bowl with inverted siphon or aquaprivy waterseal. A baffle and overflow pipe would also be added to the vault to carry the overflow liquid to a soakage pit or drain field. Annual collection of accumulated sludge would be required along with a facility to compost or digest it. The third stage would begin when the water supply service is upgraded to house connections and a large quantity of sullage water has to be disposed of. At this point a small diameter sewer system would be constructed to accept the overflow from the vaults (replacing the drain fields). This solution would permit the use of cistern flush toilets to replace the bucket flush if desired. Annual collection of sludge would still be required.

II. The Pour Flush Latrine Scheme. The initial installation would be a pour flush latrine with a vault emptied by vacuum truck at one month intervals. The collected nightsoil would be composted, digested, or treated in stabilization ponds. As the water supply was upgraded this scheme could follow the same second and third stages as Scheme I.

III. The Cistern Flush Scheme. This scheme is essentially for those few users in an urban poor area who already have water connections in their houses. It begins at the second stage of Schemes I and II but with a flush toilet rather than a hand flushed bowl ro squat plate. The eventual installation of small bore sewers would depend on water usage and population density.

All of those schemes require offsite facilities in stage three such as ponds for the treatment of effluent and digestors for sludge treatment. Figure I shows a diagramatic presentation of the various components and their possible combinations into schemes.

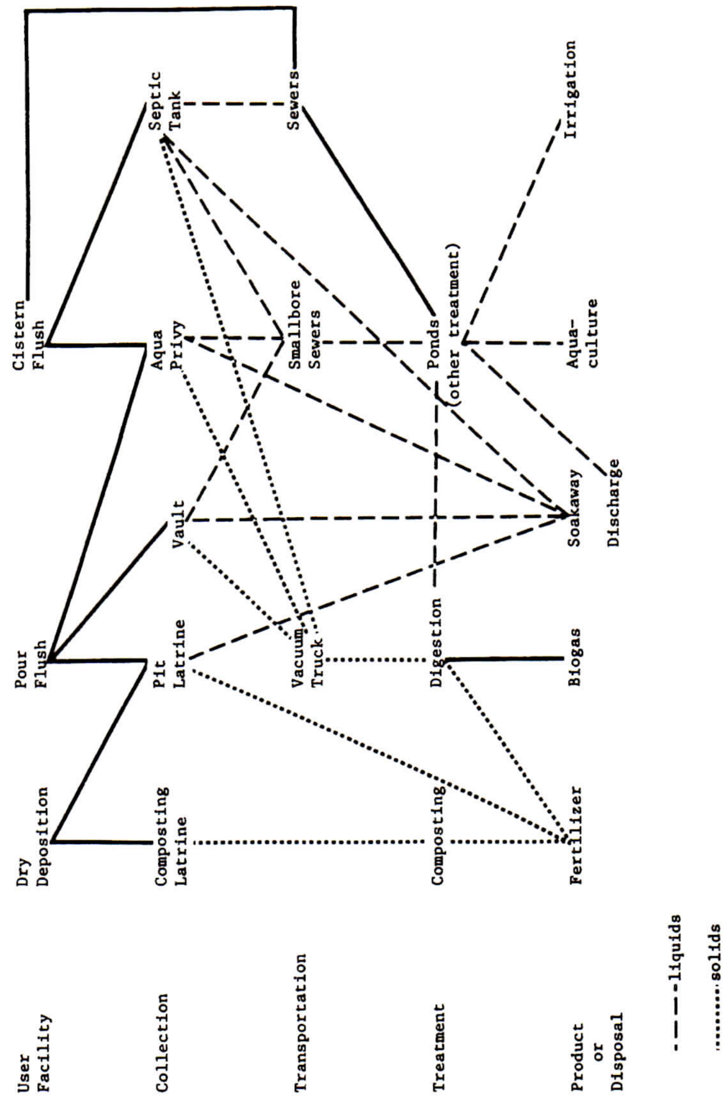

Fig. 1 Alternative technologies for excreta management.

Comparative economic costs, on a household basis, have been prepared for Scheme I and three variations including the alternative of proceeding immediately with the construction of a sewerage system. The costs are derived from those of existing African offset pit latrines, aquaprivies, sewered aquaprivies, and sewerage systems. They include all construction and maintenance costs of on-site, collection, and treatment facilities. They are economic rather then financial costs in that they include costs borne by all parties (not just the utility), and the value of inputs such as water and capital has been set at reasonable opportunity costs rather than at typical market prices[1/]. In addition, the per household cost of sewerage is calculated on the (discounted) population served over time rather than on the design population to reflect its gradual utilization.

Scheme I is costed on the basis of an offset pit latrine installed in year 1, upgraded to an aquaprivy with drain field in year 11, and then connected to small bore sewers in year 21. Sludge removal and composting occurs annually after year 11. Sewage treatment after year 21 is accomplished through two trickling filter plants. The annual cost per household of this three-stage system over 30 years is &72.4[2/].

The second alternative is a two-stage scheme which moves directly from the offset pit latrine (installed in year 1) to small bore sewers in year 11. The annual cost per household over 30 years is $133.5, or about 85% more than the three-stage alternative.

The third alternative is simply to install a small bore sewerage sytem from year 1. This would cost $160.9 per household per year over 30 years.

1/ Water is valued at $0.35/m^3$ and the opportunity cost of capital is taken to be 10%.

2/ This figure includes the "salvage value" of the sewerage system which is assumed to have a 40-year life.

The final alternative, calculated in the same way and with data from the same city as the sewered aquaprivy for purposes of comparison, is the immediate construction of a full sewerage system. The system was designed to serve about 190,000 people in an area of 3,500 hectares. A five-year construction period is assumed. The facility is assumed to be two-thirds utilized upon completion and fully utilized 10 years after completion. Based on these assumptions the annual cost per household over 30 years is $318.0. This includes the cost of flushing water and all regular operating and maintenance costs. It is four times as high as the cost of the three-stage scheme and nearly double that of the one stage sewered aquaprivy alternative.

All calculations utilized conservative assumptions in the sense of choosing a relatively inexpensive sewerage system as the basis for sewerage costs and relatively expensive pit latrines and aquaprivies as the basis for on-site costs. However, they were prepared for illustrative purposes only and should not be taken to represent costs which would be duplicated in an engineering simulation of the various alternatives on a particular site. They do indicate that considerable savings can be achieved through a staged upgrading scheme.

RECOMMENDATIONS

The single most important activity required for a more rational decision making process and subsequent achievement of appropriate solutions for the human excreta disposal problem is the dissemination of information on alternative waste disposal methods and the education of decision makers and designers on how to prepare and implement such projects. Only if the decision makers responsible for providing waste disposal services are alert to the possibility of using methods other than waterborne sewerage, understand the advantages and disadvantages of the various solutions and know the financial and economic costs of the various alternatives, can they make a rational decision on how to allocate a country's scarce fiscal resources.

Governments and development agencies must insist that designing engineers prepare master plans for sanitation rather than sewerage. Master plans should provide intermediate solutions for those areas which are not to be sewered so that all inhabitants of the area obtain excreta disposal services. A master plan should foresee the gradual improvements of services to whatever level the community desires as ability to pay for a higher level of service increases.

The preparation of such sanitation master plans and projects requires both a greater sensitivity by the designer to the needs of the community and a much more direct participation by the community in the design process. It is essential that service level options, their associated cost, and operational requirements be explained to the prospective users so they can select the system which most adequately serves their needs.

Designers have to be paid for undertaking these tasks, rather than by a percentage of construction cost which will be less for sanitation system than for sewerage. Further, the fee will also have to provide for the participation in the design process of sociologists, health specialists, etc., without whose input sanitation projects are unlikely to be successful.

Finally, research work must continue on those aspects of waste disposal not yet fully understood and evaluated, for example, the impact of sullage water disposal on the environment. Another area requiring attention is the development of appliances which provide the amenity of water use without high water consumption. Success in this area would permit the use of such appliances in areas of low-density development without the need to construct waterborne sewerage. Another area requiring additional work is the reuse of excreta, solid wastes, and agricultural wastes. This research topic has the potential of creating a whole new industry which could substantially lower a community's waste disposal costs and produce valuable products ranging from energy to food to pharmaceuticals.

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