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9. ABSTRACT

This study gives a cost-effectiveness analyses of the health and sociocultural benefits of sewerless alternatives for domestic waste disposal in developing countries. This involves a comparison of the conventional methods of treating sewage with newer, higher-level technological methods which eliminate the need for sewers. "Sewerless" refers to waterless or water restricted systems, while "conventional" means water-borne. There are five basic categories of advanced methods of sewerless treatment: incinerating toilets, biological toilets, composting toilets, vacuum systems, and aerobic tanks. Oil flush toilets may also be applicable. The major advantage to these methods is the low water consumption. Two alternate disposal techniques are aquaculture (the use of sewage as a fish food) and land applications. Since piped water is not available in many areas of LDCs, the necessity for consideration of alternatives to centralized sewage treatment practices is evident. Transfer of technology from developed countries is fiscally prohibitive. In this report, cost effectiveness techniques are applied to identify the most cost-effective, commercially available systems. Unit costs are developed using a decision weighting model which seeks a measure of objectivity by delineation of the physical performance characteristics of the available alternatives. A comprehensive literature and market survey on conventional and individual household treatment systems was conducted to obtain data on costs, technology requirements, and other pretinent factors. The report includes an historic development of wastewater systems and treatment, a discussion of conventional treatment systems, the state of the art of sewerless treatment systems and water reduction, and many tables and illustrations supporting the text. This study is useful to engineers, planners, and administrators when making decisions on selecting disposal for new or expanding areas.

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FINAL REPORT ON THE COST-EFFECTIVENESS OF THE SOCIO-CULTURAL AND HEALTH BENEFITS OF SEWERLESS ALTERNATIVES FOR DOMESTIC WASTE DISPOSAL IN DEVELOPING COUNTRIES

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ABSTRACT

The objective of this study is to evaluate within a cost-effectiveness analyses format the health and sociocultural benefits of sewerless alternatives for domestic waste disposal in developing countries. This involves a comparison of the conventional methods of treating sewage with the newer, higher-level technological methods which eliminate the need for sewers.

Cost effectiveness techniques are applied to identify the most cost-effective, commercially available systems. Unit costs are developed using a decision weighting model which seeks a measure of objectivity by delineation of the physical performance characteristics of the available alternatives. A comprehensive literature and market survey on conventional and individual household treatment systems was conducted to obtain data on costs, technology requirements, and other pertinent factors.

The results of the study could help engineers, planners, and administrators to make decisions when selecting disposal for new or expanding areas, particular waste problem areas where conventional systems have not been successful and for areas of unserved population not amenable to sewerage. Furthermore, this study is one example of how system technology can be used in the solution of complex environmental quality management systems.

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Regards.

George W. Reid
Regents Professor/Director

GWR/mn

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EXECUTIVE SUMMARY

CONCLUSIONS

The alternate technological developments in the last thirty years, together with the impracticality of conventional treatment systems from developed countries for all applications, serves to reinforce the need for selective decision-making policies based on experience and appropriate technology.[29] Results of a group report from the "Global Workshop on Appropriate Water and Wastewater Treatment Technology for Developing Countries" (1975), cited that the rate of sewerage construction was falling behind world population growth.[30] It is not expected that the rate of connections will rise above 0.7% in the foreseeable future for developing countries. Thus, with only 9.7% of the total population or 6.5% in LDC's[31] serviced by sewage treatment facilities and the majority without piped water, the necessity for consideration of alternatives to centralized treatment practices is evident. The IDRC preliminary report showed supporting evidence to the consideration of alternatives in a review of 500 international documents on wastewater practices with their comparison of waterborne, cartage, and on-site systems (Table 48).

	Waterborne	Cartage	On-Site
Capital Cost	High	High/Low	Low
Operating Cost	Low	High	Low
Offshore Cost Component	High	High/Low	Nil
Water Consumption	High	Low/Nil	Low/Nil
Optimal Density	High Density (High Rise)	High Density (Low Rise)	High & Low Density (Low Rise)
Adaptability to Incremental Implementation	Nil	High	High
Adaptability to Self-Help	Nil	Low	High

*Stop the Faecal Peril from IDRC Preliminary Report

Table 48. General Conclusions about Various Methods

Conclusions reached during the course of this study for AID into the sewerless alternatives to conventional treatment systems are as follows:

1) Developing and/or less-developed countries have one thing in common: Lack of, or minimal, sewage collection and disposal of waste. This waste is usually domestic sewage.

2) To transfer developed country (DC) technology of conventional sewerage and sewage disposal systems is fiscally prohibitive and alternatives must be explored.

3) On-site systems for individual households or small groupings of homes, community centers, etc., are technically available and are to be found in several variations. They are characterized as hydraulic, biological, and chem/thermal, and in sufficient numbers to warrant further applications and demonstrations.

4) Some have been manufactured on a production level but real hard site data is not available, particularly for chem/thermal units in LDC's.

5) Evidence, even in U.S. production, indicates the acceptance of the biological units for small rural communities or dispersed housing areas.

6) Lacking hard data, in-country (LDC) application for chem/thermal methods, as an alternative, does appear feasible from synthesized costs for units compared to the conventional systems (Table 47).

7) Consumer acceptance is not so much a matter of cost (as demonstrated by D.C. acceptance) but rests on health and socio-cultural factors, such as necessity, availability, and alternatives.

8) What is needed is an LDC demonstration-level study to validate the findings or guide of this study, that is, a comparative study of conventional solutions vs on-site ones, including site feasibility and an inplace practice demonstration.

9) Such a study would consider cost, capital and operation & maintenance; look at various units, or combinations, for several LDC sites, such as large, medium, and small urban areas; and compare results to a conventional system (sewers and treatment). The primary goal would be nuisance and health control. Various waste considerations such as laundry wastewater may require separate handling. As LDC's develop in density at various sites alternatives may be required to meet socio-cultural changes.

10) For chem/thermal units, electricity can be assumed to be a social good and as a corresponding price.

11) Several management schemes should be explored:

Private Enterprise - Similiar to U.S. plumber.

Private Manufacture, Public Installation and Control - Similar to the Appalachian experience.

Public Manufacturing and Installation - May be for a city or for a region.

12) All schemes should also have a built-in, public incentive or incentive concept.

13) Performance, e.g., effluent, should be in accordance with local standards.

14) Cost studies should be considered along with consumer acceptance of actual in-place study. (Chert and Reid et al studies can serve as cost references)

It is clear that LDC's because of low domestic water requirements, no waste disposal standards, and little industrial and trade wastes have a unique opportunity to explore an alternative solution that will advance their ends and avoid pitfalls that the DC historic development has encountered. DC countries now use 2000+ gcd of water, 160 gcd municipal water, so that a loarge percent of it ends up as waste. Regional systems or large metropolitian systems, even at 90+ treatment levels, still discharge unacceptable loads.

So, the correct focus is to reverse the trend into manageable units, using segregated units, sequential use, separate systems, re-use, and in-place control. All concepts that can be worked on with on-site treatment as LDC's develop economically should be encouraged and will be beneficial to their future development.

COST EFFECTIVENESS OF THE SOCIO-CULTURAL AND HEALTH BENEFITS OF SEWERLESS ALTERNATIVES FOR DOMESTIC WASTE DISPOSAL IN DEVELOPING COUNTRIES

CHAPTER I

INTRODUCTION

Background

Treatment of water and wastewater has become an accepted facet of everyday life in developed countries in the last thirty years. One expects, without prior thought, that the drinking water is safe and that proper toilet facilities are readily accessible for comfort and convenience. This is particularly true for those under twenty-five years of age and urban residents in the United States.

The everyday expectations in lesser developed countries, though, is not the same. What is an accepted practice, particularly in Western Countries, is sometimes unacceptible or inappropriate behavior by the health or cultural standards elsewhere in the world. The need to remove or dispose of human waste is an integral part of every culture. The manner in which it is done has had widespread health effects and has influenced man's progress throughout recorded history.

Two methods, burial and stream usage, have been the traditional methods of maintaining a healthful human environment within any tribal, family, or cluster of living units. It has only been in the last two hundred years that a waterborne piped collection network has been

utilized to remove wastewater from households in populated areas. These wasteborne sewage systems have served admirably in cities or urbanized areas with high density populations to enable a large number of persons to be free of the associated diseases, especially enteric and helminthic diseases that accompany unsanitary conditions.

Where and when abundant water is cheaply available and the level of wealth can support the high capital costs required, centralized collection and treatment systems have been very successful in influencing the improvement of health conditions. Usually such systems have become possible only with the advent of a centrally piped water supply system.

Sewage systems in developed nations have grown for the most part with the expansion of municipal facilities and the increase of suburban population density in outlying areas. They have been appropriate also where the natural environment has had a capacity to absorb a concentrated flow of wastes in an untreated or semi-treated state. These conditions apply to some major metropolitan areas of lesser developed countries and occasionally are present in developed countries on a short-term basis.

Thus, efforts to control or solve human waste problems have been effective only when waste is either removed from the human habitat or treated within some type of sewage system. Still limited is the knowledge of current waste disposal technology due to limited access to the latest developments.

The list of available processes for sewage treatment encompasses

both the waterborne sewage systems and the newer waterless or water-restricted sewage systems. The waterborne systems are referred to in this report as conventional treatment due to their widespread acceptance. The waterless or water-restricted systems are referred to as the sewerless treatment though some devices are initially included which connect such systems to sewage lines.

International Development

President Carter, in a message to Congress Monday, May 23rd, 1977, pledged the "unsparing support" of his administration to the protection of nation's environment and the preservation of its resources. Included in that message was the use of the Agency for International Development programs to encourage environmentally sound policies in developing countries.

This effort to analyze the applicability of new technologies in wastewater treatment systems for developing countries is very much in keeping with that policy announcement. It was initiated by AID/TAB, Office of Health in the Fall of 1974 as a work-study program. The schedule of work was developed and undertaken in the Spring of 1975 by the Office of Health and the University of Oklahoma.

Two reports have been made during the project prior to this one. The first progress report was filed in 1976 at the end of the first year. In order to meet project evaluation objectives a status report was developed and submitted for review on the sewerless and other alternate technology in May 1977. This second report contained supply data on types, costs, socio-economic acceptability and resource

requirements. A comprehensive literature and market survey update on conventional and individual household treatment systems was also conducted in the development of the status report.[1,2]

Statement of the Problem

From the time of this project's initiation to the present the technological advancements under consideration, namely, sewerless systems and devices, have evolved from a relatively unknown status to a position of more positive recognition in at least a dozen centers of engineering research in the US, Canada, and Sweden. The culmination of this project's research objective was validated with the National Conference on Less Costly Wastewater Treatment Systems for Small Communities, sponsored by the US Environmental Protection Agency in April 1977. That conference served to announce a policy change in favor of the support of cost-effectiveness alternatives which may be found in on-site treatment systems for communities with less than 10,000 population. The announcement was made by both the US Senate Chairman of the Environment and Public Works Committee, Senator Jennings Randolph and the newly appointed Administrator of the US Environmental Protection Agency, Douglas Costle. Consideration of alternative systems vs conventional systems is now required for cost-effectiveness.

Costs associated with sewage treatment have often been the sole determinating factors in the past selection of alternative sewage treatment systems. Availability, adaptability, and latest technology of methods and equipment have also had some influence. None of these are

particularly "bad" reasons for selecting a system but by themselves have not proven to be adequate reasons in the light of failures, system breakdowns, and partial treatment.

Because centralized treatment facilities are generally one's of a kind, just as collection systems vary as to topography and settlement patterns, responsibility for failures has been difficult to establish. Plumbing is dependent on manufacturer's equipment and current installation practices. Ultimate disposal is determined by engineering design. Engineering expertise for the design, installation, and equipment requirements for such facilities has been almost entirely transferred from the more industrialized nations. All of these facts have led to slower adaptation, treatment, mis-application of system designs, higher or unexpected costs, unanticipated construction delays, greater equipment replacement, and early system failures, especially in LDC's.

Need for Study on Wastewater

The need for treatment of wastewater in lesser developed countries (LDC's) is no less than the need for safe water supplies.* In many LDC's living conditions are at best what United States recreationalists consider "roughing it". Certainly such methods are undesireable, even unimaginable for some city dwellers on a long term basis. Basic sanitation services are needed for the prevention and control of communicable diseases and for the promotion of physical, mental, and social well-being throughout the world.

*Wastewater and sewage treatment have become synonymous in recent years due to the inclusion of all spent water being discharged into the sewage collection system.

Actually, the overall picture of sewage disposal gained through research of 90 selected LDC's is worse than that of water supply. This is due somewhat to the earlier emphasis on safe drinking water prior to concern for a treated effluent. On the basis of currently available information from the World Health Organization, estimates are that 50% of urban residents are served with public sewerage systems and 45% more with individual households systems. In rural areas the conditions are much worse with 91% of the population estimated to have inadequate excreta disposal facilities. This means that greater then one billion people are following primative excreta disposal practices, burial and stream, which lead to unnecessary illness, disability, and death.

It is these one billion or more people incapable of being reached by conventional treatment systems which could potentially benefit from sewerless alternatives. Target areas should be those areas which have been shown to public health officials to have the highest risk for waterborne diseases. Even areas in developed countries cannot be excluded from the potential benefits exhibited by such alternative applications when evaluated on the basis of cost-effectiveness analyses.

Benefits of Treatment

The interrelationship between water and sewage treatment in conventional waterborne sewage systems makes the benefits of each difficult to separate. Little data is available which delineates the exact benefits accrued from wastewater or sewage treatment alone. Water supply treatment normally proceeds wastewater treatment though some

studies have shown a reduced rate of infectious diseases as a result of the installation of either system. Generally 40% of the treated water is required to flush away the waste from a residence. Some studies have indicated that there is a greater than 70% reduction in water-related communicable diseases with water treatment and an additional 25% or greater with the introduction of sewage treatment.

Using conventional treatment methods the design of the water supply system is greatly influenced by the sanitation services proposed, a greater amount of effluent being required for the centralized collection systems. Sewage treatment is the reverse of water supply in that water is returned to the general environment after it has been treated, rather than treated before it is used for human consumption. A closed system for both, together or separate, provides the greatest benefit.

Technology Transfer

As can be demonstrated by many documents the application of new or "developed" technology to other socio-economic cultures is a very specialized profession. The implications of technological changes in foreign cultures can have a profound impact on their social systems. Cultural values and traits, the social processes, and the political and economic forces may all be affected by the innovations adopted. A planned evaluation of the proposed technological transfer is imperative to maximize the health and socio-economic benefits from the new innovations. The stage of advancement from which any adoptive change is drawn has not precluded its widespread use, i.e., transister radios.

Too low a transfer price for technology (which would include lower costs or intermediate methods) could possibly inhibit local adaptation.

Cost-Effectiveness

Cost-effectiveness analysis as applied to this research work, is defined as an analytical study designed to assist a decisionmaker in identifying a preferred choice among possible alternatives and involves two steps of evaluation. The first is cost evaluation which entails the delineation of all major system components and the development of capital and operating costs for each. A second is the effectiveness evaluation in which one attempts to generate a single basic measure or indicator of effectiveness using multiple considerations. The essence of cost-effectiveness analysis then compares the trade-off of cost with effectiveness to identify the most cost-effective alternative.

The traditional economic analysis of engineering systems were dependent on cost consideration alone. Decision-makers initially used the least cost solutions that met required constraints. In this case, systems were measured by minimizing the cost without referring to the benefits. Following this approach, evaluations emphasized net cost or net savings, with this representing the difference between total cost incurred and any resultant benefits which could be expressed in monetary units. However, it has been well known that combining costs and benefits into a single measure will not necessarily indicate the most economically efficient alternative. Thus, cost-benefits analysis which centered on the cost/benefits ratio as the indicator of economic efficiency was introduced.

Cost-benefits analysis, however, is not satisfactory in evaluating wastewater treatment and disposal systems for any public application because the overall utility of any alternative system depends upon multiple criteria or measures of effectiveness (reliability, operational simplicity, automation, public acceptability, and others) which cannot be expressed directly in monetary units without losing the true significance of cost and/or benefit.

Thus, selection of one wastewater system from among a group of alternatives, with respect to multiple criteria, asserts a complex problem in decisionmaking for local administrators and consulting engineers when recommending one alternative as well as for federal agencies and international loan institutions when approving the final selection. The decision-making difficulties and evaluation of final recommendation problems come from the multiplicity of considerations which must be weighed one against the other in order to reach a decision. This usually means a need for some type of decision-weighting model. Decision-weighting models have been criticized by several authors. However, one cannot skip the fact that the decision maker must take a final choice. Diverse factors must be weighed so as to reach a final overriding value evaluation and to make a choice. In addition to the general benefits which have been derived from such models, recently they have become vital in preparation of environmental impact assessments.

Use of decision-weighting models has become a necessity for placing some value upon the importance of varied considerations and summing these values for each alternative when considering projects

where real data or data sources are inadequate such as in developing countries. This ability to measure formerly non-quantitative values for comparison with quantitative ones enhances the use of such modeling techniques for decision making in these countries. (LDC's).

Materials shown in Chapter III represent the possible conventional treatment systems which have been or could be used in developing areas, as well as their advantages of disadvantages. During the evaluation, they served as the fundamental knowledge that must be referred to when evaluating those system criteria which can only be judged from the knowledge of current practices. A comprehensive survey of disposal devices and hardware manufacturers on available systems was conducted and is shown in Chapter IV.

The work reported in this study is directed toward a cost-effectiveness analysis of those systems. The metholodogy and analyses are V and VI. The specific objective was to identify the most cost-effective systems for use in developing countries. Technical and economic data provided by the manufacturers was utilized in performing the cost-effectiveness analyses of these systems. Chapter VI is intended to serve as a guide for engineers or health officials in the field.

CHAPTER II

HISTORIC DEVELOPMENT OF WASTEWATER DEVICES AND TREATMENT

General

Removal of human and other types of waste products from the human environment is imperative to the health and well being of man. Even other animals and lower organisms are affected by the continuous presence of their own excreata. So, if they are kept in a confined space, they will gradually die off. The earliest human remedy to this self-poisoning or hazardous exposure was migration, but with the population increase this possibility has continually decreased.

Other early methods of waste removal were cremation and burial or earth systems. Streams and water supply sources were considered either too scarce, valuable, or sacred to be purposely polluted by dumping of waste into them. Cremation was not considered as the most favorable method because of the "wet" nature of the waste, the fuel requirements in mixed conditions, and the resultant intolerable odors from primative burning.

As larger portions of the population aggregated into settlements, different disposal techniques became necessary. Special places were set aside for the reception of refuse, thus the midden heaps. After the heaps came the ditches or trenches which were dug to receive larger

quantities. Then came the great pits, roofed over with beams and earth, which had to receive the larger quantities of water from washing, cooking, and sewage. At a still later period these excavations were lined with brick, arched over, and connected with the houses by brick or flagstone drains. The pits were not usually cemented because it meant more frequent emptying. If they were air tight, it meant venting the sewer gases.

With the advent of running water and waterclosets in the 1800's the cesspools became completely inadequate. Overflows of cesspools and privy vaults were not uncommon occurrences, particularly with absentee landlords, but the waterclosets resulted in continuous flooding. Up until that time sewers were considered to be the receptacles of surface water runoff only. The disposal method for the collected sewage was primarily sewage farming though some dumping into streams occurred.

The increased volume of water use by householders brought about the demise of farm utilization of sewage and resulted in the sewerage development. Disposal by dilution became the rule with sewers emptying into rivers, streams, and lakes. Finally, this method of disposal was replaced by sewage treatment after water treatment alone proved inadequate for the maintenance of a sanitary water supply.

Sewerage

The history of sewerage is noteworthy in engineering circles because it is marked by experience rather than experimental development. Sewerage has always followed in importance to water supply. As a result experience was the early method of learning, sometimes at a slower pace than necessary for public health needs and always at the expense of the public.

The first record of a sewer was found on an old Babylonian seal-cylinder. Arched sewers in Mineveh and Babylon were found dating back to the seventh century before Christ. Sewers have also been unearthed in Jerusalem, Greece, and Rome. These were designed primarily to receive surface water which also contained sewage (ordure) washed from the streets. Frontinus, a water commissioner and engineer of Rome, wrote about the sewers noting that a diversion of part of the water supply was necessary to flush them.

From the time of Frontinus till the renaissance in Hamburg in the mid 1800's no marked progress in sewerage was made until W. Lindley, one of the leading English engineers of his day, designed a complete systematic sewerage system for Hamburg. The great feature was the weekly flushing at low tide by letting the river water flow through the sewers at great force. In general, though, the lack of central authority in most countries rendered a systemic study and execution of sewerage works impossible. Compulsory sanitation practices as we have them today would have been considered an invasion of personal rights. The benefits of effective sewage treatment was unknown.

Sewerage systems were inaugurated in both Paris and London as a result of cholera epidemics. The first attempt to study sewerage needs in Paris was made about 1808 but it was not until a cholera epidemic in 1832 that authorities recognized the need for central collection. In 1847, scared by a cholera epidemic in India which had begun to work westward a royal commission was appointed. This body reported that a single board should handle the sewerage of the entire metropolitan district. In 1848 Parliament followed this advice and created the

Metropolitan Commission of Sewers. It was not until 1859 that any comprehensive construction work was undertaken.

In London the situation was much the same as Paris but later in correcting the problem. The city was better off than most metropolitan areas of that period in that it had Commissioners of Sewers elected annually. The problem came in the outlying areas which were greater in size, population and the number of homes but which had fewer commissioners with less authority. In 1847 the same cholera epidemic which produced a scare in Paris also moved a royal commission in London to recommend to Parliament a single board, the Metropolitan Commission of Sewers. Unfortunately the action was too slow and a series of cholera epidemics from 1848-1854 resulted in over 15,000 deaths. The connection between a contaminated water supply and the disease was clearly shown, but it was also due in part to the failure to remove sewage from most homes. J. W. Bagalgette, in 1852, became chief engineer of the Metropolitan Commission and moved to formulate policies. He developed plans for intercept or lines with the aid of W. Haywood, engineer of the City Commissioners of Sewers. These plans were not executed until 1859 when construction began.

With the introduction of running water and water closets after 1870, came a demand for house connections to sewer systems, especially in the U.S. The connection of the water closets favored by U.S. residents over the earth closets only served to accentuate the problems of the already overcharged, underdeveloped disposal systems. The loads became so immense in developing cities that as a city developed its water supply it had to accelerate the sewer building activities to provide sewerage for all city residents receiving water from the central supply.

Engineering methods for sewers were marked, as previously noted, by the experience of others and improper information for design in the early years. Adaption of the plans of other cities in different climates proved impractical and forced the planning and design to be conducted on a one-to-one basis. Reports of royal commissions on river pollution, sewerage, and sewage disposal provide valuable information about sanitary conditions and of English and European experience prior to current sewerage practices.

Considerations of public health were equally important motivators in the sanitarian's demand for sewers and sewage disposal as society became aware of cholera and yellow fever as social diseases that could be cured by sanitary reform. Edwin Chadwich, "the father of sanitarians in England," unquestionably aroused that country to the need of greater cleanliness not only in cities but also in rural districts. His cause was continued in this country by sanitarians such as Lemuel Shattuck and Col. George Waring.

The critical turning in the development of sewers and sewage treatment came when the great majority of cities abandoned farm disposal (agricultural use) and elected to dump their sewage into water courses from which they also drew their drinking water. Incredibly high typhoid fever death rates were the result. Filtration of water supplies rather than sewage treatment evolved as the answer. Sanitary engineers of that period argued that, given the level of benefits, the costs of sewage treatment were too high when compared to the costs of water filtration.

Waterclosets

The water closet, commode (a misnomer) or toilet as it is called today has a long history. Types of closets, perhaps so named because the seat used to be mounted over a box with a little door for access to the pail or pot, have been used as early as Minoan Civilization. One of the earliest indoor bathrooms was found on Crete. Patents on water closets did not become issued until the first English one in 1775 and the first American patent in 1833.

Widespread adoption of water closets did not take place though until running water became prevalent in homes at which time flush toilets became feasible. Up until then water closets were a luxury of a nation's royalty and of wealthier persons. In the 1850's some toilets were connected to sewers but most flowed into cesspools or privy vaults. The earth toilet was adopted in England and Europe but found little acceptance in the U.S. It gradually fell into disuse with piped water and better sewerage.

Toilets from 1870 to today have changed very little. Styles, placement of the watertank, capacity of the water tank, flush valves, piping, and construction materials have varied slightly but the overall design concept is much the same.

Estimates of water use in the 1900's were from 1/6 to 1/10 of today's water demand per person. This was based on two flushes per capita per day at a rate of two gallons per flush or four gallons per capita per day (gpcd). Water consumption of most American toilet brands is greater than two gallons per flush.

Septic Systems

Septic tank systems began to replace cesspools and privy vaults after the 1890's as the public became aware of sanitation problems and accepted the necessity for new methods. Septic systems were first patented in England by John Louis Mouras and Abbe Morgno in 1881. Their first application in the U.S. was in Boston in 1883. Septic tanks were commonly used in earlier days for the treatment of municipal sewage, even for relatively large communities, in addition to single family dwellings.

Initially, septic tanks were constructed by rule-of-thumb estimates and later according to the construction guides published by various state and federal authorities. These early systems consisted of the septic tank itself with a soil leaching or absorption field which received the overflow of anaerobically decomposed wastewater. After introduction in the U.S. several modifications in the basic design and principles of operation in the tank took place. No major modifications have taken place in the last thirty-five years.

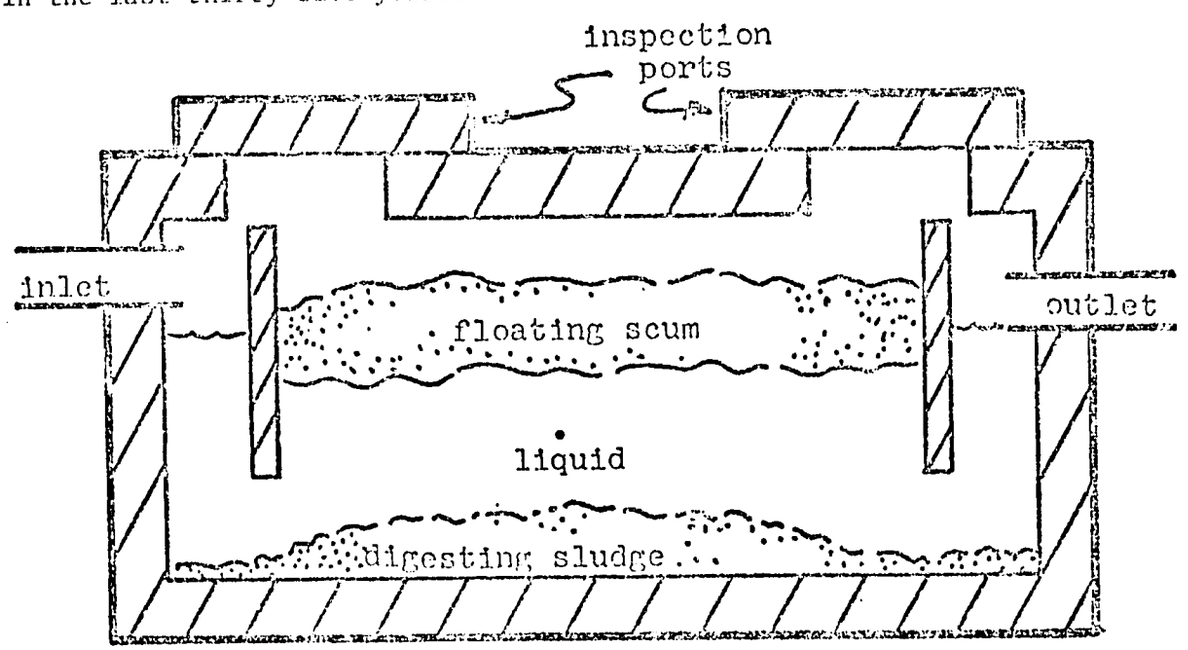

Figure 1. Typical Septic Tank Design

The widespread use of septic systems has persisted through the years in the face of consistent failures and disapproval of their use by various public health engineers. In sparcely populated areas these systems apparently worked well, i.e., unless the isolated failures were not reported and recorded as significant. Whatever the case, the problems of waste disposal from homes did not become important until the rural electrification program was initiated in the 1930's bringing a pressurized water supply. Septic tanks have been in great demand ever since for individual waste disposal sites. They are now used primarily to treat household sewage whenever access to central sewerage connections are unattainable.

Involved in the continued use and expansion of individual home waste treatment units in the U.S. has been a change in growth pattern and land use development. Since 1940 the farm population has decreased while the non-farm population has increased by a factor of four. Most of this non-farm population now resides in suburbia. Some of it beyond the reaches of sewerage systems. The new non-farming population is the prime user of septic tank systems.

Today, the number of septic tanks in the U.S. is unknown with estimates ranging from 13 to 25 million individual disposal units. This estimate would also include aerobic systems which have had some acceptance with an estimated 20,000 to 30,000 in use in 1970.

The public health effects are most critical when septic systems are built close to private wells. Outbreaks of typhoid fever, dysentery and gastrointestinal infection, infectious hepatitis and infant methemoglobinemia have been traced to malfunctioning septic tank systems, often

improperly designed systems located too close to water wells. Lack of known alternatives, especially lower cost or more effective available treatment methods has led to the continued installation of septic tank/soil absorbtion systems (ST/SAS).

Sludge removal from septic tanks is necessary every two to four years or when the system fails. Problems associated with this disposal are addressed infrequently but require removal and hauling of sludge and scum to a disposal site.

Municipal Treatment

The concept of municipal treatment, the central collection of wastewater from a populated area and its subsequent treatment before disposal, came into being in the 1890's with the water carriage system. The dilution of sewage and other wastes with water prohibited the disposal practices of formerly available methods. Cesspools and the surrounding soils were saturated and flooded when the diluted waste was emptied into them. The volume of wastewater was also too great for the pail system because of the weight, vehicle capacity, and subsequent transport problems. Midden heaps, of course, were not even considered.

Originally, the waste from water closets was dumped through the streets, sewers, or direct piping into the water courseways and the sea. With the increased size of some populated areas or towns such disposal appeared to be sufficient. As more and more water closets were added it became apparent to health officials that some method of pretreatment was needed if the rivers and lakes were not to become extended sewers and cesspools. Estimates of sewage tolerance levels were calculated in

various countries: Germany, 1 to 15th or 6.7 percent of the river water; England, 1 to 130th; America was allowed more than England due to the greater volumes of the rivers. By 1900, previous treatment before disposal was recommended. Some authorities believed that pretreatment would be mandatory in the future.

Summary of Wastewater Devices and Treatment

Though one would assume that a chronological order could be easily derived for historical home treatment of sewage that is not the case. Evidence is available which shows that as early as 2000 B.C., a flush toilet was engineered for the Palace of King Minos of Knossos. In the centuries following that time there is also evidence of other kings, queens, abbots, and various notables having a more sophisticated method than the pail system. What is not available is the development of background which led to these adoptions or inventions, nor is there any consistent scientific development for them.

In general, it is the home treatment of sewage for the public which is more classifiable into scientific and/or acceptance levels. 1870 is the year which marks the turn away from pit privies and cesspools to flush toilets. Rev. Henry Moule's Earth Closet of 1860 is a side issue to the general trend toward dilution.

A noncomprehensive cataloging of events to the 1890's is as follows. Centralized treatment from 1890 is referenced in many engineering textbooks and is readily available.

Chronological Order of Treatment

First Reference

Deuteronomy 23:12, 13 -- Excreta shall be covered by earth.

Settlements

Early small settlements -- Special places for the reception of refuse or "midden heaps."

Early medium sized settlements -- Human excreta ditches or trenches were dug, later covered with earth, over which a rank vegetation grew. This plan is still followed in the case of temporary camps and in Eastern villages.

Later larger settlements -- Great pits were dug to also receive washing and cooking water. To keep the rain out these were roofed over with beams and earth.

Methods and Systems

600's B.C. Rome -- Seven rivers made by artificial channels served as the sewers. These were built by Torquinius Priscus.

500's B.C. Rome -- The Cloacae Maxima, constructed of cement or concrete, made Rome the first city in the world to have a water-borne disposal method.

800 A.D. Ireland -- Kilkenny Castle toilets were built on an upper floor with slots to deposit the sewage to the street below.

12th Century -- Dukes of Ormond Castle in Kilkenny deposited sewage through slots into the moat.

1200's Ireland -- Blarney Castle had "garderobes" in the tower. A row of toilet seats were cut out of slabs of stone and the short sewer deposited the sewage out the wall to the treetops below.

Methods and Systems (Cont'd)

1594 -- Sir John Harington, an English physician invented a water-closet differing little in essentials from those in use today.

16th Century -- First water-borne sewage system on the North American Continent in Antigua, Guatemala.

1702 Queen Anne's Reign -- A little water-closet with water sluices was installed in Windsor Castle for the use of the Queen.

1833 Paris -- Sewer Systems were started large enough for a man to enter to clean them.

1840's Early Victorian Period -- For houses in isolated positions the cesspool was the only means of sewage disposal.

1847 London -- Compulsory for all houses to be connected to sewers.

1850's The Pail -- Iron or tarred oak pails, capacity under 2 cubic feet, provided with lids, were placed under the seat of the closet; the contents were covered with cinders or ashes and removed at least once a week, a clean pail being substituted.

1850's The Continental Pail -- Collected at night-time, called "night-soil," with or without disinfection, and emptied into ditches or pits.

1850's School Bldg -- A large cemented brick pit was constructed underground and arched over. When a floating guage indicated full, contents were pumped and discharged over cultivated slopes, finally filtering through soil into a moderate-sized reservoir and discharged by mixing with stream water.

1860's Goux-Thulasne or "the Goux" -- Used both in England and Continent. It is a combination of the earth and pail systems. An

Methods and Systems (Cont'd)

iron barrel with conical-shaped, packed dry earth or pulverulent disinfectant was carried round on a dray and left at the houses. After a few days they were collected, shaken, and closed with an air-tight iron lid before removal.

1863 Moule -- Introduced the system of Earth Closets. By a mechanical arrangement on pulling a handle each discharge was covered by a shovelful, about 1½ lbs, of baked dry earth. Process was a deodorizing rather than a disinfecting one.

1870 Towns -- Pollution occurring by crowded cesspools with large areas of soil waterlogged so waste was discharged directly into streams which became open sewers.

1870's Watercloset Towns -- Water use was approximately two gals/flush/person. Water-carriage systems now general in towns. Discharged directly into streams.

1876 The Rivers Pollution Prevention Act -- Permitted the discharge of crude sewage into the sea (even at low water mark) and charged public or private persons should see that "the means used for rendering harmless any sewage matter or poisonous, noxious, or polluting solid or liquid matter falling, or flowing, or carried into any stream are the best or only practicable and available means under the circumstances."

1880's -- Wooden closets built over running streams.

1885-1890 Standards Set -- 1) Privy must be at least 6 feet from any dwelling and 2) that it must be 40 or 50 feet away from any well, spring, or stream.

Methods and Systems (Cont'd)

1890's Rivers -- Thames at London, Seine at Paris, and Irwell at Manchester were so polluted that sludge in bottom emitted visible gas to surface and no fish could live.

1890's Farms in England -- Upper reaches of rivers and streams were contaminated by dairy cattle on farms located above towns.

1890's America -- Prof. G. S. Williams showed typhoid outbreaks related to dredging of river bottom at Detroit.

Historical Toilets

Toilets from 1870 to today have changed very little in concept; that is, the addition of water to flush the contents into a pipe for nontreatment and discharge into a receiving stream or for treatment in a septic tank or sewage works before ultimate disposal by land application or stream discharge. Lawrence Wright's Clean and Decent is the bible for this subject on the design of water-closets up to the 20th Century.

Examples of the fixtures available were:

"Optimus" Valve Closet with or without casing

"Moreton" Chair Enclosure for the "Optimus"

"The Dolphin", 1882

"Mulberry Peach Decoration", 1890

"Blue Magnolia Design", 1895

"Lowdown Suites", 1895

"Epic" Symphonic Closet, 1897

"Closet of the Century", 1900.

A portable water closet "with pump and copper pail" was also available

in 1882. But, the "conservancy" or "pail-and-tub" system of disposal continued into the twentieth century.

Around 1900 came some inventions to combine bathroom equipment. G. Jennings managed to combine a bidet, a footbath, a Sitz bath and a "commode pail" in one reversible double receptable. Adamsez evolved the Patent Concealed Closet Set in 1907 which is a combination water-closet with swinging washbasin above. The Swing Lavatory of 1907 was a similar device with the wash basin mounted on the wall, swinging to the side, above which was a medicine cabinet with mirror and an overhead tank.

Alternative Technological Advances

From the 1900's forward little change has occurred in the removal of waste from the home, even though there has been some movement to limit the quantity of water required per flush. Modern man uses 40 percent of the treated drinking water to flush away the waste to treatment plants. This is the most expensive system ever devised by man, though the flush system accompanied by treatment is undoubtedly responsible for maintaining the health of the developed world.

Reportedly, 70 percent of the world's population does not even have piped water so that they are automatically excluded from use of the flush toilet system. An estimated 5.8 million people in the U.S. do not have sewage or water systems which is startling to those who take it for granted that everyone has it. The World Health Organization estimated that only 8 percent of urban families in Lesser Developed Countries have a sanitary sewage system.

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CHAPTER III

CONVENTIONAL TREATMENT SYSTEMS

CONVENTIONAL COST DATA

Cost data on municipal and/or conventional treatment systems is available in varying amounts dependent upon the particular system, the number of references and the type of costs being sought, (Table 1). Those systems with widespread application such as septic tank, slow sand filter, rapid sand filter, and stabilization ponds have very definite established ranges for each facility. This has been validated in the U.S. and elsewhere (Table 2). The larger, more individual or customized systems, or the higher technology designed facilities have less predictability in: cost--particularly O/M, efficiency, effectiveness, and long range investment liability. Waste stablization ponds are the primary treatment process in use in developing countries at the current time (Table 3).

Preliminary results through conversation with the World Bank show that total system costs are not available for other countries. Facility costs are available for Asia and Africa (Table 4) but the investment requirements for the entire system, i. e., sewerage, house connections, and household plumbing and equipment costs have not been established for the population to be served by the facility. The reasons for this are complex. Financing is done by various methods and sources with the UN providing some of the investment capital in addition to that of the

Table 1.* References by Treatment Process and Continent

Process	Continent or Area: Africa	Asia	Arctic	Australia	Europe	Latin America	Middle East	North America	General	Total
1. General	14	23	2	8	83	13	8	40	31	227
2. Waste Stabiliztion Pond	29	54	3	14	34	14	20	35	42	245
3. Agriculture Utilization	--	2	-	4	70	--	4	1	16	97
4. Combustion	--	---	-	--	2	--	--	---	---	2
5. Disinfection	--	1	-	--	3	--	1	1	1	7
6. Disposal to the Ocean	1	---	-	--	---	3	--	---	---	4
7. Ground Discharge	--	---	-	--	6	--	1	---	3	10
8. Ion Exchange	--	---	-	3	2	--	--	2	---	7
9. Literature Review--Water Pollution	--	---	-	--	---	--	--	---	4	4
10. Primary Treatment--Conventional	1	2	1	1	9	--	1	1	2	18
11. Reverse Osmosis	--	---	-	--	2	--	--	1	---	3
12. Secondary Treatment--Activated Sludge	1	8	-	--	39	--	1	7	3	59
13. Secondary Treatment--Extended Aeration	1	3	3	2	12	1	--	11	2	35
14. Secondary Treatment--High Rate Filter	--	---	-	--	5	--	--	---	1	6
15. Secondary Treatment--Standard Filter	--	1	-	--	12	--	--	---	1	14
16. Septic Tank	--	3	-	--	---	6	--	1	1	11
17. Sludge - Advanced	--	---	-	--	3	--	--	---	---	3
18. Sludge - Conventional	7	5	-	1	10	--	--	---	2	25
19. Sludge - Imhoff	--	---	-	--	---	1	--	---	---	1
20. Tertiary Treatment	--	---	-	--	4	--	--	---	1	5
TOTAL	54	102	9	33	296	43	36	100	110	783

*Canter, L. W., and J. F. Malina, Sewage Treatment in Developing Countries, Global Workshop, Voorburg (The Hague), Netherlands, November 1975.

Table 2.* Treatment Process Applicability to Wastewater Treatment Goals in Developing Countries

Process \ Goal	Current Time Period			Future Time Period						
	Coliform Control	Solids Removal	Oxygen Demand Removal	Coliform Control	Solids Removal	Oxygen Demand Removal	Phosphorus Removal	Nitrogen Control	Sludge Control	Toxicant Control
PS1 Primary - Conventional		x			x					
PS2 Primary - Stabilization Pond	x	x	x	x	x	x				
PS3 Sludge - Conventional									x	
PS4 Sludge - Advanced									x	
PS5 Sludge - Combined Imhoff		x	x		x	x			x	
PS6 Secondary - Standard Filter		x	x		x	x			x	
PS7 Secondary - High Rate Filter		x	x		x	x			x	
PS8 Secondary - Activated Sludge		x	x		x	x			x	
PS9 Secondary - Extended Aeration		x	x		x	x			x	
PS10 Disinfection	x			x						
Agricultural Utilization	x			x						
Ground Discharge	x			x						
Ocean Disposal									x	
Septic Tanks	x	x	x	x	x	x			x	
Tertiary (RO, IX, Combustion)							x	x		x

*Canter, L. W., and J. F. Malina, Sewage Treatment in Developing Countries, Global Workshop, Voorburg (The Hague), Netherlands, November 1975.

Table 3. Estimated Cost of Wastewater Treatment in Asia Using OU-AID and CPHERI Nagpur Studies

Type of Treatment Process	Design Population	Design Flow in MGD	% Cost of Imported Waste Water Dispol Material	Estimate of Mean Construction Cost in $ per capita		Estimate of Mean Operation and Maintenance Cost in $ per capita per yr	
				ASIA OU-AID Study	INDIA Nagpur Study	ASIA OU-AID Study	INDIA Nagpur Study[1]
STABILIZATION LAGOON	5,000	0.15	--	3.27	2.09	0.54	0.32
	10,000	0.30	--	2.81	1.84	0.47	0.25
	50,000	1.50	--	1.99	1.29	0.35	0.17
	100,000	3.00	--	1.71	1.25	0.31	0.14
	200,000	6.00	--	1.48	1.17	0.27	0.12
AERATED LAGOON	5,000	0.15	--	4.00	2.54	1.22	0.69
	10,000	0.30	--	3.59	2.18	1.15	0.60
	50,000	1.50	--	2.79	2.00	0.98	0.48
	100,000	3.00	--	2.50	1.81	0.92	0.44
	200,000	6.00	--	2.25	1.60	0.86	0.40
ACTIVATED SLUDGE	5,000	0.15	25	10.99	--	2.92	--
	10,000	0.30	25	9.00	--	2.17	--
	50,000	1.50	25	5.65	--	1.09	--
	100,000	3.00	25	4.62	--	0.81	--
	200,000	6.00	25	3.79	--	0.61	--
TRICKLING FILTER	5,000	0.15	25	12.09	8.65	3.66	1.89
	10,000	0.30	25	9.55	8.54	2.88	1.55
	50,000	1.50	25	5.51	3.85	2.58	0.86
	100,000	3.00	25	4.33	3.51	2.29	0.70
	200,000	6.00	25	3.43	2.22	1.00	0.51

[1] Low Cost Waste Treatment. Central Public Health Engineering Research Institute, Nagpur, India, 1972.

Table 4. U.S. Wastewater Treatment Cost vs. Developing Countries Wastewater Treatment Cost

		United States[5]		India[6]	
Process	Population	Construction dollars/capita	Operation and Maintenance $ per yr capita	Construction dollars/capita	Operation and Maintenance $ per yr capita
Waste Stabilization Lagoon	5,000	16.56	0.50	2.09	0.32
	10,000	10.89	0.39	1.84	0.25
	50,000	4.11	0.20	1.29	0.17
	100,000	2.70	0.14	1.25	0.14
	200,000	1.78	0.11	1.17	0.12

Source: [5]Smith and Eiler, Cost to Consumer for Collection and Treatment of Wastewater, United States Environmental Protection Agency, July, 1970.

[6]Low Cost Waste Treatment, Central Public Health Engineering, Nagpur, India, 1972.

country and the financial lending institutions. Construction of water and wastewater projects are often tied together with each one servicing a varying population. Financing and construction is done in steps or stages for urban areas with cost estimates sometimes based on a larger population than that which will be initially served. Each additional step or extension is then divided by the same or a portion of the same population already included in the previous estimate. Such estimates have been necessary to obtain approval for projects which would have been economically unacceptable otherwise.

These reasons for the lack of comprehensive data, of course, are not limited to economic development projects in other countries. Cost estimating projects of all forms of public works construction have utilized various projection techniques to improve the feasibility and to secure the acceptance of projects which would have otherwise been fiscally impossible for cities in the U.S. to undertake. Because of the widespread use of such techniques and the multiple forms of financing possible, public works projects in the U.S. have hidden costs which have not been explored to this date. Cost studies have primarily centered on the treatment and sewerage portions, thus not revealing the total encumberance of the public for such projects.

Present Systems Costs

Tremendous volumes of cost data are available on conventional treatment systems. Variations within the publication costs are complex. Developments with the implementation of the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500) have provided us with

unprecented cost data for conventional systems. In the review of the previous cost data available from EPA before the latest publications a comprehensive analyses of conventional treatment costs was impossible. Too much information was missing or categorized in an incomparable manner.

Several excellent documents which supercede previous efforts at analysis of conventional treatment costs have been produced. The first one, A Guide to the Selection of Cost-Effective Wastewater Treatment Systems, provides by diagram the alternative wastewater treatment systems which are capable of achieving the same effluent quality.[3] This guide's main use is to make rough "comparative" analysis during the facilities planning phase. The costs of the systems can then be determined by referring to the unit process cost curves (Figure 2). Prices are based on the February 1973 National Average Wastewater Treatment Plant Cost Index, the Wholesale Price Index for Industrial Commodities, and Labor Costs from EPA and the Department of Labor Statistics Office. A summary of treatment plant construction cost estimates was developed for the unit processes (Table 5) with the requisite alternatives (Tables 6,7, and 8).

Since construction and O&M costs are constantly changing an Appendix is provided where costs equations have been developed with a flexibility that permits changing various economic parameters, e.g., cost indices, labor rate, etc. The desireability for such flexibility in the analysis of conventional treatment alternatives in developing countries has been unavailable in other costing sources. The following table gives price increases based on certain indices[4] (Table 9).

(Figure 2)

AA. PRELIMINARY TREATMENT
Influent: Raw Wastewater

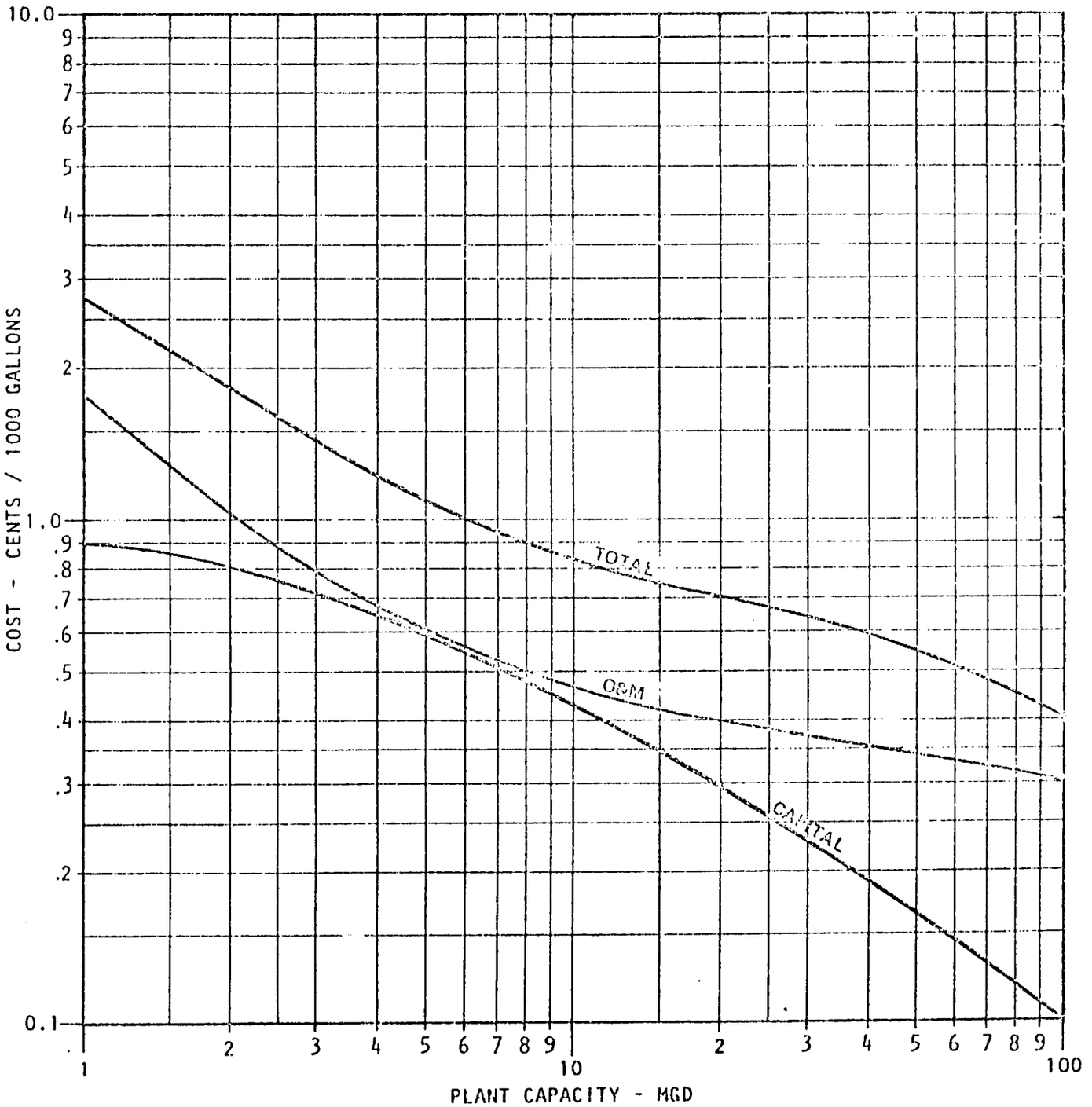


Table 5. Conventional Wastewater Treatment Processes

Treatment Processes	Code
Preliminary Treatment	AA
Pumping	AB
Primary Sedimentation	A-1 thru A-5
Trickling Filter	B-1 thru B-3
Activated Sludge	C-1 thru C-8
Filtration	D
Activated Carbon	E
Two Stage Tertiary Lime	F-1 thru F-2
Biological Nitrification	G-1 thru G-4
Biological Dentrification	H
Ion Exchange	I
Breakpoint Chlorination	J
Ammonia Stripping	K
Disinfection	R

Sludge Handling Processes

Treatment Processes	Code
Anaerobic Digestion	L-1 & L-2
Heat Treatment	M-1 & M-2
Air Drying	N-1 & N-2
Dewatering	O-1 thru O-9
Incineration	P-1 thru P-7
Recalcination	Q-1 thru Q-3

TABLE 6. SUMMARY OF TREATMENT PLANT CONSTRUCTION COST ESTIMATES

Treatment Category[1]	Att. No.	Unit Processes by Alternative	Estimated Cost ($ Million) at Design Flow Rate (mgd)[3]			
			1	5	20	100
1	1	AA, AB, A-1, C-1, R, O-5, L-1	2.06	3.73	9.05	34.4
	2	AA, AB, A-1, C-1, R, P-6, O-8, M-1	2.67	5.13	11.7	38.7
	3	AA,AB,A-1,C-1,R,O-1,P-1	2.53	4.97	11.5	38.7
	4	AA,AB,A-1,C-1,R,O-1,P-5	2.36	4.58	10.7	36.7
	5	AA,AB,A-1,B-1,R,L-1,N-1	1.63	3.54	9.79	40.2
	6	AA,AB,A-1,B-1,R,L-1,O-5	1.84	3.50	8.81	34.1
	7	AA,AB,A-1,B-1,R,O-8,P-6	2.42	4.90	11.4	38.4
	8	AA,AB,A-1,B-1,R,O-1,P-1	2.30	4.74	11.3	38.4
	9	AA,AB,A-1,B-1,R,O-1,P-5	2.14	4.35	10.4	36.4
1	-	Mean Cost (Alternatives 1 to 9)	2.22	4.38	10.5	37.3
2	1	AA,AB,A-3,R,C-2,O-4,P-4	2.70	5.32	12.3	35.8
	2	AA,AB,A-3,R,B-2,Q-2,O-4	2.36	4.63	10.7	36.0
	3	AA,AB,A-3,R,B-2,O-4,P-4	2.50	5.10	12.0	35.0
3	1	AA,AB,A-1,C-1,F-2,R,O-5,L-1	2.70	4.61	10.8	41.0
4	1	AA,AB,A-2,G-4,R,O-3,P-3	3.22	5.29	12.1	41.3
5	1	AA,AB,A-2,G-4,H,R,O-3,P-3	3.56	5.90	13.7	48.2
6	1	AA,AB,A-2,G-4,H,O,R,O-3,P-3	3.97	7.09	16.7	56.8

Notes: [1]Treatment categories from Table 2.

[2]For unit process codes, see Tables 8 and 9.

[3]Estimated using cost equations from Table B-1 of "A Guide to the Selection of Cost Effective Wastewater Treatment Systems" (EPA 430/9-75-002), March 1975, an STP Index of 263, and a 20% surcharge for site work and buildings .

Table 7. Influent of Conventional Wastewater Treatment Unit Processes

AA. Preliminary Treatment
Influent: Raw wastewater

AB. Raw Wastewater Pumping
Influent: Effluent from AA

A. Primary Sedimentation
Influent: Effluent from AA or AB
- A-1 Conventional
- A-2 Two-Stage Lime Addition
- A-3 Single Stage Lime Addition
- A-4 Alum Addition
- A-5 $FeCl_3$ Addition

B. Trickling Filter
- B-1 Influent: Effluent from A-1
- B-2 Influent: Effluent from A-3
- B-3 Influent: Effluent from A-4 or A-5

C. Activated Sludge
- C-1 Conventional
  Influent: Effluent from A-1
- C-2 Conventional
  Influent: Effluent from A-3
- C-3 Conventional
  Influent: Effluent from A-4 or A-5
- C-4 Alum Addition
  Influent: Effluent from A-1
- C-5 $FeCl_3$ Addition
  Influent: Effluent from A-1
- C-6 High Rate
  Influent: Effluent from A-1
- C-7 High Rate & Alum Addition
  Influent: Effluent from A-1
- C-8 High Rate & $FeCl_3$ Addition
  Influent: Effluent from A-1

D. Filtration
Influent: Effluent from A-2, B-2, B-3, C-2, C-3, C-4, C-5, F-1 or F-2 G-1, G-2, G-3, G-4, H, J, K

E. Activated Carbon
Influent: Effluent from D

F. Two-Stage Tertiary Lime Treatment
- F-1 Influent: Effluent from B-1
- F-2 Influent: Effluent from C-1

G. Biological Nitrification
- G-1 Influent: Effluent from C-6
- G-2 Influent: Effluent from B-1
- G-3 Influent: Effluent from A-3, A-4 or A-5
- G-4 Influent: Effluent from A-2,C-7 or C-8

H. Biological Denitrification
Influent: Effluent from G-1, G-2, G-3 or G-4

I. Ion Exchanges
Associated with A-2, B-2, B-3, C-2, C-3, C-4, C-5, F-1, or F-2

J. Breakpoint Chlorination
Influent: Effluent from A-2, B-1, B-2, B-3, C-1, C-2, C-3, C-4, C-5, F-1 or F-2

K. Ammonia Stripping
Influent: Effluent from F-1 or F-2

R. Disinfection
Influent: Effluent from any treatment process

Source: "A Guide to the Selection of Cost Effective Wastewater Treatment Systems" (EPA 430/9-75-002, March 1975)

Table 8. Influent of Sludge Handling Unit Processes

L. Anaerobic Digestion
- L-1 Sludge Influent: Generated from A-1+B-1, C-1 or C-6
- L-2 Sludge Influent: Generated from A-1+C-4, or C-5, or C-7, or C-8, A-4+B-3 or C-3, A-5+B-3 or C-3

M. Heat Treatment
- M-1 Sludge Influent: Generated from A-1+B-1, C-1 or C-6
- M-2 Sludge Influent: Generated from A-1+C-4 or C-5, or C-7, or C-8, A-4+B-3 or C-3, A-5+B-3 or C-3

N. Air Drying
- N-1 Sludge Influent: Effluent Sludge from L-1
- N-2 Sludge Influent: Effluent Sludge from L-2

O. Dewatering
- O-1 Sludge Influent: Generated from A-1+B-1, C-1 or C-6
- O-2 Sludge Influent: Generated from A-1+C-4 or C-5, or C-7, or C-8, A-4+B-3 or C-3, A-5+B-3 or C-3
- O-3 Sludge Influent: Generated from A-2
- O-4 Sludge Influent: Generated from A-3+B-2 or C-2
- O-5 Sludge Influent: Effluent Sludge from L-1
- O-6 Sludge Influent: Effluent Sludge from L-2
- O-7 Sludge Influent: Generated from F-1 or F-2
- O-8 Sludge Influent: Effluent Sludge from M-1
- O-9 Sludge Influent: Effluent Sludge from M-2

P. Incineration
- P-1 Influent Sludge: Effluent Sludge from O-1
- P-2 Influent Sludge: Effluent Sludge from O-2
- P-3 Influent Sludge: Effluent Sludge from O-3
- P-4 Influent Sludge: Effluent Sludge from O-4
- P-5* Influent Sludge: Effluent Sludge from O-7+O-1
- P-6 Influent Sludge: Effluent Sludge from O-8
- P-7 Influent Sludge: Effluent Sludge from O-9

Q. Recalcination (includes chemical storage & feeding)
- Q-1 Sludge Influent: Effluent Sludge from O-3
- Q-2 Sludge Influent: Effluent Sludge from O-4
- Q-3 Sludge Influent: Effluent Sludge from O-7

Source: "A Guide to the Selection of Cost Effective Wastewater Treatment Systems" (EPA 430/9-75-002, March, 1975)

Common Terms and Some Costs From the Guide

"Total cost for each unit process comprises the sum of the capital, operating and maintenance costs." Capital costs included construction amortized over 20 years at 5-5/8 percent, structures equipment, pumps and integral piping, and appurtenances described or implied by the unit process, land requirements at $2000/acre, and engineering, contingencies, and interest during construction at 27 percent. O&M costs included annual average equivalent of O&M Costs at 100 percent utilization throughout the life of the plant, and all material costs, including chemicals, power and fuel, and other materials. Capital costs are trended at the National Average Wastewater Treatment Plant Cost Index of 177.5 for February 1973. Materials are at the Wholesale Price Index for Industrial Commodities of 120.0 for February 1973. Labor cost, including allowance for fringe benefits, was taken at $5.00 per hour.

Land application treatment costs have been developed in a series of three document: Design Factors - I, Design Factors - II, and Case Histories.[5] Five of the most well known case histories of land application of municipal wastewater are presented. Costs associated with land application are as follows: Advanced Waste Treatment Alternatives (AWT), Land Treatment Alternatives (L), and Costs of Spray Irrigations Systems.

An Analysis of Construction Cost Experience for Wastewater Treatment Plants is based on the grant eligible cost data for over 150 treatment plants constructed in the last four years.[6] Costs in the Analysis were

Table 9. Price Index Trends

Index	Price Index	Percent Increase Over Preceding Year			
Bureau of Labor Statistics Wholesale Prices and Price Index	June 1972	June 1973	June 1974	June 1975	June 1976
General Purpose Machinery and Equipment	122.7	3.7	17.3	19.4	6.6
Pumps & Compressors	124.2	2.8	15.7	26.8	5.7
Electrical Machinery & Equipment	110.6	1.9	7.0	16.4	3.6
Motors, Generators	123.3	4.5	7.0	26.6	8.9
Chemical Engineering					
Plant Cost	136.5	5.9	14.0	9.7	6.2
Equipment, Machinery	135.4	5.0	20.8	12.3	6.5
Engineering & Supervision	111.9	16.0	2.3	5.9	7.5
	4th quarter 1972	4th quarter 1973	4th quarter 1974	4th quarter 1975	2nd quarter 1976
Marshall & Swift Equipment Cost Index	336.7	3.8	10.5	16.7	4.0
Survey of Current Business	June 1972	June 1973	June 1974	June 1975	June 1976
Dept. Commerce Construction Cost Composite Index	137	10.2	14.6	9.8	4.7
American Appraisal Co. Construction Cost Ave. 30 cities	1357	11.3	5.5	6.5	7.3
Atlanta	1545	13.5	4.3	2.2	5.9
Boeckh Construction Cost Index	May 1972	June 1973	June 1974	May 1975	May 1976
Ave. 20 cities - Commercial & Factory Buildings	144.2	7.7	12.2	7.7	9.3
Engineering News Record	June 1972	June 1973	June 1974	June 1975	June 1976
Construction Cost	1726.15	13.6	3.8	11.1	6.2
Building Cost	1038.43	9.5	8.3	6.9	7.5
Engineering News Record	Labor Cost Indexes				
Common Labor	3437.63	8.5	6.2	13.1	5.8
Skilled Labor	1629.94	5.8	7.1	7.9	7.6
Bureau of Labor Statistics Employment & Earnings					
Contract Construction	$5.97	6.4	5.0	7.6	5.8
Special Trade Construction	6.42	2.2	8.8	5.9	5.3
Electrical Work	7.02	6.0	4.0	6.3	8.1

adjusted to include 20% for site work and updated from 1973. The comparison established that bid costs are 1 to 2.5 times higher than cost predicted. Thus less economy of scale is shown by the bid data than has been previously assumed because of the cost escalation (Table 10).

The market place is found to limit accurate quantification from the type of unit processes or the required effluent quality. Previous cost data publications had failed to address this problem (Table 11). Factors which any specific wastewater treatment plant are subject to included such things as:

The standard design requirements

Conventions of engineering practice and procedures

Construction and supplier market competition

Cost as a controlling parameter in design, techniques, and procedures

Timeliness of construction

Site conditions

Local labor and material costs

The following cost curves are a best fit of extremely variable data points and might require adjustment for a specific project (Figure 3).

Small Community Cost

Summarizing from the EPA in Washington the results of their survey of towns under 50,000 population in the summer of '76 indicated the following:

"258 facility plans for 49 states were analyzed. The results indicate that operation and maintenance plus debt retirement of the local share for recommended new facilities will cost in excess of $100 per household in 40% of the communities and $200 per household in 10%.

Table 10. Cost Escalation Factors Between Treatment Category One and Specified Treatment Category for Selected Alternatives

Treatment Category[1]	Selected Alternative[2]	Cost Escalation from Treatment Category One to Specified Category[3]					
		Design Flow Rate (mgd)				Average	Factor Used
		1	5	20	100		
1	1	1.00	1.00	1.00	1.00	1.00	1.00
2	1	1.31	1.43	1.36	1.04	1.28	1.20
3	1	1.31	1.24	1.20	1.19	1.23	1.23
4	1	1.56	1.42	1.34	1.20	1.38	1.38
5	1	1.73	1.58	1.52	1.40	1.56	1.56
6	1	1.92	1.90	1.85	1.65	1.83	1.83

Notes: [1]Treatment categories from Table 9.

[2]Alternatives as specified by "Alternative Number" in Table 6.

[3]Ratio of estimated construction at specified treatment category to that at Treatment Category 1, at each flow rate.

TABLE 11. IMPORTANT 1976 COLLECTION SYSTEM CHARACTERISTICS OF AGENCIES STUDIED *

Agency[a]	Population	Miles of Sewer	Population per Mile	Annual Sewer Line Cost, $ per Mile	Number of Lift Stations	Installed Pump Horsepower	Millions of Kilowatt-hrs Consumed
A	10,000	29	345	185	5	52	0.0239
B	36,685	128	287	297	5	220	0.120
C	43,000	153	281	910	22	1390	0.608
D	84,700	337	251	521	5	16	0.006
E	89,200	360	248	839	26	565	N/A
F	309,000	1211	255	469	48	3112	4.0
G	383,000	1600	239	2444	57	1997	1.93
H	557,000	1450	385	674	13	N/A	N/A
I	728,400	1355	538	1370	5	855	0.491
Limits of Values Lower to Upper	10,000 to 728,400	29 to 1600	239 to 538	185 to 2444	5 to 57	16 to 3112	0.006 to 4.0

a. Agencies ranked according to population.

N/A - - Not available

*Brady, Goodman, Kerri, and Reed."Per formance Indicators for Wastewater Collection Systems", Present.. at the 50th Annual Conference Water Pollution Control Federation, Philadelphia, PA, October 2-7, 1977.

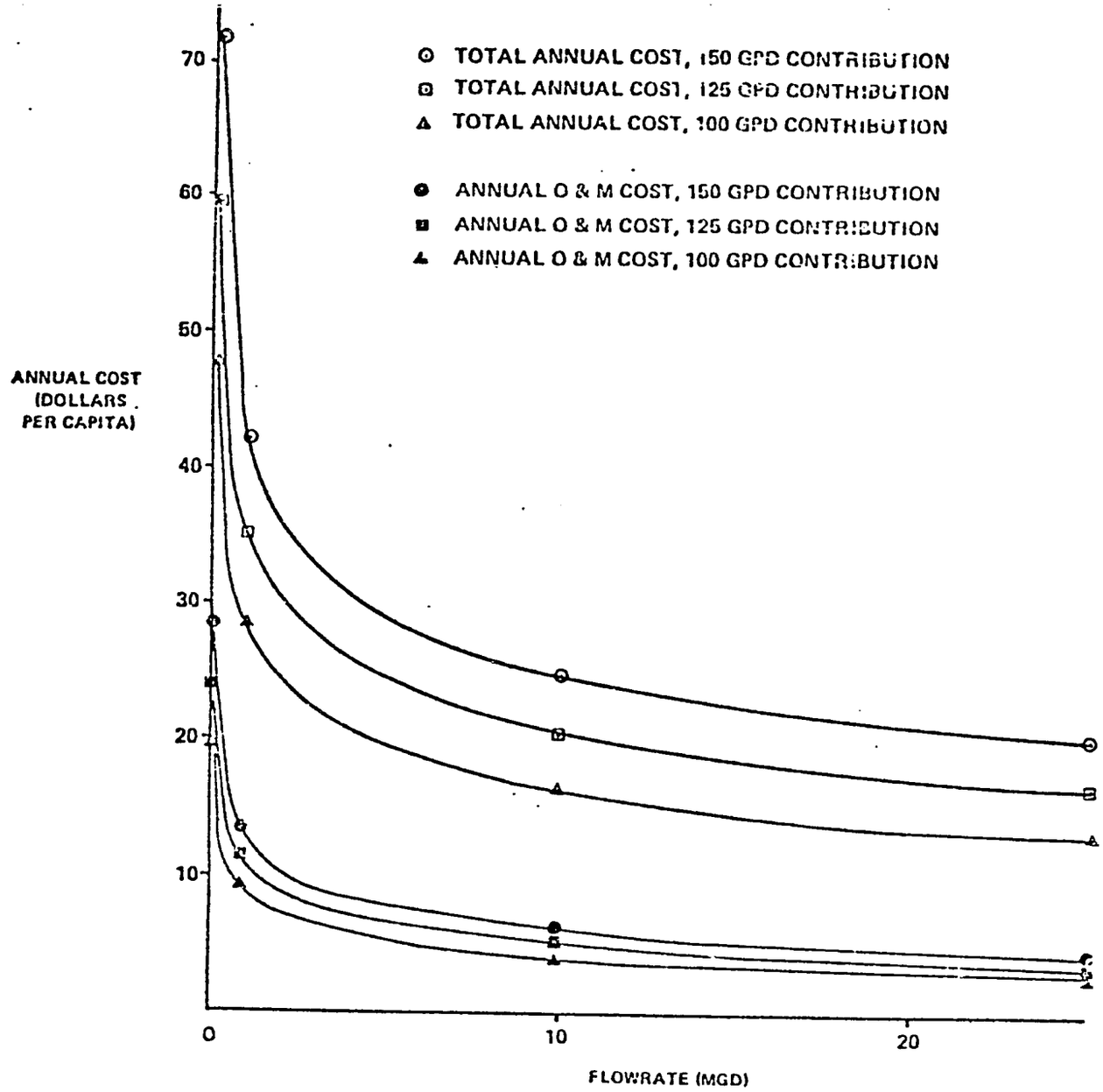


Figure 3. Annual Costs vs. Plant Size

Costs exceeded $300 per household per year in several cases. Communities under 10,000 population experienced much higher costs on, the average than larger communities."

This meant to the householder in a small town that the sewage portion alone of his monthly bill from the city could run in the neighborhood of $12-20. J. Timothy Winneberger, an expert in the field of sewage treatment from California, stated at the National Conference in April 1977, that some of their small towns in California had experienced costs amounting to almost $30 per month. A mayor of a small midwestern town who also spoke at the same conference said he had worked very hard to get a new facility for his town. It turned out that the cost was so high -- one electric bill in the winter was $2000 -- that his own mother-in-law refused to connect her house to the sewer line.

The costs of operation and maintenance with conventional systems have been ignored in the budgets of smaller communities for years. There has been a failure to recognize the necessity of making such an allowance as well as the lack of money and resources to meet such needs. Consideration of the annual O&M costs which is now required in Facility Plans for new construction has led to the rejection of new facilities in many instances. It is apparent that mechanical activated sludge facilities have significantly higher O&M costs than those of plants using other treatment processes. Such costs cannot be met with limited resources. Other than stablization ponds the relative economy at 1.0 MGD is more than 60% higher for all other secondary processes.[8]

In a review for the National Conference the following O&M costs were from 1300 inspections and adjusted to 1976 dollar levels. The following small system costs are only O&M costs (Table 12). The annual O&M cost for a facility with a contributing population equivalent of 1000 persons and a 100 gal per capita per day flow is $18.61 per person per year; the cost for a population equivalent of 100,000 is $4.07 per person per year. Similarly the O&M "present worth" costs were compared with capital costs for Activated Sludge Facilities (Table 13). Results also showed the relationship between training expenditures for both BOD & TSS removal tests and O&M inspection ratings (Figure 4).

Cost-Effectiveness Experienced in the US

With the implementation of PL 92-500, the Water Pollution Control Act, the experiences of small communities has not been good. In citing reasons during the National Conference in April, EPA officials listed future increases in water damand (from 30 billion gallons to 55 billion gals/yr for US households), waste of water (from using 13,000 gals of fresh drinking quality water per year to carry away 165 gals of body waste), the costs experienced (from the application of conventional systems up to $30 per month per user rates with averages of $12 to $20 in the smaller communities for sewage charges alone), and the millions of unserved citizens (19.5 million US households are presnetly without public utility sewage service). Comparing these reasons to the needs of the rural majority in developing countries the application of conventional treatment systems would be prohibative.

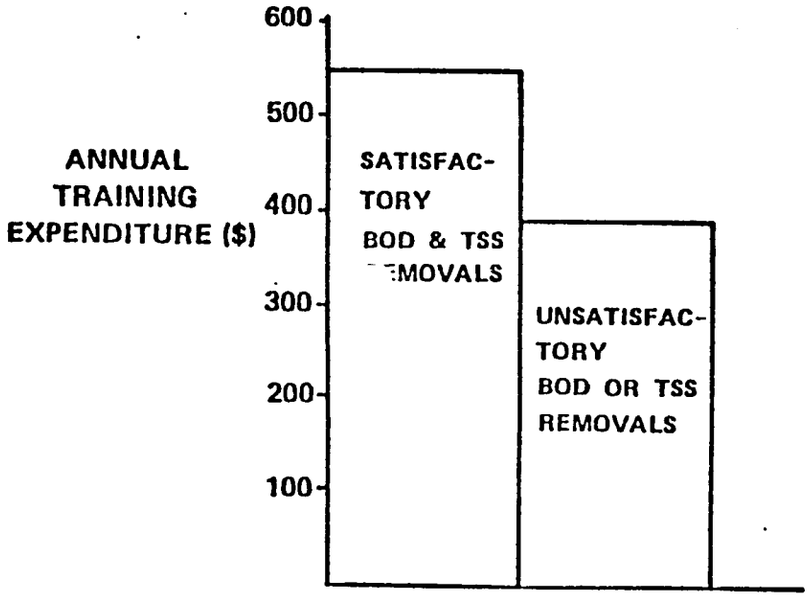
The cost of conventional systems surveyed in 1976 by EPA showed much higher costs on the average for communities under 10,000

Table 12. Operation and Maintenance Costs for Small Municipal Wastewater Treatment Facilities

Wastewater Treatment Process	ANNUAL O&M COST ($1000)	
	Avg. Daily Flow of 0.1 MGD	Avg. Daily Flow of 1.0 MGD
PRIMARY	11.6	58.5
TRICKLING FILTER	12.5	61.5
EXTENDED AERATION	18.0	66.7
ACTIVATED SLUDGE	18.6	87.0
STABILIZATION PONDS	11.2	38.1

Table 13. Comparison of O&M "Present Worth" Costs with Capital Costs for Activated Sludge Facilities

Design Flow Rate	Present Worth of Capital Cost (in millions of dollars)	Present Worth of O&M Cost (in millions of dollars)
.1 MGD	.323	.406
.5 MGD	1.226	1.193
1.0 MGD	2.140	1.899



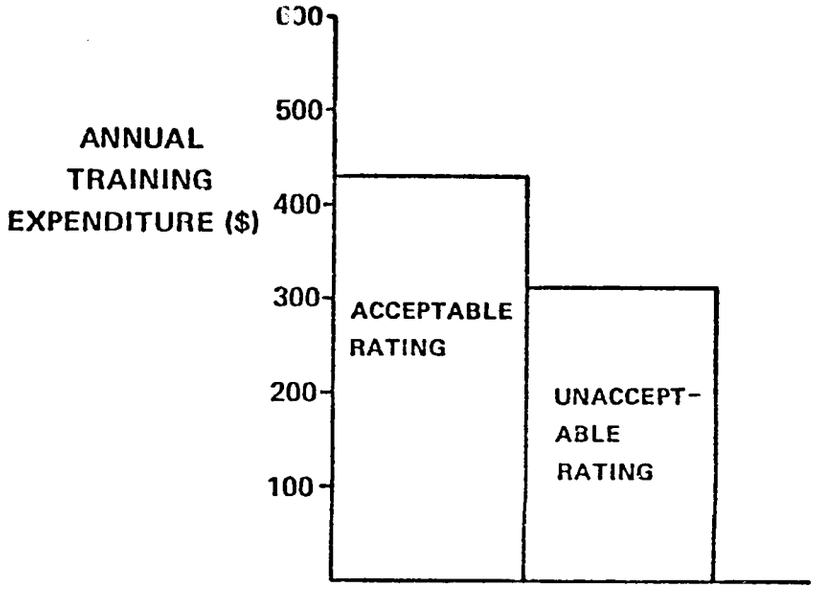


Figure 4. Training Costs vs. Plant Operating Efficiencies
(AVERAGE FLOW LESS THAN 1.0 MGD)

population. Of 8000 facility plans submitted in 1976, 4600 of these were for smaller communities. The number of plans has always exceeded 50 per cent from small communities. Of the facility plans funded the costs in some cases exceeded $300 per household per year which is over 2.3% of the $13,000 annual income of the median family. The annual income of the median family in smaller communities is usually less then the $13,000 national median.

Fault for the high cost was not attached to any particular government entity, but rather the failure to analyze the alternatives of non-sewered systems in the facility plans even where it was potentially cost-effective[9] (Figure 5).

Environmental Impact Statements

Since passage of the Environmental Protection Act of 1969, federal agencies have been required to prepare environmental impact statements (EIS's) for federally financed developments. Court rulings since the enactment of the law have established the necessity for community hearings, environmental impact assessments (EIA's) or preimpact statements, and preparation by the federal agency of the statement. Currently the U.S. Environmental Protection Agency is attempting a new scheme called "Piggyback EIS" for municipal water and wastewater facilities in an effort to facilitate handling of EIS statements later. Piggyback is a combined assessment and impact statement in which USEPA officials work concurrently with municipal officials and consulting engineers to assure the appropriateness of EIA's, to reduce the cost of additional assessments or reassessments for municipal governments, and to reduce the

federal register

Figure 5.

Title 40—Protection of the Environment

CHAPTER I—ENVIRONMENTAL PROTECTION AGENCY

SUBCHAPTER D—GRANTS

PART 35—STATE AND LOCAL ASSISTANCE

Appendix A—Cost-Effectiveness Analysis

On July 3, 1973, notice was published in the FEDERAL REGISTER that the Environmental Protection Agency was proposing guidelines on cost-effectiveness analysis pursuant to section 212(2)(c) of the Federal Water Pollution Act Amendments of 1972 (the Act) to be published as appendix A to 40 CFR part 35.

Written comments on the proposed rulemaking were invited and received from interested parties. The Environmental Protection Agency has carefully considered all comments received. No changes were made in the guidelines as earlier proposed. All written comments are on file with the agency.

Effective date.—These regulations shall become effective October 10, 1973.

Dated September 4, 1973.

JOHN QUARLES,
Acting Administrator.

APPENDIX A

COST EFFECTIVENESS ANALYSIS GUIDELINES

a. *Purpose.*—These guidelines provide a basic methodology for determining the most cost-effective waste treatment management system or the most cost-effective component part of any waste treatment management system.

b. *Authority.*—The guidelines contained herein are provided pursuant to section 212 (2)(C) of the Federal Water Pollution Control Act Amendments of 1972 (the Act).

c. *Applicability.*—These guidelines apply to the development of plans for and the selection of component parts of a waste treatment management system for which a Federal grant is awarded under 40 CFR, Part 35.

d. *Definitions.*—Definitions of terms used in these guidelines are as follows:

(1) *Waste treatment management system.*—A system used to restore the integrity of the Nation's waters. Waste treatment management system is used synonymously with "treatment works" as defined in 40 CFR, Part 35.905-15.

(2) *Cost-effectiveness analysis.*—An analysis performed to determine which waste treatment management system or component part thereof will result in the minimum total resources costs over time to meet the Federal, State or local requirements.

(3) *Planning period.*—The period over which a waste treatment management system is evaluated for cost-effectiveness. The planning period commences with the initial operation of the system.

(4) *Service life.*—The period of time during which a component of a waste treatment management system will be capable of performing a function.

(5) *Useful life.*—The period of time during which a component of a waste treatment management system will be required to perform a function which is necessary to the system's operation.

e. *Identification, selection and screening of alternatives*—(1) *Identification of alternatives.*—All feasible alternative waste management systems shall be initially identified. These alternatives should include systems discharging to receiving waters, systems using land or subsurface disposal techniques, and systems employing the reuse of wastewater. In identifying alternatives, the possibility of staged development of the system shall be considered.

(2) *Screening of alternatives.*—The identified alternatives shall be systematically screened to define those capable of meeting the applicable Federal, State, and local criteria.

(3) *Selection of alternatives.*—The screened alternatives shall be initially analyzed to determine which systems have cost-effective potential and which should be fully evaluated according to the cost-effectiveness analysis procedures established in these guidelines.

(4) *Extent of effort.*—The extent of effort and the level of sophistication used in the cost-effectiveness analysis should reflect the size and importance of the project.

f. *Cost-Effective analysis procedures*—(1) *Method of Analysis.*—The resources costs shall be evaluated through the use of opportunity costs. For those resources that can be expressed in monetary terms, the interest (discount) rate established in section (f)(5) will be used. Monetary costs shall be calculated in terms of present worth values or equivalent annual values over the planning period as defined in section (f)(2). Nonmonetary factors (e.g., social and environmental) shall be accounted for descriptively in the analysis in order to determine their significance and impact.

The most cost-effective alternative shall be the waste treatment management system determined from the analysis to have the lowest present worth and/or equivalent annual value without overriding adverse nonmonetary costs and to realize at least identical minimum benefits in terms of applicable Federal, State, and local standards for effluent quality, water quality, water reuse and/or land and subsurface disposal.

(2) *Planning period.*—The planning period for the cost-effectiveness analysis shall be 20 years.

(3) *Elements of cost.*—The costs to be considered shall include the total values of the resources attributable to the waste treatment management system or to one of its component parts. To determine these values, all monies necessary for capital construction costs and operation and maintenance costs shall be identified.

Capital construction costs used in a cost-effectiveness analysis shall include all contractors' costs of construction including overhead and profit; costs of land, relocation, and right-of-way and easement acquisition; design engineering, field exploration, and engineering services during construction; administrative and legal services including costs of bond sales; startup costs such as operator training; and interest during construction. Contingency allowances consistent with the level of complexity and detail of the cost estimates shall be included.

Annual costs for operation and maintenance (including routine replacement of equipment and equipment parts) shall be included in the cost-effectiveness analysis. These costs shall be adequate to ensure effective and dependable operation during the planning period for the system. Annual costs shall be divided between fixed annual costs and costs which would be dependent on the annual quantity of wastewater collected and treated.

(4) *Prices.*—The various components of cost shall be calculated on the basis of market prices prevailing at the time of the cost-effectiveness analysis. Inflation of wages and prices shall not be considered in the analysis. The implied assumption is that all prices involved will tend to change over time by approximately the same percentage. Thus, the results of the cost effectiveness analysis will not be affected by changes in the general level of prices.

Exceptions to the foregoing can be made if their is justification for expecting significant changes in the relative prices of certain items during the planning period. If such cases are identified, the expected change in these prices should be made to reflect their future relative deviation from the general price level.

(5) *Interest (discount) rate.*—A rate of 7 percent per year will be used for the cost-effectiveness analysis until the promulgation of the Water Resources Council's "Proposed Principles and Standards for Planning Water and Related Land Resources." After promulgation of the above regulation, the rate established for water resource projects shall be used for the cost-effectiveness analysis.

(6) *Interest during construction.*—In cases where capital expenditures can be expected to be fairly uniform during the construction period, interest during construction may be calculated as $I \times \frac{1}{2} P \times C$ where:

I=the interest (discount) rate in Section f(5).
P=the construction period in years.
C=the total capital expenditures.

In cases when expenditures will not be uniform, or when the construction period will be greater than three years, interest during construction shall be calculated on a year-by-year basis.

(7) *Service life.*—The service life of treatment works for a cost-effectiveness analysis shall be as follows:

Land	Permanent
Structures (includes plant buildings, concrete process tankage, basins, etc.; sewage collection and conveyance pipelines; lift station structures; tunnels; outfalls)	30–50 years
Process equipment (includes major process equipment such as clarifier mechanism, vacuum filters, etc.; steel process tankage and chemical storage facilities; electrical generating facilities on standby service only).	15–30 years
Auxiliary equipment (includes instruments and control facilities; sewage pumps and electric motors; mechanical equipment such as compressors, aeration systems, centrifuges, chlorinators, etc.; electrical generating facilities on regular service).	10–15 years

Other service life periods will be acceptable when sufficient justification can be provided.

Where a system or a component is for interim service and the anticipated useful life is less than the service life, the useful life shall be substituted for the service life of the facility in the analysis.

(8) *Salvage value.*—Land for treatment works, including land used as part of the treatment process or for ultimate disposal of residues, shall be assumed to have a salvage value at the end of the planning period equal to its prevailing market value at the time of the analysis. Right-of-way easements shall be considered to have a salvage value not greater than the prevailing market value at the time of the analysis.

Structures will be assumed to have a salvage value if there is a use for such structures at the end of the planning period. In this case, salvage value shall be estimated using straightline depreciation during the service life of the treatment works.

For phased additions of process equipment and auxiliary equipment, salvage value at the end of the planning period may be estimated under the same conditions and on the same basis as described above for structures.

When the anticipated useful life of a facility is less than 20 years (for analysis of interim facilities), salvage value can be claimed for equipment where it can be clearly demonstrated that a specific market or reuse opportunity will exist.

[FR Doc.73-19104 Filed 9-7-73;8:45 am]

work load of USEPA officials in the final review.

Cost of EIA's very greatly depending upon time, location, topography, etc. Apparently the number of or size of facilities is not the governing factor. It is the size of the community which is the most influential in determining the cost. EIA's are bid contracts with consulting engineering firms, usually with previous experience in environmental impact preparation. A thumbnail estimate based upon a 1MGD/10,000 pop with one or more facilities is as follows:

Community	Cost (1976)
25,000 - 35,000 population	$25,000 - $40,000
Higher for Metroplex	$80,000 -$250,000

These statements generally includes collection systems, major interceptors, archeological studies, etc. A recent EIA for the assessment of Norman, Oklahoma's proposed four lift stations cost $24,000, including an estimate on future impact to the present system. Thus, a varied, individual cost is possible.

The major problem with environmental impact statement preparation has been to identify on which projects such statements are going to be required. In other words to prepare a full EIS on every project contemplated or funded would virtually slow or stop development. So, officials have evolved the EIA concept to establish basic information with which to judge the necessity for an EIS. Statements have been known to be many thousands of pages long, even several feet thick, and to still be inadequate by court and community or conservation group opinion. Piggyback EIS's will aid in the final evaluation of when to prepare a formal EIS.

Alternate Disposal Techniques

Various means are being explored as alternatives for disposal of sewage once it has been collected. Two of these presently under study of the USEPA are:

1. Aquaculture - The use of sewage as a fish food.
2. Land Application: Spray Irrigation, Overland flow, and Rapid Infiltration - The deposit of sewage on land to increase fertility of crops. These crops have usually been lower in the food chain than that intended for human consumption.

Some difficulties are being experienced in both methods. Metals appear to aggregate in aquaculture disposal to the higher predatory fish which have the highest consumption of sewage thus eliminating them as a potential human food source. So, the cost-effectiveness is reduced with the inability to market them for food. Conservationists are in opposition to the various land application techniques because of land availability and the metal and minerals present in the wastewater other than human sewage. This opposition is due to the industrial contribution in central collection systems and to the inability to control access to sewerage systems. Environmental assessments procedures will also slow this land disposal effort reducing its effectiveness in the next few years.

Grinder pumps offer homeowners greater options in locating his septic tank. These could also be useful in areas when ecology and terrain don't permit the convenience of a gravity-flow sewage-transport system. U. S. list price: $1500 for the simplex and $3100 for the duplex models. Low pressure sewer systems could also offer significant cost advantages for

collections systems under certain circumstances. This would only be a remedy rather than an overall solution to sewerage problems since treatment is still needed at the other end.

The J.P.L. system is a new cost-saving sewage treatment process derived from NASA space research. Trial of the system is in progress in Pasadena, Calif. Key to the JPL system is a pyrolytic reactor that converts solid sewage material to activated carbon which in turn treats the incoming wastewater. It is expected to exceed EPA standards for ocean dischange and to reduce capital costs by 25 percent as compared with conventional processing systems.

The wet transfer system utilizes a grinder to mix the household refuse with sewage. A recent study by Curran Associates, "An Assessment of Wet Systems for Residential Refuse Collection: Summary Report", suggests that the wet transport of such a combination would be technologically feasible and convenient, but more expensive than the conventional method of collecting and transporting refuse by touch. A cost analysis of the two systems suggests that the wet transport system is uneconomical for present wide-scale application, while (Tables 14 and 15) lesser skilled manpower are employable and transportation costs are not excessive. Turnover rates in household refuse collections approach 90% or higher in urbanized areas while water departments have rates to 20% and wastewater departments turnover rates may be slightly higher to 30%. Rural community turnover rates are very much lower in all areas.

Table 14. COMPARATIVE ANNUAL COSTS PER HOUSEHOLD FOR CONVENTIONAL AND WET TRANSPORT SYSTEMS, BY SIZE OF POPULATION AND REFUSE GENERATION RATE*

Item	Total system cost range	
	Conventional sytem†	Wet system
Population size‡		
50,000	$57-115	$132-196
100,000	52-110	126-184
500,000	43-101	113-160
Refuse generation rates§		
1.02 kg	43-101	113-160
1.53 kg	45-103	126-172
2.04 kg	47-105	134-181

*Source: Curran Associates, "A Preliminary Assessment of Wet Systems for Residential Refuse Collection," EPA Contract No. 68-03-0183 (March, 1974), p. 152.

†Includes the usual costs for sewage collection and sludge handling and assumes incineration of refuse.

‡A generation rate of 1.02 kilograms per capita per day is assumed.

§Kilograms per capita per day are for a population of 500,000.

Table 15. COMPARATIVE ANNUAL COSTS PER HOUSEHOLD FOR CONVENTIONAL AND WET TRANSPORT SYSTEMS, SPRINGFIELD SMSA*

Item	Cost	
	Conventional system	Wet transport system
Refuse collection	$17.50	$2.50†
Bulky refuse collection	1.00	2.00
Disposal‡	3.50	1.00
Sewer maintenance	2.00	6.00-9.00§
Grinding	—	80.00-105.00
Treatment	9.00	12.50
Sludge handling	5.50	8.50
Sludge disposal	0.75	2.00
Annual Total	39.25	114.50-142.50π

*Source: Curran Associates, "An Assessment of Wet Systems for Residential Refuse Collection: Summary Report," EPA Contract No. 68-03-0183 (March, 1974), p. 80. Data are 1973 price estimates for Springfield, Massachusetts.

†Collection of nongrindables only.

‡Assumes landfill of refuse.

§Assumes one flushing per year. If four flushings are required, the cost would rise to $24 to $36.

πExcluding the grinder system costs, total costs would be $34.50 to $37.50.

CHAPTER IV

STATE OF THE ART

SEWERLESS TREATMENT SYSTEMS AND WATER REDUCTION DEVICES

Available Systems

The necessity for an evaluation of the sewerless system alternatives has been more than justified by the accumulated experiences with conventional systems. Use of water as the disposal or removal medium has led to realization of the fact that a reduced flow and treatment or substitute medium will reduce disease incidences. In addition it could provide an opportunity to accelerate the socio-economic growth of conditions in the LPC's. If sewerless systems can be viewed as alternatives in Developed Countries then would they not prove even more beneficial in the developing ones.

> The difficult challenge is to find a workable alternative. In a publication entitled "Stop the Five Gallon Flush!" the Minimum Cost Housing Group at McGill University's School of Architecture in Montreal examined systems from around the world that are designed for home use, and catalogued 52 of them from 11 countries. In their evaluation, the group steered clear of thinking of the modern flush toilet as "advanced," compared to a technology such as the pit latrine. As the researchers point out, "under certain conditions the latter is ecologically sound, cheap and quite safe."
>
> Smithsonian Magazine, May, 1975

At the present time on-site sewage treatment technology primarily utilizes septic tank (or anerobic) treatment of household wastewater. Because of the availability of septic systems, their proven acceptance, and the financing of such systems by lending institutions, this type of treatment is widespread. Introduction of septic tanks by public health

educators and sanitarians is common whenever public water supplies are extended especially in areas where central collection is impractical or infeasible.

Intermediate Technology

Another level of technology in wastewater disposal has been developing (or accumulating) in the past few years which cannot be ignored in any state-of-the-art documentation. The technology itself is not new but the techniques are, especially since their collection. Without wishing to appear disparaging these new techniques could be described as "do-it-yourself" kits for in country application.

Formally called "intermediate technology" the disposal methods being proposed are actual innovations of alternate treatment disposal methods, utilizing local materials, in on-site construction. (10) Graphically, this new level might be described as occurring between containment and treatment (Figure 6).

Technical Considerations	Disposal Methods	Economical Considerations
Low	Non-treatment Primitive Containment	Non funded
Medium	Intermediate Technology Lower Cost Methods On-site sewerless treatment	Partially funded
High	Sewerage - Non-Treatment Conventional Treatment	Major Expenditures

Figure 6. Levels of Treatment Technology

One of the major advantages with this intermediate technology is in cost. Typically, each unit has averaged $30-50 without labor in the Tanzania applications. Composting, aqua privies, and water basin discharge for flushing are part of the many disposal methods included in the intermediate category.

Botswana application of intermediate technology may have higher costs per unit than Tanzania. The $100,000 funded project is only 2/3rds complete so averages are not yet available. Local materials were used in both Tanzania and Botsuana, such as, elephant grass, ferro cement, thin and narrow concrete bricks. Costs for materials are higher though in Botswana. Preliminary results from these two projects have demonstrated the vertical vent is the key to fly control.

One successful unit which has been reported, Roec Latrine, is an inclined shaft into a trench with the vertical vent. Another successful unit, adapted to Moslem culture, allows moslems to use water in cleaning themselves. Called the Utafiti it replaced a Clivus-Multrum. It has an open bottom to filter in to sub-surface for removal of excess moisture (which would limit applications to dry areas. Innovations available in the Clivus (detailed in the Advanced Systems Section of this chapter) now include a drain pipe for liquid removal and double walls with insulation for reduction of condensation.

The recent bibliography on Wastewater in Developing Countries for the World Bank by Michael McGarry, et al, Ottawa, Canada, has also established data on a vacuum truck and vault system through Taiwan, Korea,

and Japan which is operating at 1/10 the cost of sewerage systems.[12]

Disadvantages with the intermediate technology may rest with the adaptations and adoptions by local residents and the diffusion of the technology to other geographical and socio-cultural areas. It appears in some instances that the principles governing this development are similiar to (and may utilize) in-country application of wastewater disposal technique from U.S. Peace Corps Volunteer and other technical assistance experiences.

Alternatives to the Typical Subsurface Disposal System

"Many factors must be weighed when considering alternative methods or improvements to waste disposal systems. Soils information and percolation tests indicate the probability of success or failure of a subsurface tile system.....Alternative to be discussed include: utilization of two subsurface disposal fields (Figure 7) , individual lagoons (Figure 8), above ground mounds (Figure 9), recirculating sand filter (Figure 14), aerobic digester units, holding tanks, recirculating toilets, composters, and incinerating units." Many of these use Water. John H. Armstrong, Considerations for Designing and Improving Individual Sewage Disposal Systems, Ok State Health Dept, et al. 1976.

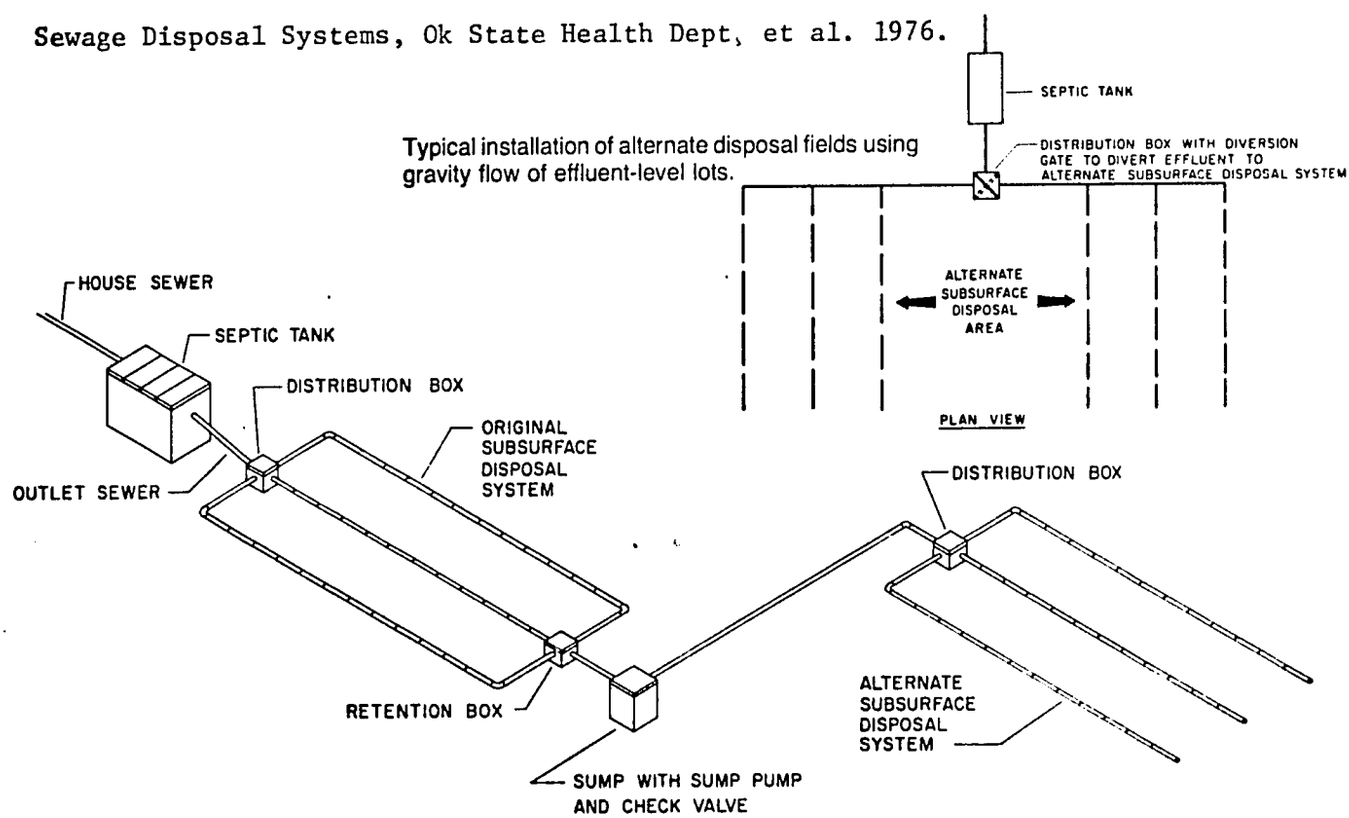
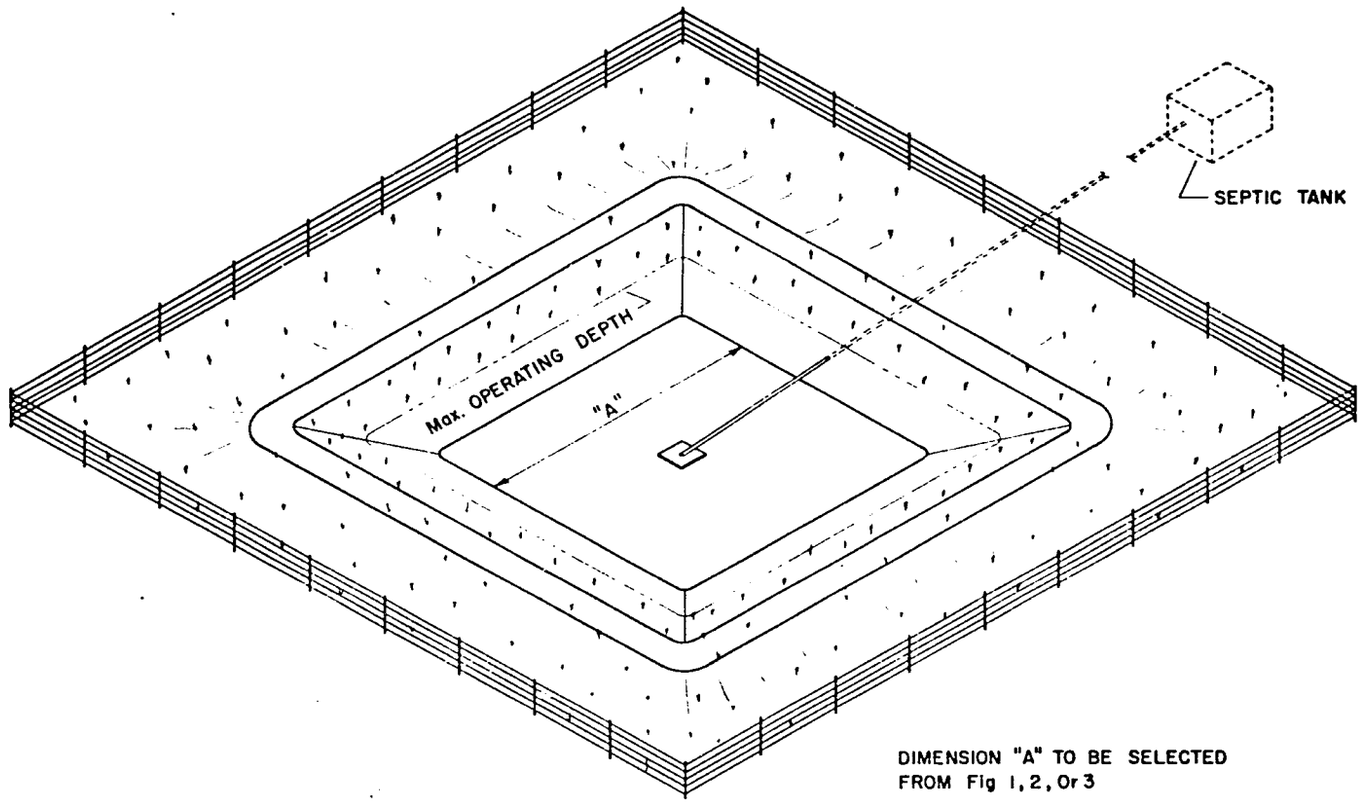


Figure 7. Alternate subsurface disposal fields



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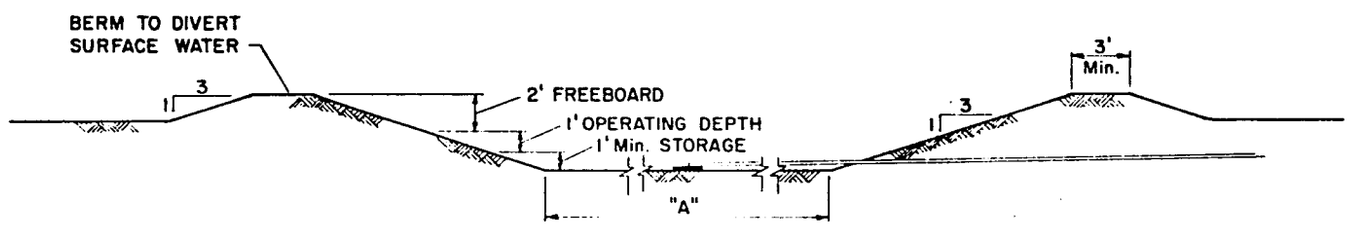


CROSS-SECTION

Figure 8. Individual Sewage Lagoon

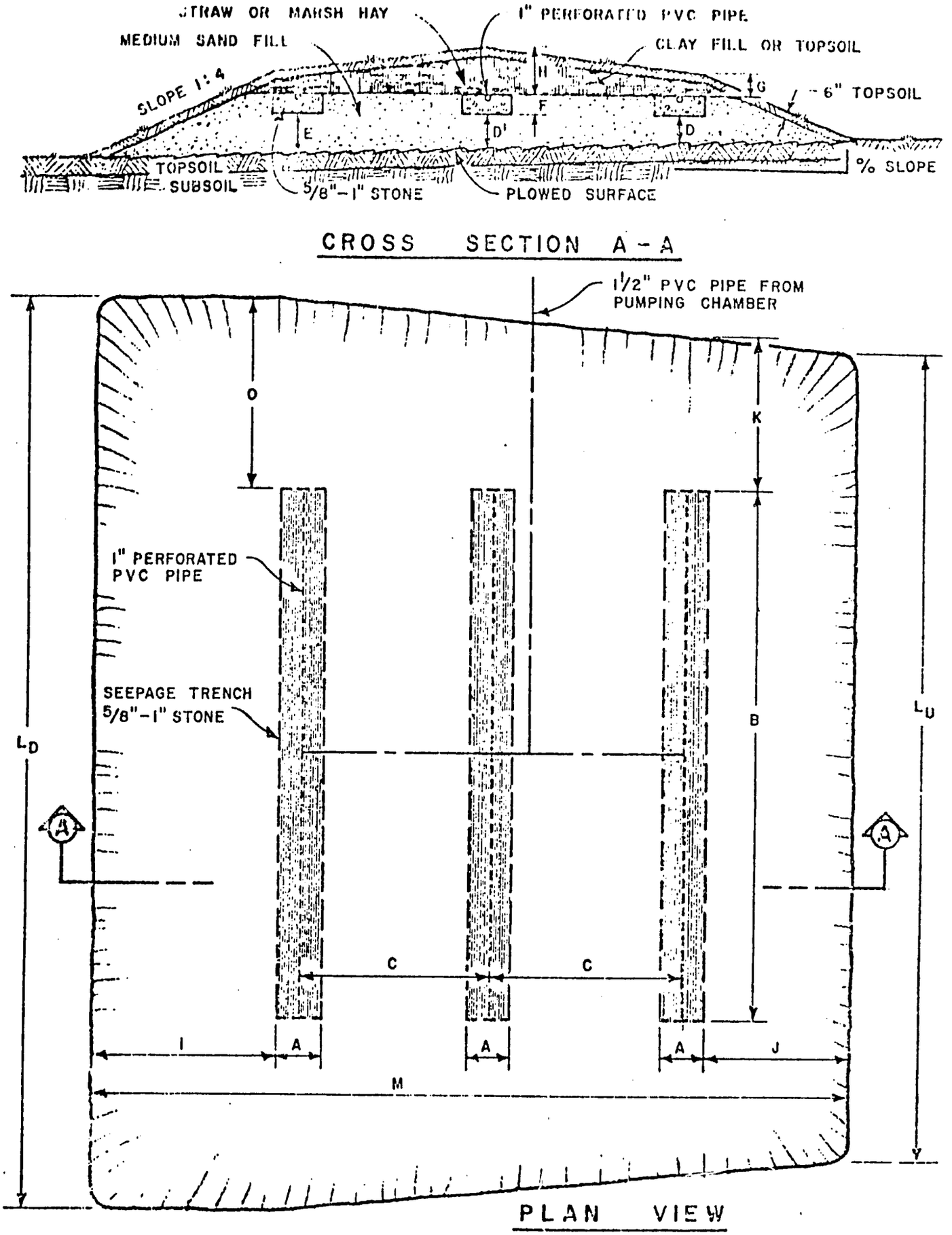
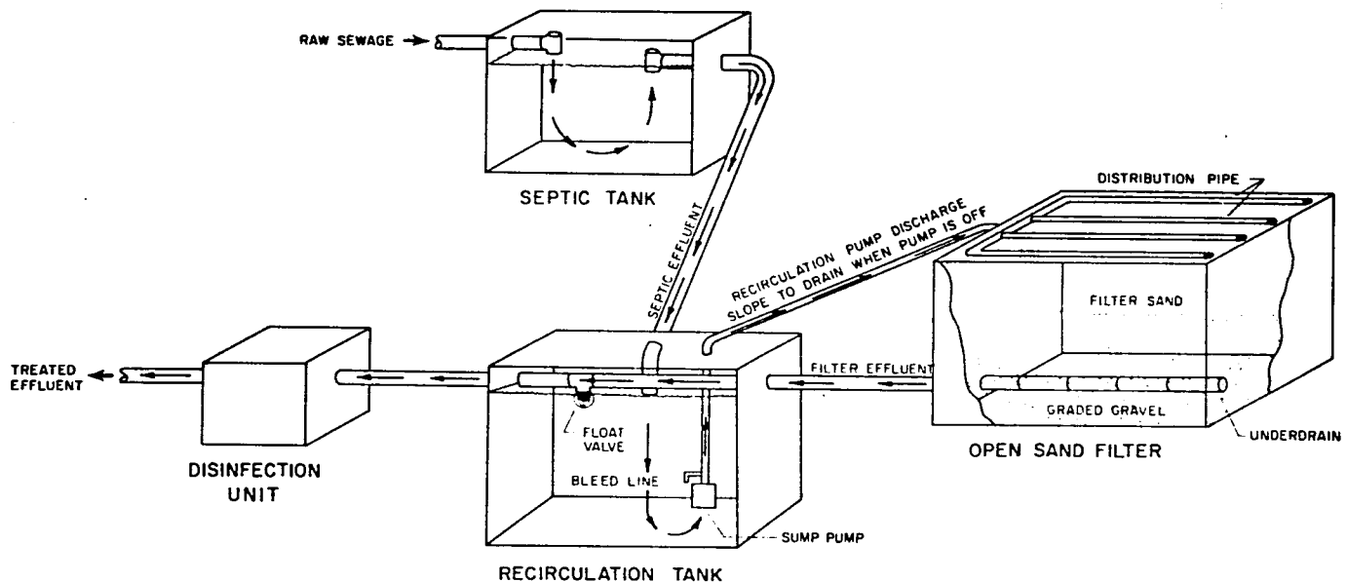


Figure 9. Mound System for a 3 or 4 Bedroom Home



Schematic layout of typical recirculating sand filter sewage treatment system

Figure 10. Recycling Sand Filter

ADVANCED SYSTEMS

Advanced methods of sewerless treatment have been classified into five categories: incinerating toilets, biological toilets, composting toilets, vacuum systems, and aerobic tanks. A sixth category, the oil flush toilets, also seems applicable with the increased application of them in remote areas. An ever expanding list of manufacturers are supplying and promoting units in these categories. The attached list details a number of th presnetly available systems.

A major concern which has been expressed about sewerless treatment is the energy requirement. Units within any of the six categories have varying energy requirements dependent on the climate, their capacity, and specific treatment process. The composting variety can be operated without electricity in some instances.

The major advantages in sewerless systems, with the exception of the aerobic tanks, is the decrease in water consumption. By US standards this would equal approximately 30-40% of domestic use. Some other advantages and characteristics are as follows. Composting toilets produce a humus product suitable for fertilizer. Incinerating toilets destroy the waste material leaving an inert ash residue. Most of the toilets can be installed in existing dwellings. Two of the composting toilets do require two stroy structures or raised dwellings.

All five of these sewerless categories (Table 16) again with the

Table 16

Manufacturers of Some Available Sewerless Devices and Systems 1975-76

Type	Figure	Brand Name	Manufacturer
Incinerating	11	Carefree V (Incinolet)	Research Products/Blankenship 2639 Andjon, Dallas, Texas 75220 Area Code (214) 358-4238
Incinerating	12	Xpurgator II	RSC Industries, Inc. 245 West 74th Place, Hialeah, Florida 33014 Area Code (305) 685-6825
Incinerating	13	Destroilet	La Mere Industries Walworth, Wisconsin 53184 Area Code (414) 275-2171
Incinerating		Envirovac	Colt Industries Beloit, Wisc. 53511 Area Code (608) 364-4411
Mineral Oil	14	The Magic Flush Toilet	Monogram Industries, Inc. 1165 East 230 th St. Carson, California 90745 Area Code (213) 775-7777
Mineral Oil	15	Aqua Sans	Babcock & Wilcox Barberton, Ohio
Composting	16	Clivus Multrum	Clivus Multrum USA Organic Waste Treatment System 14A Eliot St. Cambridge, Mass 02138 Area Code (617) 491-5820
Oil-Based Fluid	17	Sarmax	Sarmax Corporation Los Angeles, California

Manufacturers (Cont'd)

Type	Figure	Brand Name	Manufacturer
Minimum Water	18	Microphor	Microphor, Division of Harrah Indus. 475 East San Francisco Ave. P. O. Box 490, Willits, CA 95490 Area Code (707) 459-5563
Vacuum Collection System	19	Airvac	Airvac, Vacuum Sewage Transport & Collection, P. O. Box 508, Rochester, Indiana 46975 Area Code (219) 223-3980
Marine	20	Vacu-flush	Mansfield Sanitary, Inc. 150 First St., Perrysville, OH 44864 Area Code (419) 938-5211
Marine	21	Lectra/San	Raritan Engineering Co. 1025 North High St., Millville, Millville, N. J. 08332 Area Code (609) 825-4900
Collective	22	Incerator	Incerator Systems Corp. 520 E. 72nd New York City, N.Y. 10021 Area Code (212) 249-6836

exception of the aerobic tanks and non-treatment methods, need a gray water disposal system for total wastewater treatment. Gray water is the discharge water from the bath, kitchen, and laundry which usually contains soaps, fats, and virus from the skin and clothes.

DESCRIPTION OF WASTE PROCESSING METHODS

Incineration of waste is a newer development based upon the destruction of human waste. It represents a waterless, sanitary method which produces an inert ash that is easily disposed with no detrimental environmental effect. Three units manufactured or to be manufactured in the USA have been previously evaluated by CIVENGRLAB, the Naval Civil Engineering Laboratory, Port Hueme, California. The U.S. Navy, Army, and Marines have all performed research evaluations. Over 15,000 units are now in operation in the U.S.

Biological processing consists of the addition of chemicals to liquify the solid waste, inhibit biological decomposition, and colorize the liquid. These type of toilets are currently used in commercial passenger planes. The system uses very little water and wastes must be disposed of ultimately. Electric power is also required.

Composting as a method for decomposition of animal and human waste to provide fertilizer has been in practice for centuries, especially in India and China. In its present form a fiberglass container is used to catch the waste together with additions of garbage. Air is circulated through the mass and in some circumstances manual stirring is required and heat is added in order to maintain a normal temperature range or to speed up processing. The waste is eventually reduced to about 10% of the original

volume and can be removed by a door in the lower portion of the container. Difficulty with this method is experience when the system is overtaxed or the bio-organisms are killed off. The fertilizer is high in nitrogen and suitable for use in a varing time frame dependent on the particular device. The largest and most successful marketed composting device is the Clivus Maltrum from which teh waste product is usually ready in approximately two years for removal. Some difficulty has been experienced with improperly emplaced heating and wiring systems required for operation in cold climates.

The aerobic systems combine the traditional flush toilet with aerobic decomposition rather than anaerobic or septic tank treatment. These systems may or may not be recirculating ones but the principle is to aerate the liquid aiding decomposition before injection into a tile field. In the recirculating systems odors develop when the system is overused or not used for a few days. These aerobic devices have been very successful in the replacement of septic systems which have failed because of soil conditions.

The vacuum systems have the advantage of requiring very little water for unit operation, about 1 quart. This system was developed in 1957 in Sweden and overcomes the gravity flow problems in the centralized collection systems. Sewage could be transported up to 640 feet away horizontally and 16 feet vertically away to a collection tank if desirable. Both the vacuum and pressure collection systems have been suggested for the central areas of small towns.

Oil base type methods have also been examined by CIVENGRLAB previously.

Available units have been manufactured in the USA only at this time. This system consists of a non-water soluble fluid being substituted in a water-tight tank which recirculates in one or more toilets after a separation process. Eventual breakdown of the liquid occurs after one year or sooner dependent upon use. Some color problems have been experienced in the otherwise odorless and colorless fluid. The National Park Service was also sued when a vacationer slipped on the liquid which had splashed out of a trial unit. The recirculating fluid toilets are now in operation at several national parks.

Incineration Toilet (Incinolet) (Figure 11)

Incinolet uses heat alone to reduce human waste, both solids and urine, to inorganic, odorless and bacterial-free ash. All models are equipped with a blower which is locked electrically with the heater. The blower is always on when the heater is on. Both heater and blower are actuated simultaneously. After the heater cuts off, the blower stays on until the incinerator chamber cools to room temperature. Moisture and other vapors driven off during incineration are vented to the atmosphere by the blower and vent line. The blower is integral with the unit. Residual ash is accumulated in an ashpan located at the bottom of the unit which is emptied once or twice monthly. To use the incinerating toilet, a wax-vapor liner is utilized to carry the water from the bowl to the incinerator chamber. The liner prevents the waste from contacting the bowl surfaces. The user drops the liner into the bowl prior to use. After use, the incinolet is flushed by stepping in the foot pedal. The incineration cycle is actuated by the flushing action.

A catalytic odor control device is associated with the heater. The catalyst, when heated, causes the odor molecules to degenerate into other type molecules. Incinolet Carefree IV is Research Products' newest model: new incineration configuration, 60% more catalytic odor control section, higher heavy-gauge stainless steels and nickel alloys in unit's exterior and interior incineration chambers.

Screening-Incineration Unit (RSC Xpurgator) Figure 12

Cost: $2,000

The unit is developed and designed mainly to treat the human body waste. It involves the steps of moving the sewage to a filtration area. Solids are removed by deposit on a moving porous medium through which the aqueous medium passes to a filtered liquid accumulator. The porous medium carries the deposited solids through a thermal chamber where the deposited materials are destroyed.

The Xpurgator system filters, sanitizes and recirculates flushing water, separates solids and destroys them thermally without odors or fumes. Fluids are automatically controlled and excess fluids are also thermally vaporized. All fluids are chemically disinfected and deodorized.

The Xpurgator II system is built to provide maintenance-free operation. The only service required is infrequent removal of ash from the ash receptacle conveniently located at the side of the unit.

Incineration Toilet (Destroilet) Figure 13

The Destroilet is an incinerator enclosed in a functional housing. It disposes of wastes by way of a gas flame that operates automatically only after the lid has been closed. It has the ability to accomodate the toilet facilities needs of 12 people for up to approximately 60 individual uses per day.

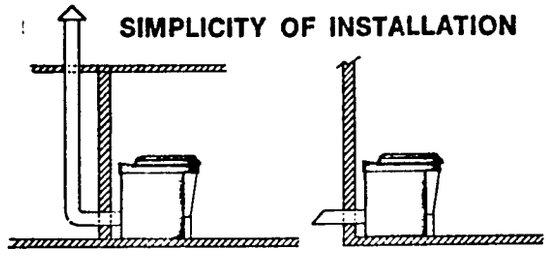


Figure 11

1. Bolt unit to floor.
2. Install ventline.
3. Connect unit to electric power.
4. Put up Bowl-liner Holder with bowl liners inside.

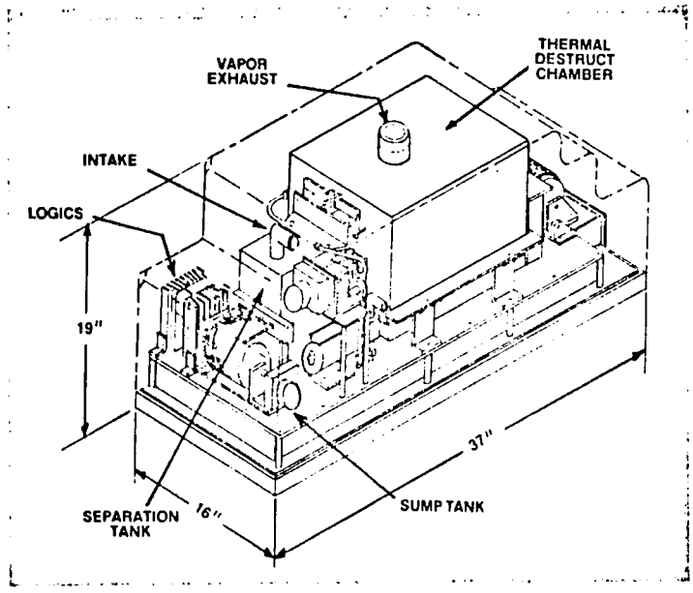
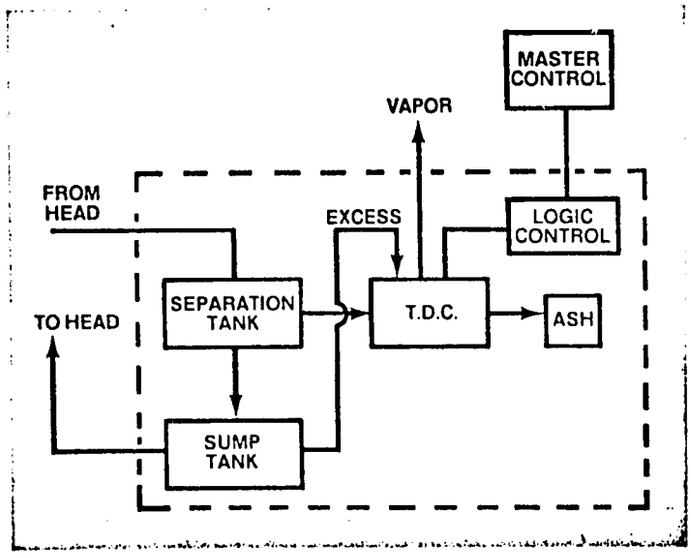


Figure 12



Operation of the Destroilet is automatic. Rising the seat winds the timer, lifts the heat shield and actuates a forced draft system which draws air through the lid, allows the timer to begin its cycle, lower the heat shield, and starts the burner.

The timer controls the cycle, which consists of two phases; a burn cycle followed by a cool down cycle.

Destroilets operate on either Natural or L.P. Gas. Installation amounts to simply connecting the gas supply pipe, attaching an outside standing vent, and connecting a source of electricity. Residential models require either 115 or 220 - 240 Volt A. C. household line current and mobile models require 12 Volt D. C. battery current.

Incinerating (Envirovac)

Cost: Over $800

Mineral Oil (The Magic-Flush Toilet - Monogram) (Figure 14)

Cost: 1975 - $3,000; 1976 projected - $2,000

The U. S. Forest Service Equipment and Development Center in San Dimas, California, after more than a year of testing, has installed its first sewerless flushing toilets in nearby Angeles and San Bernardino National Forests. More installations in other parts of California are scheduled for this fall and early spring (Table 17).

This sewerless system, called Magic Flush, was developed by Monogram Industries, Venice, California. It looks and works like a home toilet, but it uses no water. Instead, a clear, odorless, mineral-derived liquid flushes the bowl. The nonreactive fluid looks like water, but unlike water, can be used over and over again. Repeated use of the fluid is made possible by a simple purifier that is part of the underground holding tank

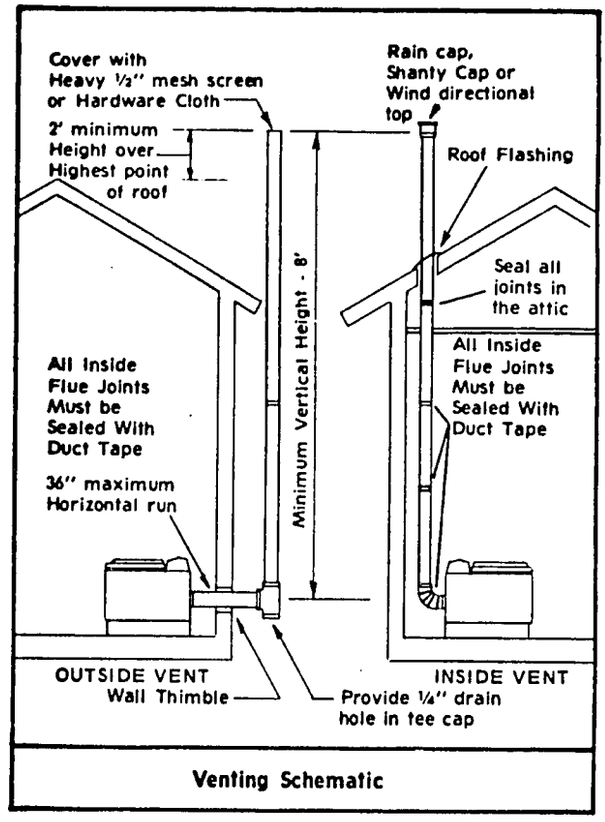
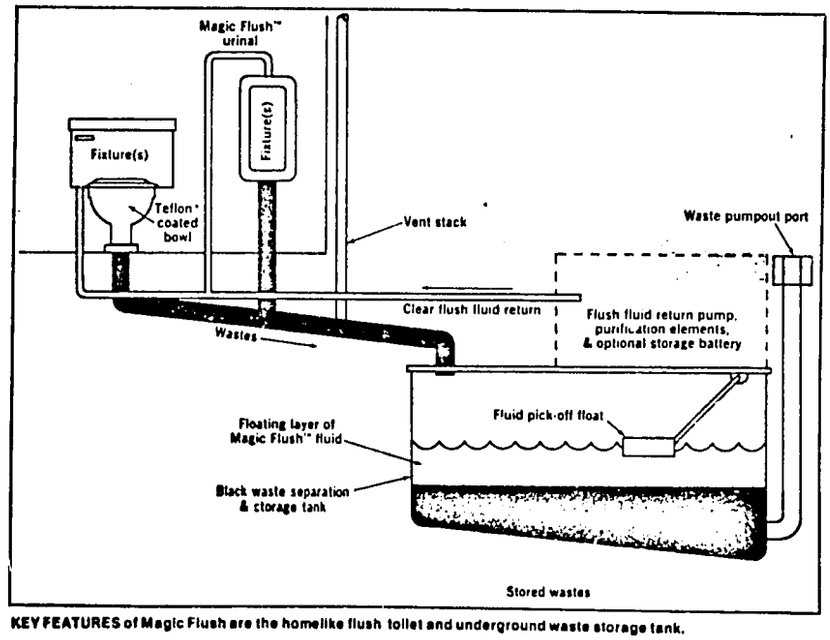


Figure 13



KEY FEATURES of Magic Flush are the homelike flush toilet and underground waste storage tank.

Figure 14

Table 17

Magic Flush Installations

The following is a list of existing and scheduled Magic Flush Installations.

1. Sequoia National Forest - Six 2 fixture units at Princess Campground.

2. Rocky Mountain National Park, U.S.D.I., Estes, Colorado - 16 fixture restroom located at the Alpine Visitors Center.

3. Tahoe National Forest, U.S.D.A. - 4 fixture unit located at Dark Day Boat Ramp parking lot.

4. West Point Military Academy, New York - 1 fixture unit on a firing range.

5. State of California, Dept. of Parks and Recreation, Perris Lake, Riverside, California - Five 4 fixture installations with cabanas located on an island in a drinking water reservoir.

6. Armco Steel, Middletown, Ohio - Three 4 fixture facilities located at Armco's employee recreational park and golf course.

7. Mono-Inyo National Forest, U. S. Forest Service, Rock Creek Project - Eight 2 fixture facilities located throughout the park.

8. Knollwood, Los Angeles County, Los Angeles, California golf course - One 3 fixture unit located between 13 green and 14 tee.

9. DuPont Corporation , Beaumont, Texas - 1 fixture facility for an office.

10. Natural Gas Pipeline, Kermit, Texas - 1 fixture facility at a pipeline pumping station. Forerunner to multiple installations along various pipelines.

11. National Park Service, U.S.D.I., Lake Meredith, Amarillo, Texas - One 2 fixture unit with cabanas.

12. National Park Service, U.S.D.I., Buffalo National River, Arkansas - One 2 fixture unit with cabanas.

13. Carey Salt Company Mine, Hutchinson, Kansas - Underground vault and storage where classified documents are processed and stored. One 4 fixture facility located 500 feet underground for employee use.

14. Angeles National Forest, U. S. Forest Service, Chilao Flats - Two 2 fixture facilities at a campsite.

15. San Bernardino National Forest - Initial test unit for the U.S. Forest Service, Jenks Lake - 4 fixture unit for a recreational lake area.

16. Plumas National Forest - Quincy, California - 2 fixture facility at a park ranger station.

17. Centralia, Illinois - 4 fixture facility at a boat ramp access area for a local lake.

18. Town of Coventry, Connecticut - 1 fixture facility. The initial installation for a total community project which surrounds a lake.

19. National Park Service - U.S.D.I., Hubbard Trading Post, Granado, New Mexico. One 2 fixture unit with cabanas.

20. Oak Hill Country Club - Richester, N.Y. 1 fixture facility at golf course.

(see diagram). Gravity carries waste from toilet to tank where it stays until a truck hauls it away.

Because there is no power source available at present Magic Flush installations, a small, 3½-hp., 30-a. gas generator is used. It periodically charges the 12-v. batteries that operate the system.

Recirculation Oil Flush Unit (Chrysler Aqua-Sans Systems) (Figure 15)

Cost: $4000

The Chrysler Aqua-Sans systems are designed to use oil as the flushing medium. The density of the oil is some 17% less than that of human waste, permitting gravity separation. It is immiscible with the waste and chemically stable under the operating conditions and in the presence os human waste.

The human waste is received in a standard commode, flushed with the oil to the separation tank where it is separated and from which it is transferred to a waste collector. A two-stage incinerator renders the waste into an acceptable condition for disposal. The separated oil is filtered, lightly chlorinated, and returned to the heads. Four models are available for capacities at 600 gpd, 1500 gpd, 5000 gpd, and 10,000 gpd. A system schematic is shown in Figure 15.

Waste is transferred by the flush liquid from the commodes to the separation tank where the solids are separated and settled in the sump while the flush fluid rises to the top due to the differences in density of oil and waste. The flush fluid rises, passing through a coalescer which remove entrained urine, and then flows over a weir through a bag filter into the second stage tank.

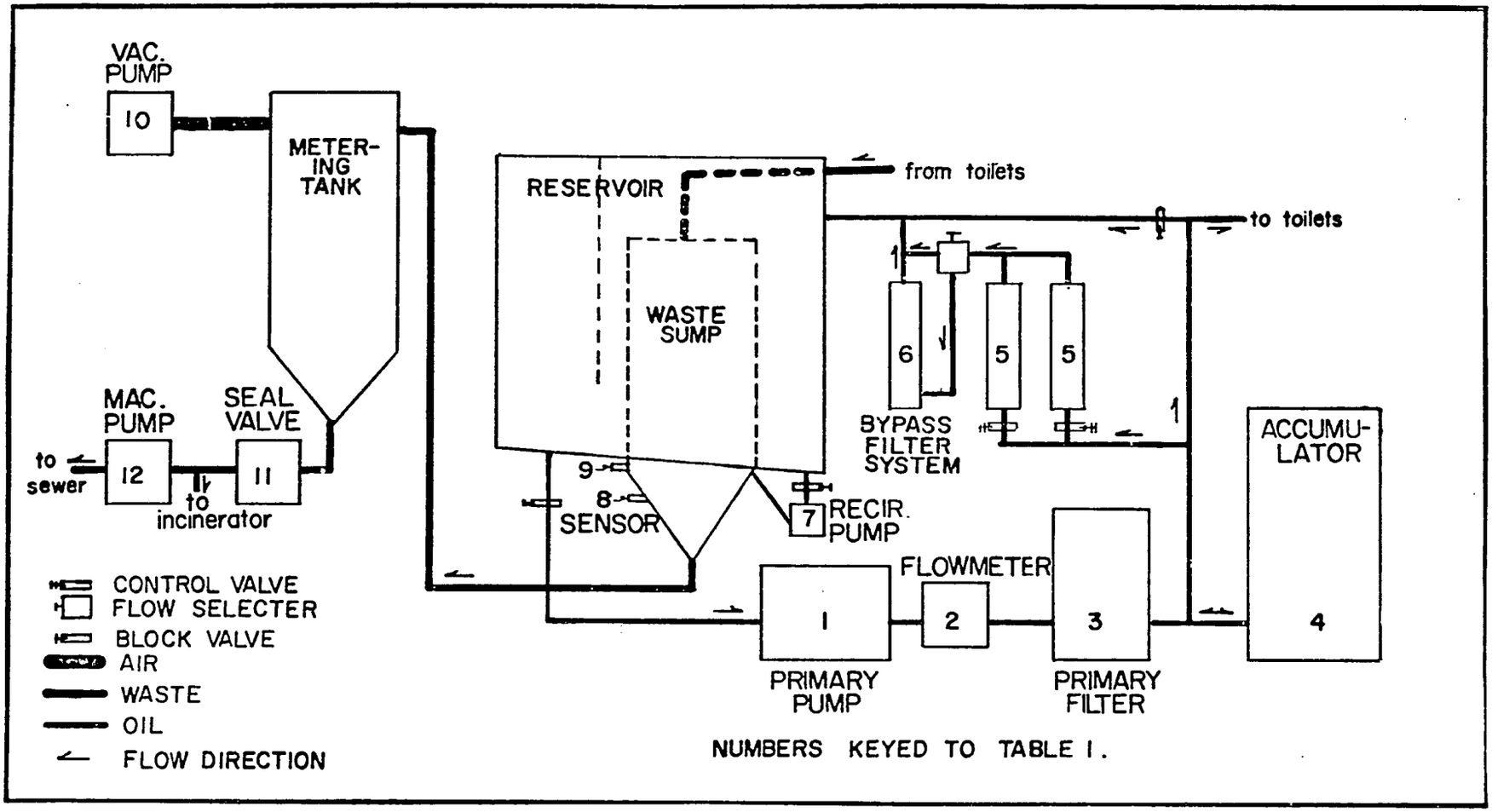

VAC. PUMP
10
METER-ING TANK
RESERVOIR
from toilets
to toilets
WASTE SUMP
6
5
5
BYPASS FILTER SYSTEM
ACCUMU-LATOR
MAC. PUMP
SEAL VALVE
to sewer
12
11
to incinerator
9
8
SENSOR
7
RECIR. PUMP
FLOWMETER
1
2
3
4
PRIMARY PUMP
PRIMARY FILTER
CONTROL VALVE
FLOW SELECTER
BLOCK VALVE
AIR
WASTE
OIL
FLOW DIRECTION
NUMBERS KEYED TO TABLE I.

Figure 15

Flush fluid is recirculated to the commode by a pressure pump which is activated by a pressure switch. A bladder type accumulator is provided to prevent surges and to meet peak flow condition.

Gravity flow is maintained by circulating the flush fluid through a pre-filter, an activated carbon column, and a clay filter. These units remove fine particles and dissolved contaminants such as lipids, surface active agents, color bodies, and some odor producing contaminants. Bacteria and odor are controlled by the periodic addition of chlorine compounds to the flush fluid.

When sufficient waste accumulates in the sump, it is detected by a waste sensor. This activates the macerator pump which transport the waste to the waste holding tank. The dump switch actuates when the waste holding tank is half full and initiates incinerator warm up. Waste transfer start, stop, and incinerator shut down are controlled automatically.

Composting (Clivus Multrum) (Figure 16)

Cost: Approximately $1500/installation

The best-known technology, the oldest and virtually the only device that can function without either an external supply of energy or maintenance is the Swedish Clivus Multrum. It is an organic waste treatment system (Tables 18 & 19).

Developed by Rikard Lindstrom some 30 years ago for his house on one of the fingers of the Baltic, this system employs the principles of gravity, natural draft, and unaided microbial decomposition processes. The container is nine feet long, four feet wide, and five feet high - large enough to hold all the organic wastes of a family for several years while the waste decomposes. It can be located either in a basement directly below the toilet and garbage inlet, with gravity-feed by means of vertical

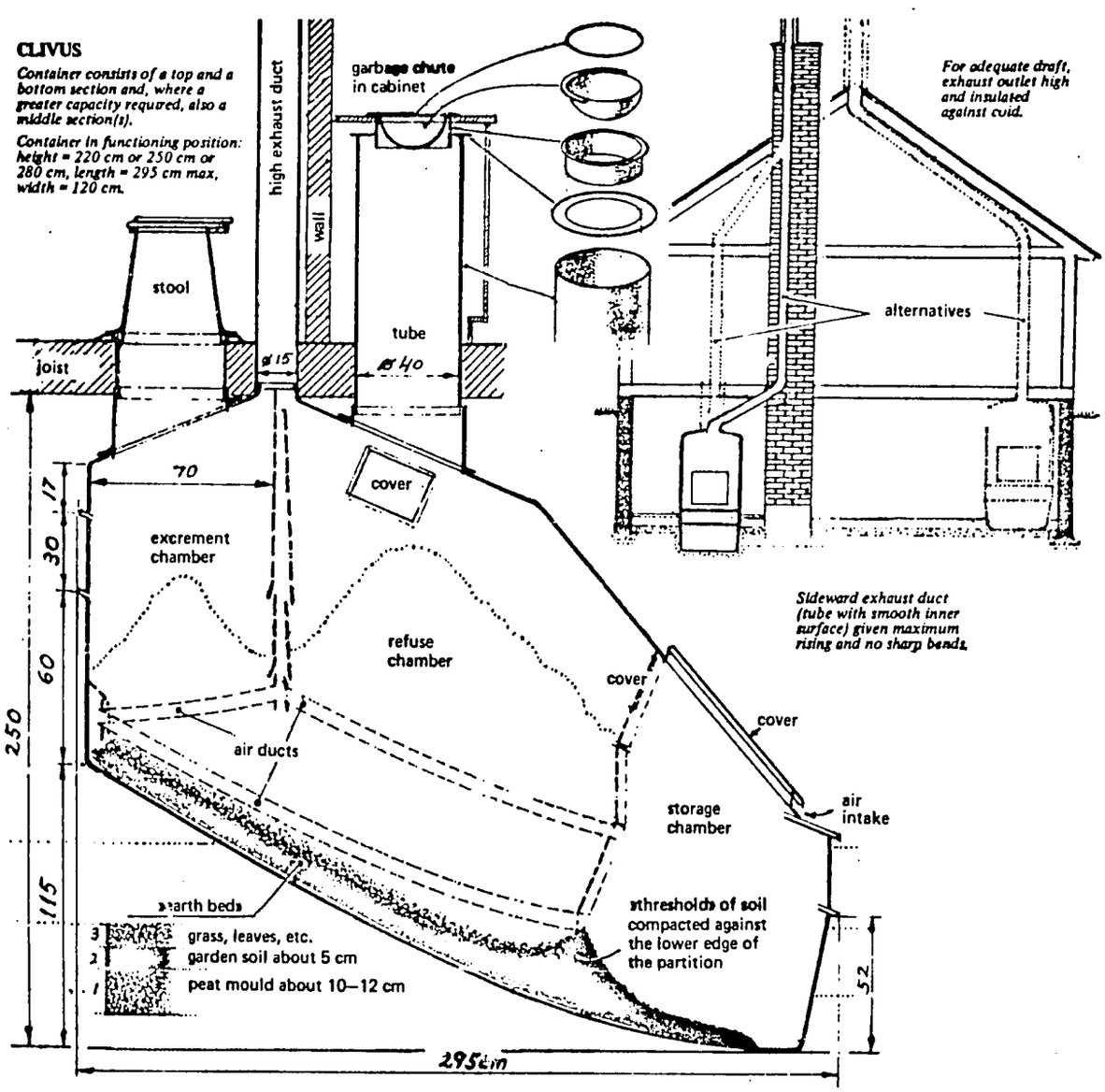

CLIVUS
Container consists of a top and a bottom section and, where a greater capacity required, also a middle section(s).
Container in functioning position: height = 220 cm or 250 cm or 280 cm, length = 295 cm max, width = 120 cm.
high exhaust duct
wall
garbage chute in cabinet
stool
joist
tube
ø 15
ø 40
70
cover
excrement chamber
refuse chamber
cover
cover
air ducts
storage chamber
air intake
»earth bed»
»thresholds» of soil compacted against the lower edge of the partition
grass, leaves, etc.
garden soil about 5 cm
peat mould about 10–12 cm
250
17
30
60
115
52
295cm
For adequate draft, exhaust outlet high and insulated against cold.
alternatives
Sideward exhaust duct (tube with smooth inner surface) given maximum rising and no sharp bends.

Figure 16

Table 18

Cost Detail: Clivus Multrum System

	List Price Single Unit Sale	Community Single Home	Costs 300 Homes
I. Toilet and Garbage Waste System:			
Multrum tank, small	975	300	90,000
Garbage Inlet assembly	75	40	12,000
Pipes for garbage assembly	27	14	4,200
Pipes for ventilation system . . .	60	30	9,000
Ventilator roof cap	18	14	4,200
Ventilator fan	37	30	9,000
Equipment costs	1192	428	128,400
Freight and handling.	70	20	6,000
Installation	300	200	60,000
Conveyor system for ½ of all homes:			
Horizontal conveyor system parts . . .	400	300	45,000
Installation	200	100	15,000
Sub-total	2162	1048	254,400
III. Greywater Pre-treatment System (½ of homes)			
Trickling filter	300	150	23,000
Pipes to connect	150	100	15,000
Installation	150	100	15,000
Sub-total - greywater treatment system	600	350	53,000
TOTAL: Installed cost of equipment	2762	1398	307,400

AVERAGE COST, PER HOME, INSTALLED 1,024

Table 19

Comparison of Clivus to Central Sewerage Costs

Central Sewer Construction Costs

two Massachusetts towns

total and local-share costs

	- Groveland Mass. -		- Peperell Mass. -	
	Total Costs	Local Share Costs	Total Costs	Local Share Costs
Number of homes served	500	500	300	300
Construction Costs:				
Treatment Plant	1,170,000	117,000	2,480,000	248,000
Interceptor Sewers . .	2,904,000	290,400	806,000	80,600
Lateral Sewer Lines . .	1,905,000	1,905,000	1,133,000	1,133,000
Total construction costs	5,979,000	2,312,400	4,419,000	1,461,600
Cost per home served . . .	11,958	4,624	14,715	4,867
Comparable cost of Clivus Multrum system (see detail)	NA	NA		1,024
Percentage Saving - Clivus Multrum				79%

pipes, or it can go in the gound outside the house and be fed by a horizontal spiral conveyor which is powered by a small motor.

Because of the inclination of the floor of the container combined with the air flow through the mass, no turning of the wastes is necessary. As the bacteria doing the decomposing are naturally predacious on most organisms harmful to people, the humus produced is safe to use in vegetable gardens.

There are never any odors in the bathroom or kitchen because of the draft caused by negative pressure in the tank which carries them away through a vent in the roof. The kitchen garbage, which is mostly carbon, contains the energy which the microorganisms (also occuring naturally in these wastes) use to do the work of conversion.

The following headlines, "New Type Compost Toilet Viewed in Downeast Areas" appeared sometime ago in a U.S. Community newspaper. The text of the article went like this:

> A strange-looking, bulky object made of fiberglass, looking like a space-age boat, or a bathtub with a cover, tiny windows, and a hatch for the bather to enter, arrived in Milbridge early Saturday afternoon on the back of a pickup truck.
>
> Destined for delivery at the Pinkham Building Supplies Co., t he object attracted onlookers at the R.B. Strout Co. in Milbridge, where the truck driver had stopped to ask directions to Pinkham's.
>
> Seeing the beige-colored fiberglass shape, a Strout employee said, "Let's put an outboard motor on it, take it down in the bay and try it out."
>
> But this interesting experiment was not to be. Followed by two cars with curiosity-filled drivers, the truck and its mysterious burden passed slowly along Main Street to Pinkham's store and warehouse, where it was examined carefully by builder Harry Pinkham and his son David, prior to unloading.
>
> This odd-looking object puzzled many Milbridge residents before they realized it was a clivus multrum or a new compost-toilet

combination garbage disposal which converts human waste and garbage into a humus-like substance for enriching soil within four to five years. Pete H. Duston of Milbridge, dealer of the compost toilets has sold one so far to a woman from Washington, D. C. who has built a cottage in Steuben. Workers unload the toilet in Milbridge on Saturday.

Sarmax 500 R Series (Figure 17)

Using an oil-based crystal-clear flushing fluid, which is purified and reused over and over again, the Sarmax Corp., Los Angeles, Calif., has devised a waterless system, thus avoiding environmental problems created by the conventional system. The new system has no discharge. It is intended for residential and public use applications and should be particularly well-suited in areas where septic tanks are prohibited or economically impracticable.

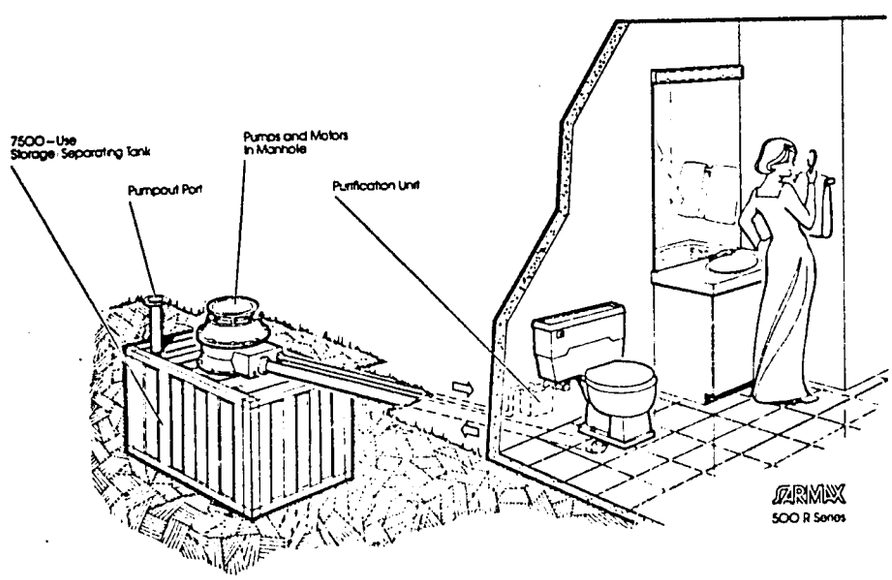
Eliminating water from the flush toilet results in average water savings of 40 percent in homes and about 90 percent in public comfort stations. The Sarmax system makes possible these reductions without affecting user acceptance or convenience. Because users see no differences, they are seldom aware that the toilet is flushed with anything but water.

The waterlike Sarmax fluid flushes the waste to a special tank where it separates from the waste. At the same time, a fresh charge of clear fluid is returned to the flush tank passing through the purification unit, emerging crystal-clear and ready for service again. The special tank stores 7500 uses, equal to 1 year of use in a normal household, before needing to be pumped out. The stored wastes are quiescent and odorless, without the addition of chemicals, and consequently, the pumped-out wastes can be delivered to treatment plants for final disposal. The Sarmax fluid remains behind for continued use.

Purification units are checked at the time of pumpout and the filter canisters exchanged, if necessary.

The system was designed to minimize maintenance and maximize fail-safe operation. Each fixture is independent of all other fixtures with individual motors, pumps, controls, and purification units. Infrequent maintenance would be accomplished without tools.

...Mechanical Engineering, Feb. 1976



Waterless flush system installed in a home.

Figure 17. Sarmax

Minimum Water (Microphor) (Figure 18)

The system requires 60-100 PSI of compressed air and a small amount of water from gravity flow for 1-60 PSI The push button activites a flow of water into the bowl and opens a valve in the toilet. The valve automatically closes and a charge of air ejects waste material into the discharge line. All Microphor Low-Flush toilets can be used with any type of sewage treatment system.

Microphor systems provide reliable waste handling, treatment and environment protection. (Figure 19)

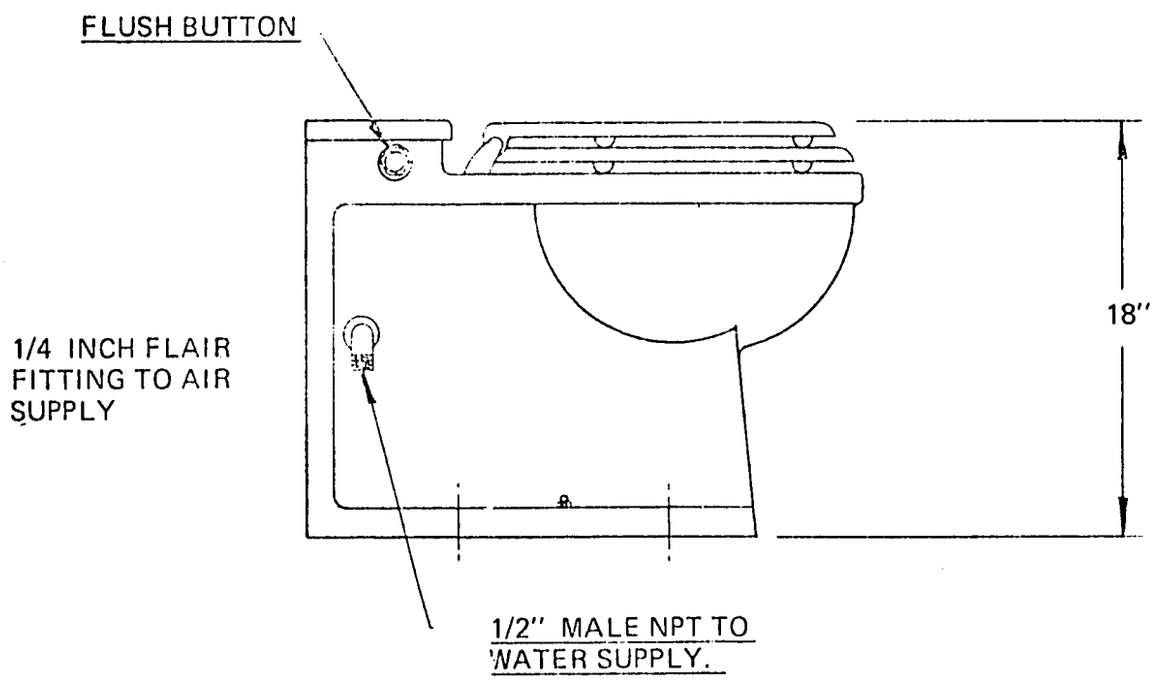


Figure 18. Microphor

Microphor

Division of Merrill Industries, Inc.

February 7, 1975

Dear Sir:

Thank you for your inquiry regarding our Microphor Low Flush Toilets.

I have enclosed our brochures covering the stainless steel and ceramic low flush toilets for your information.

You will note the water conservation features of these new improved toilets which can reduce your water consumption and consequent disposal by up to 95% per flush (1 1/2 quarts vs. 5 gallons or more for conventional toilets).

Our low flush toilets are in use in State Highway rest stops, park and recreation camp grounds, Bureau of Land Management camp grounds as well as single family residences.

In addition, we have over 12,000 of this type of system in operation on the nation's railroad systems, and have just recently supplied our units for application on the Golden Gate Bridge District ferry boats.

If any additional information is required, please advise.

Very truly yours,

MICROPHOR

EDWARD L. BRUCE
Vice President-Marketing

ELB/mjj

475 East San Francisco Avenue / P.O. Box 490 / Willits, California 95490 / Area (707) 459-5563

Figure 19. Sample Letter from Manufacturer

Vacuum (AIRVAC) (Figure 20)

The AIRVAC system is a closed sewage collection system developed in 1970 to use a one-pipe system in order to accomodate housing, both old and new that used conventional gravity flush toilets.

The AIRVAC valve is installed in a pit at the property line. Total sewage flows from conventional fixtures within the house out through the house lateral to the property line where the normally closed AIRVAC valve is located.

There is only one source of power for our entire system, including the AIRVAC valve and sensor component. Remember, the AIRVAC valve is a totally pneumatic unit. This power source is located at the collection station, and with the recommended inclusion of standby power, eliminates any possibility of system shut-down because of a power failure.

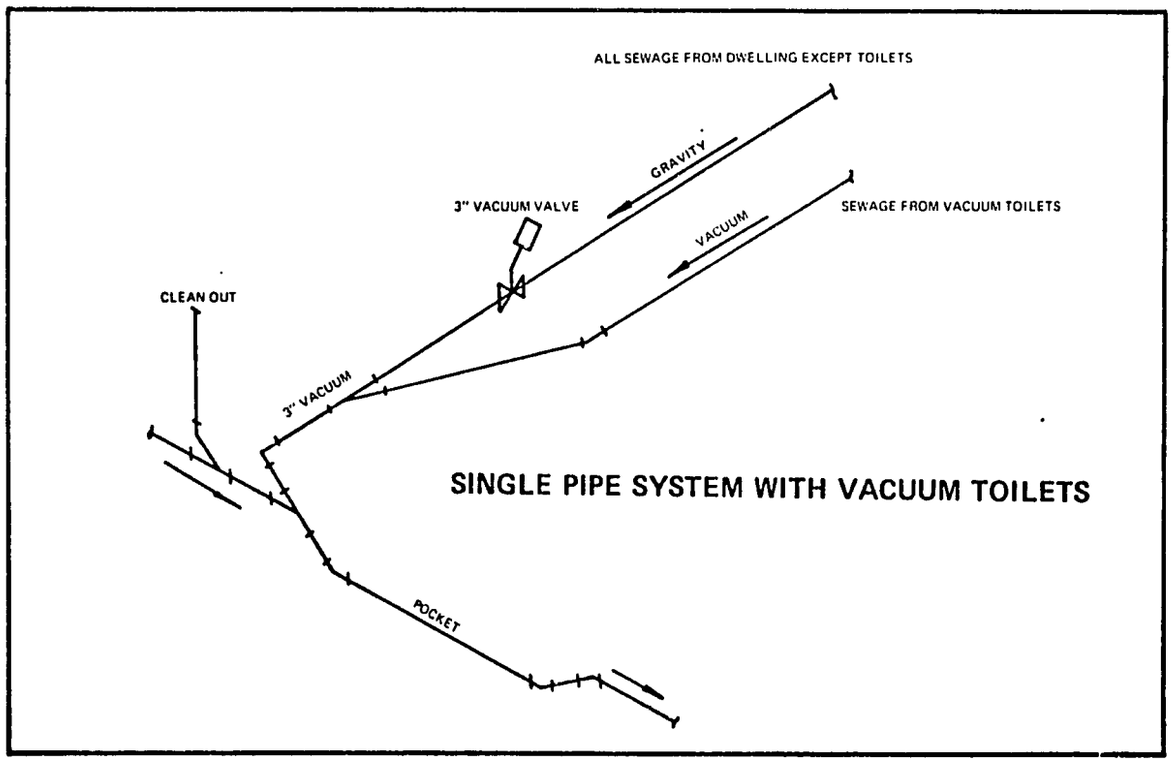


Figure 20.

Marine (Vacu-Flush) (Figure 21)

Cost: $1400-2000

Would be easily adaptable for home use.

The new Automatic Vacu-Flush System operates on the vacuum principle, instead of gravity or some other method of forcing sewage into a holding tank. The Vacu-Flush principle offers many advantages. It is odor free, and can flush on less than one pint of water and each flush can be flushed directly overboard, into a flow-through device, or into an on-board holding tank. The Vacu-Flush also has "self pump-out" capabilities at dock side septic tank facilities. The system is designed to meet any present or future pollution control law. In dual head installations, each head has its own accumulator tank thus making it possible to flush both heads at the same time!

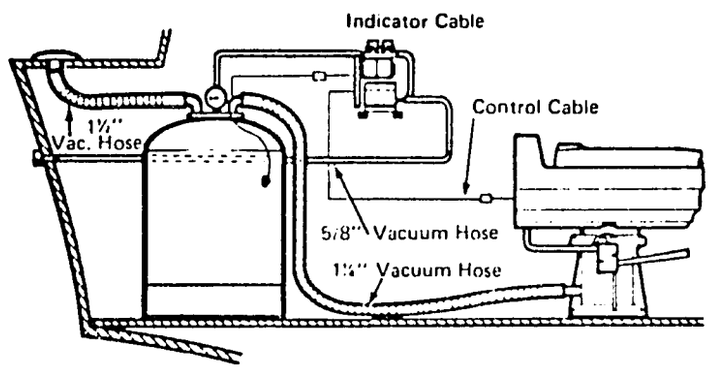


Figure 21. Vacu-Flush

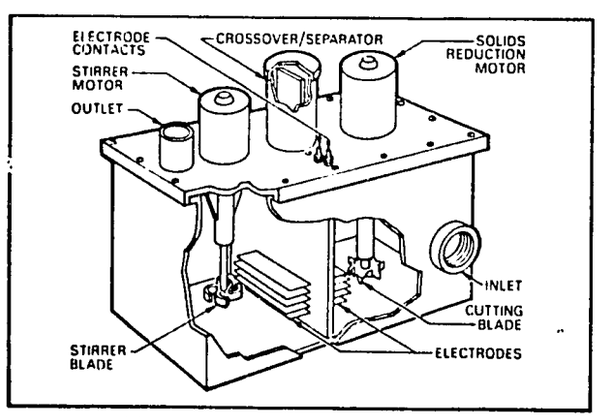
Marine (Raritan Lectra/San) (Figure 22)

Cost: $200-400

LECTRA/SAN is a compact, flow-through waste treatment system which efficiently reduces solids, destroys bacteria, eliminates odors, and lowers the Biochemical Oxygen Demand. The effluent consistently meets Federal requirements, as published in the Federal Register, Vol. 37, No. 122. No chemicals are necessary since the disinfecting agent is produced as needed by the electrolysis of the seawater used in flushing the toilet. When operating on fresh or brackish water, a small amount of table salt is used as the source of the disinfecting agent. LECTRA/SAN is completely automatic and operates on standard marine batteries.

The LECTRA/SAN system consists of a two-chambered treatment unit equipped with motors and electrode pack, a control unit with treatment indicator, a logic unit containing relays and the solid state timing circuit, and the salt feed unit. The treatment unit is located between the toilet and the discharge line. It has a total volume of approximately three gallans and is 15" x 8 3/4" x 8 1/2". Overall height, including motors, is 13 inches. The treatment unit is made of tough, chemically-resistant polyvinyl chloride (PVC).

MARINE WASTE TREATMENT SYSTEM



SYSTEM REQUIREMENTS

Figure 22.
LEXTRA/SAN^{tm}

Comparison of Devices and Systems

Table 20 has been prepared to provide a comparison of devices and systems for six categories of waste processing methods. Because of the numerous devices available for each type a narrative comparison would have been lengthy and ineffective. Instead an evaluation of each of the six categories was presented in the previous narrative portion with some of the more successful units referrenced.

Other commercially available devices which could be classified as collection or non-treatment devices, such as freeze toilets, chemical toilets, pit latrines, aqua privys, and water-borne network devices were eliminated form consideration in this report. Vacuum, oil base, and biological waste processing methods were included even though their waste product requires further treatment and/or disposal because the final product is in a concentrated form which is contained and therefore more easily disposable.

The newer methane plants were not included because the technical considerations of air emissions and the size of operation required for profitable developemnt would not be conducive for their consideraton in unsewered low density areas. The initial investment in such plants is large also but continuing operating expense is small so methane plant are more suitable for larger permanent sites.

UNIT COST

Devices were categorized in Table 20 in unit costs from $0-100, 100-500, 500-1000, and over 1000/unit. Devices with greater capacity on the average cost more than those for only three or four persons though the per person const was less. Many units were limited to only three or

Table 20. Comparison of Devices and Systems

Method	Name	Country	USA $					Detailed Requirements					
			0 - 100	100-500	500-1000	Over 1000	Operating Costs	Capacity	Water	Power	Chemicals	Effluent	Primary Application
Incinerating	Destroilet	USA			*		3-5¢/u	4-16		*		A	2nd Home
	Ecett	Sweden			*		6¢/u	4-6		*		A	2nd Home
	Electro Standard	Sweden			*		5¢/u	4-6		*		A	2nd Home
	Elonette	Sweden		*			4¢/u			*		A	2nd Home
	Incinoiet	USA			*		5¢/u	4-12		*		A	Indus.
	Toarett	Sweden		*			8¢/u			*		A	2nd Home
	Xpurgator	USA				*		4-20		*		A	Developmental
Biological	Cycle-let	USA							*	*	*	L	
	Bio-Flo	USA			*		4¢/day	1-12			*	L	2nd Home
	Jet Flush	UK		*				100/u		*	*	L	Portable
	Monomatic	USA		*				100/u		*	*	L	Airlines
	Potpourri	Canada	*					50/u			*	L	Portable
	Craft Toilet	USA		*				200/u		*	*	L	Marine
Composting	Clivus Multrum	Sweden				*		4-40				S	Home
	(Same Name)	(USA)				*		"				S	"
	Mull-Toa	Norway		*				3-4		*		S	2nd Home
	(Biu-Let)	(USA)			*			"		*		S	"
	Saniterm	Sweden			*		24¢/day			*		S	
	Toathrone	USA			*			4-6		*		S	2nd Home
	Farallones Privy	USA	*					4-6				S	Rural
		Denmark	*					4-6				S	
	Kern Compost Privy	USA		*				4-6				S	
	Mulbank	Sweden		*			6¢/day	2-4		*		S	2nd Home
	(Ecolet)	(USA)			*		"	"		*		S	"
	Humumat	Canada								*		S	
	Kombio	Norway			*							S	
	Mull-Toa Jumbo	Norway			*					*		S	
	KPS Miljoklosett	Norway		*						*		S	
	Tropic	Norway		*						*		S	
Vacuum	Vacu-Flush	USA			*			4+		*		L	Marine
	Electrolux Vacuum Sewage System	Sweden				*		4+		*		L	Recreat.
	Airvac	USA								*		L	Commun.
	Envirovac	USA			*					*		L	"
	Vacu-Flush	USA								*		L	Marine
	Lectra/San	USA						3-5		*		L	"
Oil Base	Magic Flush	USA				*		4+		*		L	2nd Home
	Aqua Sans	USA				*		4+		*		L	Recreat.
	Sarmax	USA						4-6		*		L	Home/Rec

Table 20. Continued

Method	Name	Country	USA $					Detailed Requirements					
			0 - 100	100-500	500-1000	Over 1000	Operating Costs	Capacity	Water	Power	Chemicals	Effluent	Primary Application
Aerobic	Digestomatic	USA							*	*		L	
	Aerobic Home System	USA							*	*	*	L	
	Sewerless Toilet	USA				*			*	*		L	
	Waste Tamer	USA							*	*		L	
	Microx	USA							*	*		L	
	Cromaglass	USA			*			4-25	*	*		L	Home/Indus
	Flo-Thru	USA				*		6	*	*		L	Home
	Bio Disc	Canada				*		5-500	*	*		L	H/Indus
	Aquarobic	Canada				*		8	*	*		L	Home

four persons by the design. The more complete waste treatment devices also were more expensive with the incinerating and aerobic in the higher cost range.

Energy Requrements:

All the waste processing methods require some form of energy with the exception of a few composting devices. The amount of energy is dependent upon the method with the incinerating and aerobic methods being the highest consumers. Efficiency with the individual unit process of the device produced some variation but to a lesser degree. Comparable treatment processes were found to be competitive.

Reliability:

The most successful devices would have to be termed the most reliable with the exception of developmental ones. Since the treatment of the waste is on-site, failures have resulted in immediate sales losses in their respective marketing areas. Several companies have been absorbed into the present manufacturers of the devices evaluated. USA manufacturers have purchased patents as they became available from other devices resulting in products with greater reliability.

Specific Application:

The devices examined have aimed at two primary markets, namely, the vacation home or recreation market and the industrial market, where conditions have warranted a waste processing method for on-site treatment. Both markets have been willing to pay the slightly higher price required in the developmental stage. Recent developments indicate a broader application is foreseeable with a substantial cost reduction implied by mass production methos.

User Acceptance:

The user has accepted these various methods of treatment on-the-job or vacationing as circumstances have required. Totally an estimate of 200,000 units in present day use would be a conservative one based on the number of devices available. Greater acceptance is being experienced in the USA in five or more states where sales are up. The National Sanitation Foundation has produced a draft set of standards for consideration.

Experiences in Technological Impact

In the selection of on-site wastewater treatment systems for developing contries previous experiences can not be over looked in evaluating the potential impact of new technology. In November, 1975, WHO/IRC held a community supply workshop on developing country problems. The unsatisfactory situation of sanitation in developing countries and the lack of "good" help from the industrialized countries to the developing countries was cited as the reason for the WHO/IRC workshop. The literature study by Hugo J. van den Berg, University of Delft, for the workshop reviewed some of the new on-site treatment systems which are being considered today.

The Appalachian Environmental Demonstration Project is an excellent example of previous experiences with the application of on-site systems.[16] It was initiated to demonstrate ways to improve environmental health in Appalachian Kentucky. Results from the project which were published in 1973, discuss institutional, personnel, siting, and selection of disposal systems which have just begun to be addressed today.

An example of the on-site sewage disposal in India is another example of experience in the field with alternate technology.[17] It is the evaluation of the feasibility of a biogas plant operation. The methane produced is then utilized as a cooking fuel. The value of this document seemed to be in the detailed analysis of the social and personal hygiene habits which must be addressed in order to evaluate the Socio-cultural impact of new technology. Before any meaningful transfer can be exchanged the impact of the proposed

change must be demonstrated as having potential adaptability.

The following matrix (Figure 23), prepared by David Stewart, attempts to categorize all the possible types of "innovative" systems. ("Innovative" is defined in this context as any system other than septic tank-soil absorbing field).[18] It concluded that the possible combinations were not unlimited for purposes of treatment and disposal. Essentially, any known or future system will have either a conventional, innovative or no treatment method coupled with a conventional, innovative or no (containment) disposal.

Taking this further it would seem that this is a prediction of a continued mix of systems. No rational is given for developing criteria which would allow for the successful regulation of a mixed on-site or a mixed on-site/convention combination of treatment and disposal systems.

Figure 23. Matrix of Anticipated Possible Treatment and Disposal Combinations of On-site Sewerage Systems[19]

TREATMENT \ DISPOSAL	NO (CONTAINMENT)	CONVENTIONAL (SUBSURFACE SOIL)	INNOVATIVE		
			SOIL	SURFACE WATER DISCHARGE	E-T
NO	1. Holding Tanks 2. Recycle Toilets (Non-water Carriage 3. Self Contained Toilets	1. Cesspool	UNLIKELY	UNLAWFUL	UNLIKELY
CONVENTIONAL (SEPTIC TANK)	UNLIKELY	1. Septic Tank-Soil Absorption Field	1. Mound Systems 2. Fill Systems	PROBABLY UNLAWFUL	1. E-T BEDS
INNOVATIVE	1. Composting Toilets	1. Mechanical Aeration-Soil Absorption Field	1. Mechanical Aeration-Mound System	1. Sand Filters 2. Physical-Chemical 3. Lagoons 4. Mechanical Aeration 5. Others	1. Not Known at This Time

CHAPTER V

COST-EFFECTIVENESS ANALYSIS METHODOLOGY

Evaluation Criteria or Mission Requirements for Treatment System Alternatives

At some point within each scheme or model, goals are established which become criteria or mission requirements in the evaluation of the potentially successful system. These mission requirements may be to achieve economical, sociological, cultural, or even health-oriented benefits. They usually must be measurable for accountability and effectiveness, though some measures may be expressed in qualitative terms rather than quantitative ones.

Whatever the established goals are, certain criteria have been set forth in various publications for selecting or evaluating wastewater treatment systems. The complex forms which this criteria (input information) can take in such schemes or models is evident in Figure 24. The need for financial input and cost output for example is usually rather explicit as it is in this model. The forms that cost input or output may take in the modelling can be rather implicit, too. Cost, though, is a criterion or standard of measurement used in every scheme or model.

So, within the criteria which have been published as appropriate for wastewater projects there are several criteria which are common and should not be ignored. These are:

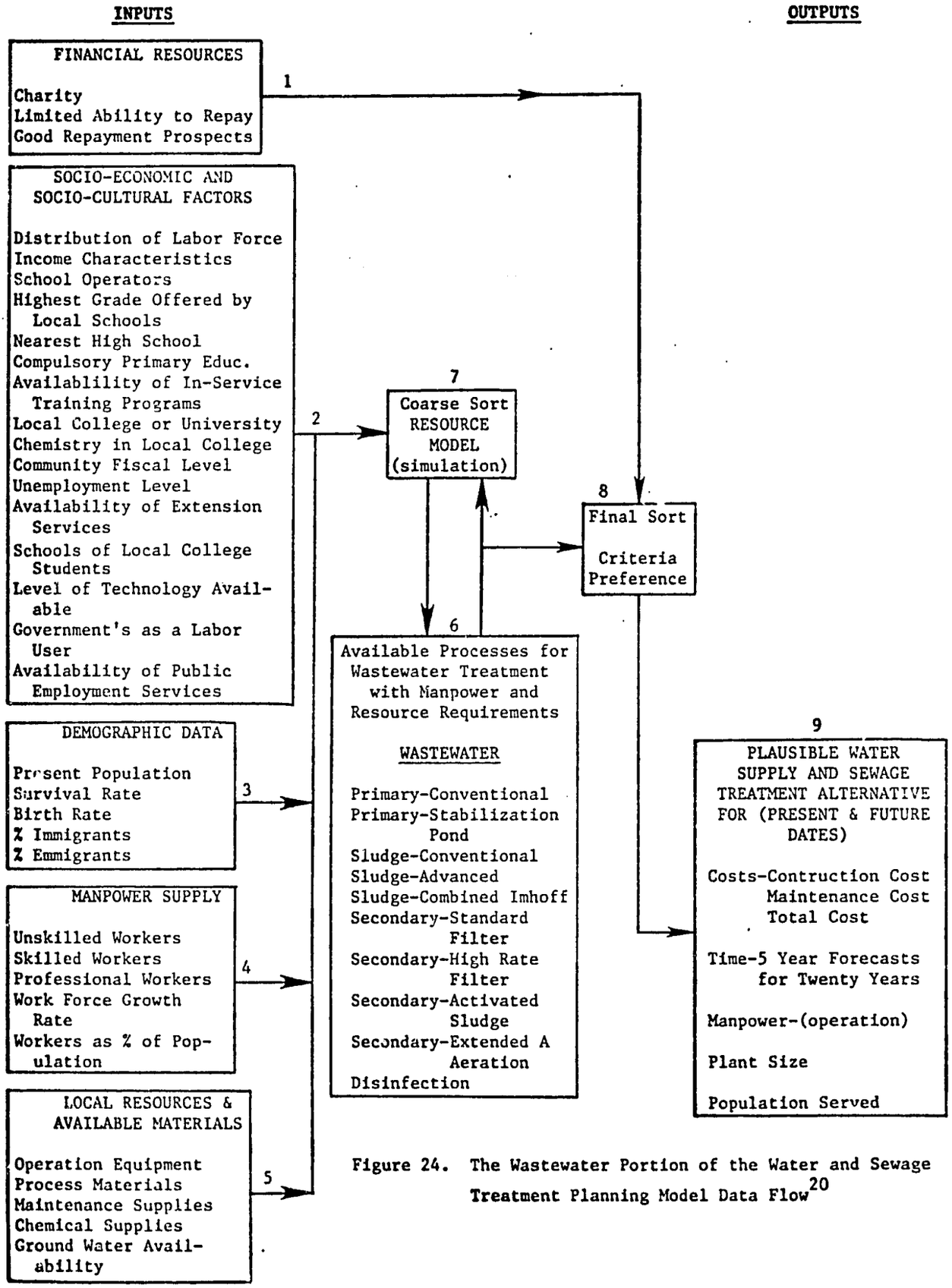


Figure 24. The Wastewater Portion of the Water and Sewage Treatment Planning Model Data Flow[20]

1) Costs

2) Facility Requirements

3) Manpower Demands

4) Resource Requirements

5) Time Demand

All five of the criterion can be described as functional to the dynamics of any wastewater system.

Interwoven in the above criteria are all the other factors: implications, impacts, interactions, and relationships which can enhance, stimulate, prohibit, retard, or otherwise affect the final outcome. The relative importance or value assigned to each of these factors rests with the decision-maker. The term, effectiveness, could probably be used to cover most of them.

Criteria

1) Costs

Costs, particularly those for typical treatment plants, are available in various forms. Many have been presented previously. Costs beyond the boundaries of centralized facilities are often more difficult to obtain or even estimate due to the complexity of financing, budgeting and the number of various governmental entities. Recent rises in cost-of-living prices have also affected the values of previous estimates and the financing of matching funds by local governments. Maintenance costs and extensions of services due to the higher manpower requirements would by nature show a higher rate of increase. If recent U.S. consumer complaints are an indication, then both construction and maintenance projects are being greatly affected by these rising costs.

Health and socio-economic costs have always been hard to isolate and quantify. Reports of contaminated supplies and consequential illnesses have depended upon awareness, communication, and reporting systems. Remedial or curative treatment have been the significant factors in estimating costs on the reported incidences. Costs which have accrued in direct costs to the individuals and indirect costs to the community and nation have not been as visible as curative treatment costs. These individual and community costs are also cumulative and especially difficult to obtain for developing countries. Therefore, some estimate of total costs in terms of health benefits may only be obtained in developing countries by isolated incidences.

2) Facility Requirements

The effluent quality, system size and performance, and the population to be served are very greatly influenced by the previous costs. In a developing country where some improvement is better than no improvement then the level of acceptable treatment, dependability of any treatment systems, and the number of households which can be reached initially with some wastewater treatment system is relative to their perceived needs. With this in mind then an advanced system has just as much chance of adoption as that of a system which was initially used during the development of other countries.

The following chart was developed during the Lower-Cost Methods study, USAID (Table 21). The effluent quality to be discharged to streams or receiving waters is not necessarily the same as that which developed countries have been in the process of attempting to litigate. If this were

Table 21. Acceptable Combination of Treatment Processes for Potable Water

	Combination CODE	PROCESS COMBINATIONS	CRITERIA LEVEL: Raw Water Concentration: Coli MPN/100 ml	Raw Water Concentration: Solids mg/l: Turb	Raw Water Concentration: Solids mg/l: Other	Receiving Water: Receiving Water Volume (7-day Low Flow Level)/Waste Volume
WATER TREATMENT	W1	PW1	1 - 2	10		
	W2	PW1 + PW7	100	10		
	W3	PW3	100	100		
	W4	PW2 + PW3	300	800		
	W5	PW11	300	800		
	W6	PW4 + PW7	2,000	100		
	W7	PW2 + PW4 + PW7	3,000	1,000		
	W8	PW5 + PW7	2,000	100		
	W9	PW2 + PW5 + PW7	3,000	1,000		
	W10	(any one of W1 to W8) + PW6			300 Hardness	
	W11	(any one of W1 to W8) + PW8			1-3 Fe & Mn	
	W12	PW7 + PW9			>3000 TDS	
	W13	PW7 + PW10			>2000 TDS	
SEWAGE TREATMENT	S1	PS1 + PS5				20 (or 3-4 CFS/1000 PE*)
	S2	PS1 + PS3				20 (")
	S3	PS2				10 (or 1.5-2 ")
	S4	S1 + PS6				6 (or 0.9-1.2 ")
	S5	PS1 + PS9				3 (or 0.45-0.6")
	S6	S2 + PS6				6 (or 0.9-1.2 ")
	S7	S2 + PS7				5 (or 0.75-1 ")
	S8	S2 + PS8				4 (or 0.6-0.8 ")
	S9	(any one of S1 to S7) + PS10	250			2 (or 0.3-o.4 ")
	S10	PS3 (Without water carriage)				- NA
	S11	PS11				10 (or 1.5-2 ".)
	S12	PS12				40 (or 6-8 ")
	S13	PS2 + PS12				8 (or 1.2-1.5 ")

* The unit is defined as cubic feet per second of receiving water flow rate/1000 popualiton equivalent. A population equivalent is a waste equivalent to one person per day, normally taken as 0.17 lbBOD/day.

the level required though the choices of systems and the comparable population numbers would be explored and potentially adopted.

3) Manpower Demands

If any lessons are to be learned from the historic aspects of manpower utilization and training programs then several assumptions need to be made.

In order to have economically active environments in water and wastewater programs manpower which can be self-sustaining and/or self-employed must be encouraged. This would include the trades in particular.

Lesser skilled jobs show the most immediate return in terms of manpower/labor dollars while the middle management positions supply the most stability. Management level positions must be obtained through experience and made viable by training for the economic stability of treatment systems. The manpower trees (Figure 25) demonstrate differences in manpower structures for developing and developed countries.

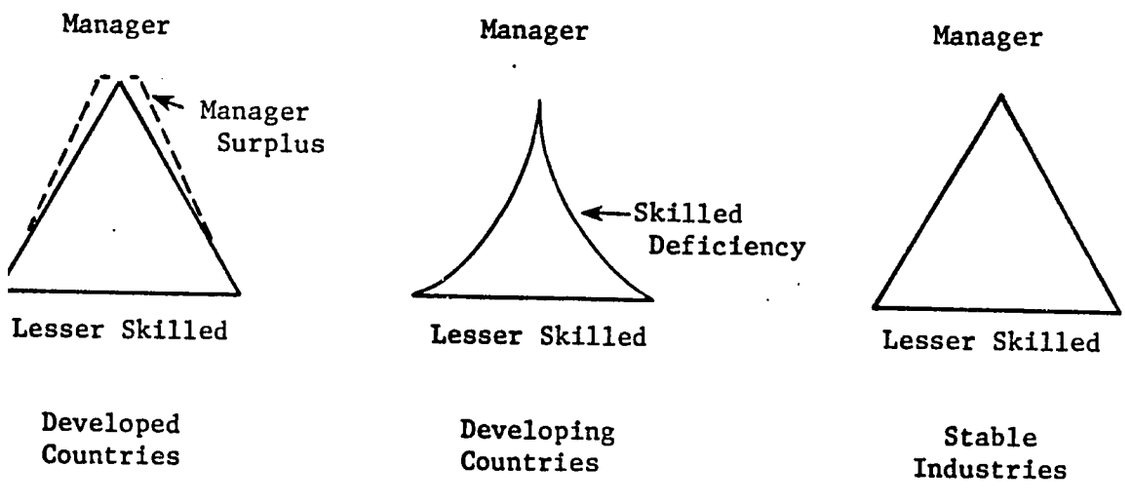


Figure 25. Manpower Trees

Training, of course, must be provided for individuals showing initiative in order to establish a self-sustaining service.

Water and wastewater should be tied to any available public services (such as electricity) in a developing community until such time as a separate water and wastewater service would be self-sufficient. This is particularly true because some of the same skills are common among utility services.

Self-sustaining manpower will be more than likely found in industrial occupations which have shared duties. This is true for two reasons: (1) the operation of an industrial treatment facility, waste disposal activity, or maintenance duties are not full time; and (2) retention of manpower, full utilization, and low turnover are industrial requirements for profit making.

Manpower in public service occupations have typically received less pay, been utilized on a part time basis, have required more training dollars because of higher turnover, and have had less opportunity for economic advancement within the public service arena. These factors have led to the utilization by industry of public service occupations as training grounds for future employees, thus encouraging the cycle of greater public employment turnover and training needs (Figure 26).

In the United States this cycle has become accepted as a means of reducing unemployment. Research is as yet unavailable as to the economic benefits of this cycling, particularly through public service employment programs.

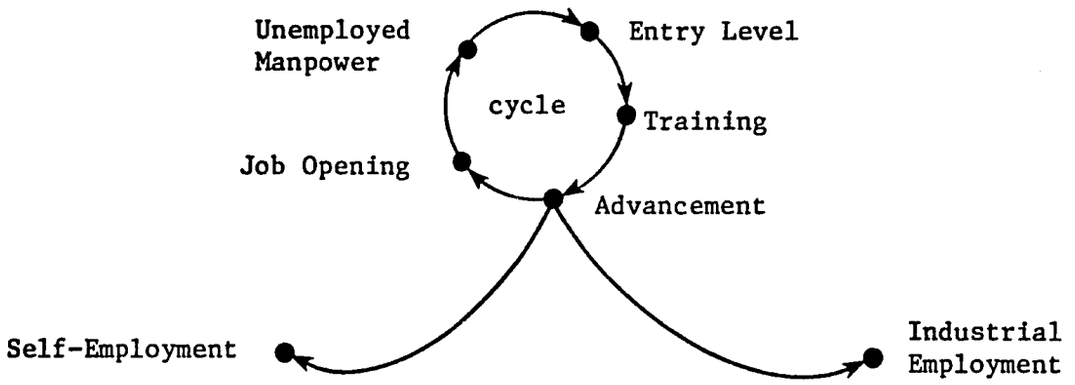


Figure 26. Manpower Cycle

4) Resource Requirements

The question of local resources and available materials has been explored in great detail during the Lower-Cost Methods Study. It is also of major importance to the savings in costs of intermediate technology for conventional systems. The fact that local resources are available, of course, influences the longevity of any system. The ease with which any replacement materials, supplies, and system expansion can be obtained is not just a problem of lesser developed countries but also of developed ones, especially in small communities and rural areas. The solution to this is in the manpower and resource delivery systems as well as with the local decision makers who ultimately must deal with such problems.

The following table (Table 22) of water and sewage treatment processes with essential components for operation contemplates a variety of waste treatment processes considering manpower operation and resource requirements. An expansion of the two individual waste processes listed at the

Table 22. Water & Sewage Treatment Processes With Essential Components for Operation.

	Treatment Methods \ Process Requirements	Process Number	Manpower Operation			Resources Required				
			Unskilled	Skilled	Professional	Operation Equipment	Process Materials	Maintenance Supplies	Chemical Supplies	Groundwater Availability
WATER PROCESSES	No Treatment	PW1	●				●			●
	Pre-Treatment	PW2	●					●		
	Slow Sand Filtration	PW3	●					●		
	Rapid Sand Filter-Conv.	PW4		●	●	●	●	●	●	
	Rapid Sand Filter-Adv.	PW5		●	●	●	●	●	●	
	Softening	PW6		●	●	●	●	●	●	
	Disinfection	PW7		●		●	●	●	●	
	Taste-Odor - Fe, Mn	PW8		●		●	●	●	●	
	Desalting-Salt	PW9		●	●	●	●	●	●	
	Desalting-Brackish	PW10		●	●	●	●	●	●	
	Containment Filter	PW11	●					●		
WASTE PROCESSES	Primary-Conventional	PS1	●							
	Primary-Stab. Pond	PS2	●							
	Sludge-Conventional	PS3	●	●			●	●	●	
	Sludge-Advanced	PS4	●	●		●	●	●	●	
	Sludge-Combined (Imhoff)	PS5	●			●		●		
	Secondary - Standard Filter	PS6	●	●		●		●		
	Secondary - High Rate Filter	PS7	●	●	●	●	●	●	●	
	Secondary - Activated Sludge	PS8	●	●	●	●	●	●		
	Secondary - Extended Aeration	PS9	●	●		●		●		
	Disinfection	PS10		●		●	●			
	Aqua Culture	PS11	●							
	Dilution	PS12	●							
	Individual	PS13	●							●
	Individual (adv)	PS14		●		●		●		●

bottom into more specific types of advanced treatments gives a slightly different selection of process requirements (see Chapter VI).

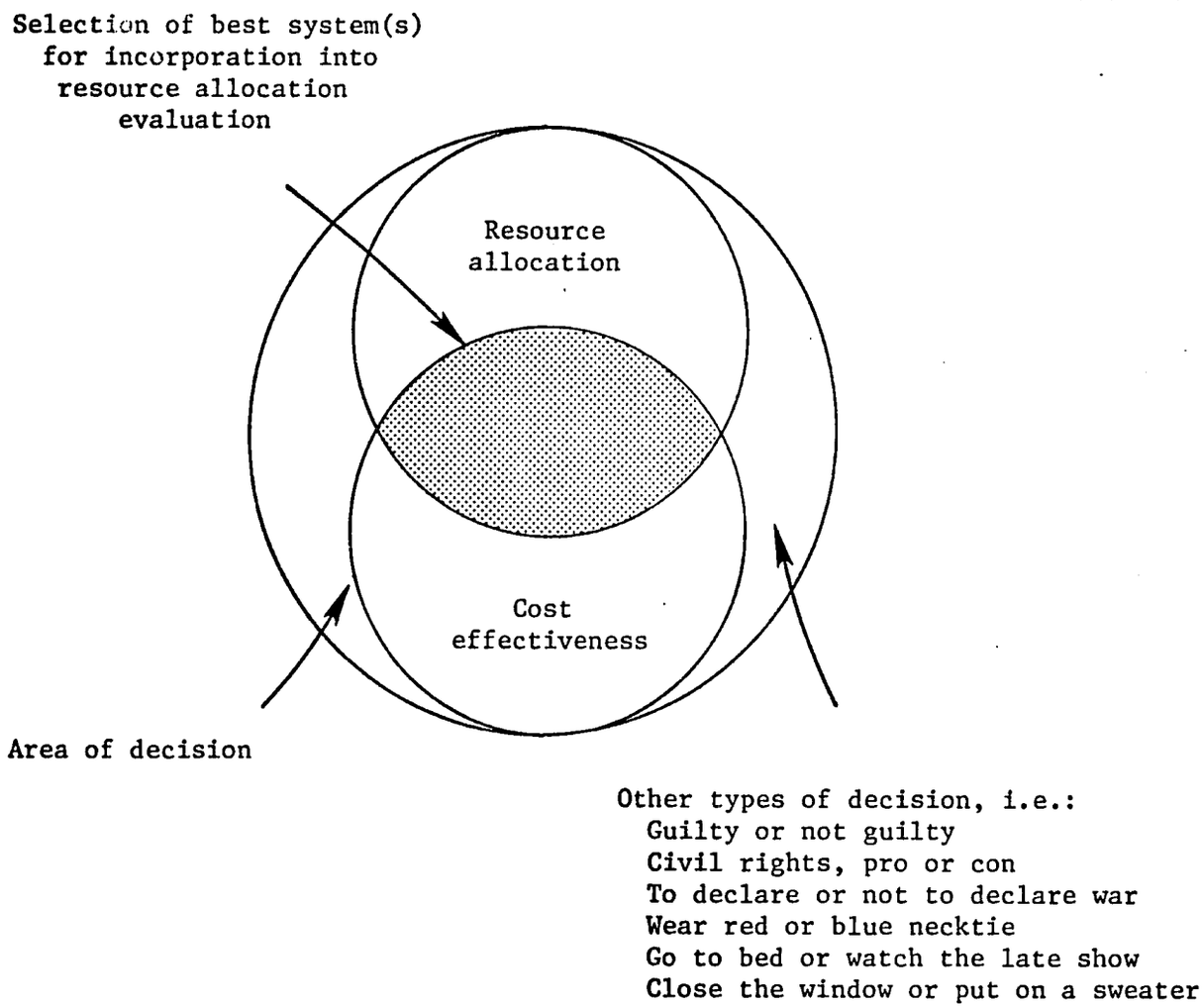


Figure 27. Schematic Portrayal of Interrelationship Between Cost-Effectiveness and Resource-Allocation Techniques as Aids to Decision Making.

5) Time Demands

In over-all planning great difficulty is found in compromising between short-term immediate environmental health care needs such as local outbreaks of disease due to water pollution and the long-term, lower environmental health conditions which are attributable to lower rates of water consumption. During a health crisis, it is relatively easy to justify a sanitary water supply or waste treatment program on the basis of an existing or clear and present danger to the public health from a hepatitis outbreak, while justification on the basis of improving general health, residential satisfaction and community pride by providing water plus wastewater facilities has limited political appeal, especially because such things are long range.

On the average, most governments will pay much more attention to economically active environments, such as industrial communities, recreational facilities, eating establishments, and transportation services. Environments which do not show a direct relationship to the economic well-being of the community, i.e., long term efforts which are not self-sustaining, will always be second or extras. Therefore, any effort to undertake long term efforts must be tied to immediate returns in a step wise projection of economic benefits to enable its acceptance. Governments on any level are more inclined toward the decisions which will bring about an immediate return per dollar invested and which will satisfy the majority of local decisionmakers. These are usually the shorter term needs of the economically active part of the population.

In the aggregate resources can be freed up readily for much needed environmental programs in wastewater, as we can for individual health care

problems, but rather in the manner of dealing with a heavily traveled road. Resources can be found to patch the road but not to overhaul the transportation system. To proceed beyond curative or patchwork efforts in establishing adequate wastewater treatments systems requires organization, planning, and resources within the context of a time frame. That time frame must include the short-term needs of the economically active environments which can lead to the long-term goals. Assessing economic and social costs has similar difficulties as experienced in assessing health costs. Economic and social benefits are a different matter, especially in terms of economic activity, so benefits could provide the necessary short-term goals.

An example of an assessment to compare long- and short-term impacts is demonstrated in the following table (Table 23). The listing was made to show direct and indirect impacts of conventional treatment system development. The adverse impacts are the same as those usually cited in the deliberations of project planning conferences, while the beneficial impacts have not been shown even though more economic activity could be demonstrated as noted by the author.

Effectiveness Balance

Effectiveness is the term now being used to balance all the rest of the system components. Included in the term, effective, are health implications, cultural implications, and social concepts as well as the process methods. These are discussed in detail in the following sections.

Utilizing a series of criteria for effectiveness measurements for systems applications of process methods the following have been used most

Table 23. Partial Listing of Direct and Indirect Impacts of A Sewage Treatment Plant

ADVERSE IMPACTS/Direct

	Primary Effects	Secondary Effects	Tertiary Effects
Short Term	Erode soil during construction	Degrade aquatic habitat of stream	Decrease fisheries
Long Term	Periodic release of noxious gases	Decrease surrounding property values	Change socio-economic composition of neighborhood*

ADVERSE IMPACTS/Indirect

Short Term	Construction employment	Temporary housing	Does not occur
Long Term	Permit-encourage residential development within service area*	Increase traffic on local streets	Traffic congestion, noise, smog

Note: Impacts are described for illustrative purposes only; a complete matrix for a sewage plant would contain many more impacts within each of the respective cells of the matrix. A separate matrix could be constructed for beneficial impacts.

*Irreversible impact.

SOURCE: Canter, Larry. School of Civil Engineering/Environmental Science, University of Oklahoma, Norman, Oklahoma, 1976.

often, namely, reliability, operational simplicity, automation, public acceptability and adaptability or adoptability. It is very probable that some or most of these will be used again when the final project or treatment system is selected to validate the selection.

Another way of measuring effectiveness for ecological analysis would be with the following or similar criteria:

1) Management of Production (Industrial Utilization)

2) Ecological Preservation (Nondegradation)

3) Pollution Control (Technical Assistance)

4) Levels of Acceptance (Community Participation)

5) Improved Property Values (Economic Incentive)

6) Improved Life Styles (vis-a-vis Health Benefits)

7) Management of Operation and Maintenance (Local Employment).

These measurements are the ones not so easily quantified. To avoid long written descriptions which do not speed the decision process the methodology and a formulating procedure sections assign scoring functions and weights to quantify the measures. The weighting based on the perception of the decisionmaker between pairs of choices leads to assignment of weight in final order to the number of times each criterion is selected as more important. This weight is then multiplied times the score given to the criterion originally to form the index. The final ranking with the highest index rating first shows the most preferable.

The use of this method makes it possible to consider consequences which could not otherwise be assigned a perceived value. It broadens the general decision making process so that social, economic, cultural, etc. criteria or requirements can be included during the decision making process.

Health Implications

For those wastewater systems which reduce or eliminate water usage in the treatment systems the health implications can only be viewed as beneficial. The role of water as a vehicle for the transmission of bacterial and viral diseases is well established in numerous health publications.[22] Control of water as a vehicle or intermediary transfer agent is necessary for health benefits in whatever system is adopted. Several different patterns of water-related disease transmission are recognized. Table 24 demonstrates the role of water to disease from some of these.

Many studies have shown the health benefits of sanitary facilities vs. non-facilities. Two such studies were conducted in rural populations. The Public Health Service program evaluated the health effects of the installation of basic sanitation facilities in American Indian homes. Analyses showed that the morbidity rates of the members of homes equipped with sanitary facilities were significantly lower than the morbidity rates of members of homes without such facilities for the two years during and after construction. There was no significant difference between the two types of homes before the installation of the facilities.[23]

The study by Schliessmann involved an extensive investigation among 62 rural communities (including 11 coal mining camps in eastern Kentucky) for the purposes of developing specific environmental control measures against diarrheal diseases (Table 25). It was found that the lowest rates of Shigella and Ascaris occurred among families served by complete facilities. A marked variation was demonstrated by the assessibility of the facilities.[24]

WATER AND HEALTH		
ROLE OF WATER	DISEASE	REMARKS
Major Vehicle for Direct Transmission	Cholera	Classic example of water-borne disease
	Diarrhea and Enteritis	Symptomatic of many infections and toxemias; often non-specific
	Dracontiasis (Guinea worm disease)	Ingestion of infected *Cyclops*; 50,000,000 active cases
	Hepatitis, Infectious	100,000 cases in 1955 Delhi outbreak
	Leptospirosis (Weil's disease)	A zoonosis; ingestion of urine of infected animal
	Paratyphoid Fever	Milder than typhoid
	Schistosomiasis (Bilharziasis)	Requires aquatic snail as intermediate host and water contact, with skin penetration by cercariae, or, less often, their ingestion; over 150,000,000 active cases
	Typhoid Fever	Major 19th-Century U.S. disease
Occasional Vehicle	Dysentery, Amebic (Amebiasis)	World-wide endemicity
	Dysentery, Bacillary (Shigellosis)	Many outbreaks due to cross-connections
Possible Vehicle	Poliomyelitis	Virus is found in sewage
	Pleurodynia	Non-fatal; Coxsackie virus
	Tularemia	A zoonosis; usually direct contact
Clean Environment (Lack of Safe Water)	All above except Schistosomiasis and Dracontiasis	
	Ancylostomiasis (hookworm)	Water-borne sanitation best preventive
	Ascariasis	Avoid ingestion
	Echinococcosis (Hydatidosis)	Food and drink contaminated by dog feces
	Enterobiasis	Personal hygiene
	Mycoses	Fungal diseases; personal hygiene
	Relapsing Fever	Louse-borne; poor sanitation
	Scabies	Personal hygiene
	Trachoma	150,000,000 victims with impaired vision
	Trichomoniasis	*Trichomonas hominus, Giardia lamblia*; contaminated food and drink
	Typhus Fever	Louse-borne; crowding, poor sanitation
Vector Habitat	Clonorchiasis	Ingestion of parasitized fish
	Dengue	Mosquito
	Diphyllobothriasis	Ingestion of parasitized fish
	Encephalitis	Mosquito
	Fasciolopiasis	Ingestion of water chestnuts containing cercariae
	Filariasis	Mosquito
	Loaiasis	Aquatic fly (*Chrysops*)
	Malaria	Mosquito
	Onchocerciasis	Aquatic fly (*Simulium*)
	Paragonimiasis	Ingestion of parasitized crabs and crayfish
	Rift Valley Fever	Mosquito
	Yellow Fever	Mosquito
Carrier	Chemical Poisoning	Natural and polluted waters; acute and chronic
	Radiation Exposure	Cumulative

Table 24. Role of Water in Disease Transmission

Prevalence Rates for *Shigella* by Date and by Selected Sanitary Facilities in Kentucky, California, and Georgia

Sanitary Facilities	Kentucky[a] 1954-56		California[b] 1952-53		Georgia[c] 1949-52	
	No. of Cultures	% Positive	No. of Cultures	% Positive	No. of Cultures	% Positive
Water and Flush Toilet Inside Dwelling	5,017	1.1	985[d]	1.6	2,988	0.4
Water Inside Dwelling Privy Outside	2,195	2.4	688	3.0	5,392[e]	2.2
Water and Privy Outside Dwelling	3,994	5.9	4,438	5.8	5,586	5.0
Water on Premises	1,988	5.8	–	–	2,791	4.1
Water off Premises	2,006	6.0	–	–	2,975	5.8

[a]Cultures from preschool children.
[b]From Hollister, et al. (1955). Cultures from children 10 years and younger.
[c]From Stewart, et al. (1955). Cultures from children of unspecified ages.
[d]Water and flush toilet and/or shower inside dwelling.
[e]Single source of water only inside dwelling.

Table 25. Diarrheal Diseases and Sanitary Facilities

A recent study about the separation of gray water from black water was made by Siegrist.[25] The following figure (Figure 28) was developed to demonstrate the average daily household water use in the U.S. From the results it was shown that grey water has potentially a much lower pathogenic and virus contamination than the black water. Black waters were also shown to contain the majority of nitrogen and suspended solids in addition to significant quantities of BOD_5 and phosphorus, and the majority of pathogenic organisms. Removal of such quantities of pollutants should facilitate the goals of health planners by minimizing the health hazards of any system malfunction.

The new emphasis being placed upon grey water as a separate entity is apparent in the first book on the subject by J. T. Winneberger, project director of California Management Districts, for the Governor's Office of Appropriate Technology. Approached from a pollution standpoint it deals exclusively with techniques for treating grey water and then discharging it on-site in a manner to insure the health and safety of the people and communities involved. Winneberger also makes a case for water reduction.[26]

The French who have long been pioneers in the advances of sanitary engineering and plumbing have recently published regulations emphasizing the separation of grey and black waters. Designated for rural and small communities where centralized sewerage networks are not possible the use of separate collection systems for both black waste and grey water is recommended.[27]

Many lower cost methods utilize the soil for treatment and disposal of wastewater. Containment of wastes still requires further treatment to insure health protection. In much of the developing world the use of soil

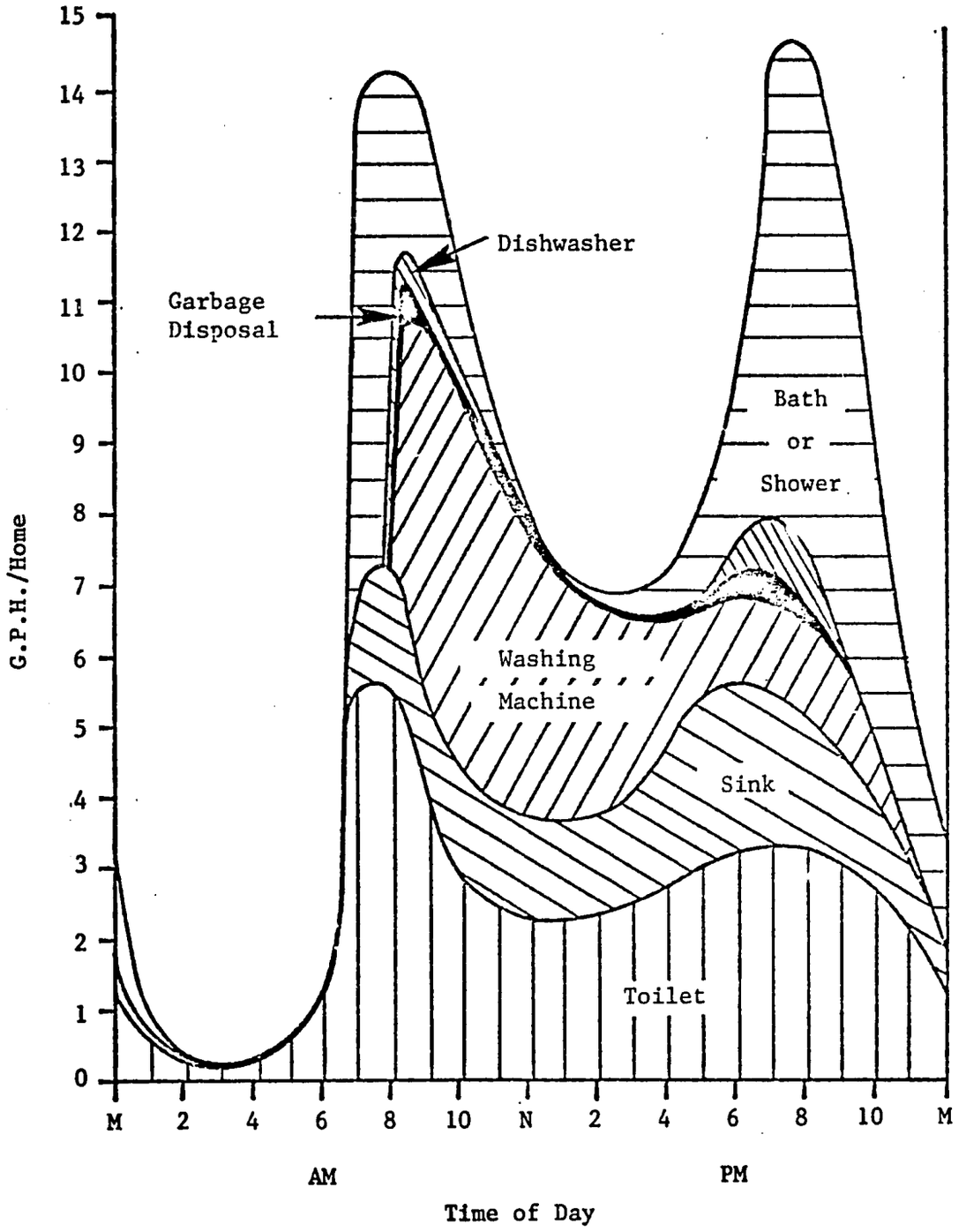


Figure 28. Daily Household Water Use

as a treatment is not possible during periods of high rainfall. The hydraulic characteristics of the soil cannot purify the liquid waste without absorption and movement through the soil at specified percolation rates. Consequently, systems which are installed under adverse soil conditions have little chance of success. In the septic tank-soil absorption system utilized in many parts of the world today the hydraulic characteristics of the soils are not conducive to either adequate absorption or purification. Only 32% of the total land area of the U.S. has soils suitable for the installation of septic tank systems.[28]

Cultural Implications

Acceptance of change in human habits regarding sanitation practices has always been a slow and difficult process. Clearly on the basis of the historical development of the toilet man has not immediately accepted technological advancement which affected personal habits nor has that acceptance been uniform once it was introduced. Only when change has been for comfort, simplicity of effort, financial improvement or an immediately recognizable benefit has the adoption been rapid.

Various methods have been used to stimulate such acceptance when change has been deemed important by decision makers for human health. Stimulants have typically been in the form of education, training, examples and/or sample experiences. These methods have consistently required a long-term commitment of manpower and/or financial resources.

Especially in developing countries where local customs have remained more or less constant, traditional behavior of man in regard to his personal sanitation habits are exemplified. Disposal of waste has been and

is still in one of two natural resource receptors. These are (1) stream or water and (2) soil, garden, ditch, or land application. In the Western United States there has been the following progression of events since settlement in the 1800's:

1. Stream or Hole
2. Out-house or Dirt Privy
3. Sanitary Pit Privy
4. Conventional treatment
   a. Septic tank
   b. Primary treatment
   c. Primary with lagoon
   d. Secondary
   e. Secondary with land application
5. Sewerless Treatment
   a. Incinerating
   b. Composting
   c. Biological
   d. Vacuum System
   e. Aerobic

Institution of new sanitary facilities in developing countries involves moving inhabitants from Step 1 to some form of Step 4 in one step. Step 5 which would be sewerless treatment would involve no less personal adjustment than Step 4 nor personal time commitment than was involved in Step 3 and 4a.

Toilet paper regarded as a necessity by United States housewives also reflects custom and is an unaffordable or unknown commodity elsewhere. Currently in Indonesian farm areas corn husks are used and in China bamboo leaves are typically used in lieu of paper. In india the right hand is reportedly used for food and left hand for feces in some sectors. Thus, reflecting what has been a universal custom of greeting with a shake of the "right" hand only, it appears to have been based upon necessity in former times. Only within the last thirty years has it been accepted for United States students to be taught to write with their left hand. In Greece the right hand is still referred to as the "good" hand and is

considered the preferred hand for children to use, the left hand being "bad" or "unclean."

Based upon known personal health habits, such as the use or nonuse of paper, and/or other materials for personal hygiene, it appears that any waste treatment system other than the ones currently used in local areas would require reorientation of residents to the new treatment regardless of the treatment process. The ease with which this could be done by Public Health Officials and the amount of effort required by users should be the influencing criteria. A review of the past in a listing of progressive events since the 1800's on the basis of public and personal time and monetary commitment should provide value in the final cost-effectiveness analysis.

Social Concepts

One of the greatest problems in accessing social concepts is the assignment of a numerical and/or quantitative values to qualitative measures of human perceptions and attitudes. To make such an assignment involves human factors analyses which have been shown to be so difficult to grasp that the reduction of any particular events or actions can lead to the loss of the originally distinguished concepts. Various governmental institutions or agencies in the U.S.A. have attempted to establish standardized measurement principles for social assessment through a variety of elaborate procedures. The guidelines written to require specific scientific inquiry by experts for the evaluation of environmentally related projects. Results of these inquiries has resulted in a broadening of the originally perceived "environmental impacts" and a loss of comparable and/or compatible measures which can be applied uniformly.

What can be measured in the assessment of a social environment though is the presence of interaction and change. This analysis is performed by taking a population whose choices are ranked from high to low, best to worst, or as positive and negative impacts for the purpose of demonstrating the relative differences of such rankings or ratings among the population. Common applications of the forms of rating are frequently printed in such indices as the Gallup Poll. From such an analysis values can be assigned which will portray a multi-dimensional scaling so that the relative values of social change can be measured for a proposed project. Through this comparison of the social concepts as they relate to an environmental development project it is possible to look intensively into the relationships of man to his environment. Limitations to the amount of variance, interactions among the social levels, and the selection of the most appropriate parameters can reduce the benefits of this sort of inclusion in the analysis. The weakness of including social concepts is dependent upon the actual selection of the concepts and their organization. Successes, limitations, and weaknesses are all functions of the researcher.

Decision Weighting Methodology

The evaluation procedure in the decision process is basically a motivating device. It assumes that people in most situations do not make decisions in a strictly rational manner.

The process rests ultimately on concepts of the psychological states of performance, aversion, and indifference. An individual is said to possess a positive preference for some object, activity, or situation if and only if its contemplation or experience elicits a positive emotional

feeling, and conversely, aversion or negative, if and only if its contemplation and experience elicits a negative emotional feeling. An individual is said to be indifferent to object, activity, or situations if and only if he possesses neither a preference for it nor an aversion to it.

Preference, aversion, and indifference are nonrational in nature. Yet, they do not refer to those cognitive correlates of emotions that are frequently confused with the emotion itself. Thus, justifications, explanations, and reasons for one's feeling must be clearly distinguished from the feelings themselves. That is, a value system should be generated and associated with the decision making process.

Consequently, the concept of worth or utility is defined as conscious perceptions held by the decision-maker relating to his underlying feelings of preference, aversion, and indifference. This includes not only direct awareness of the feeling themselves, but also the entire range of cognitive elements supporting such feelings. Conscious rationalizations, justifications, and explanations would all be included within the broad meanings of worth. So, the worth of any object or activity inherits in it the degree to which it or its consequences are perceived by a given individual in a given situation as satisfying his preferences.

Worth need not be the same or consistent for one or more individuals even under similar circumstances. Since everyone does not have the same experience and knowledge about a particular system their preference or aversions may change over time and according to circumstances.

Therefore, evaluation of worth or utility does not imply simply the measurement of the physical characteristics of an object or activity

itself, nor does it imply simply the measurement of the surrounding circumstances, but does imply the investigation by human beings. The decision maker observes the system's objects and activities and considers the existing environmental, social, political, and fiscal circumstances. He formulates the notions of worth, that is, his value system, and projects these notions onto the system's objects and activities. The comparison of wastewater disposal methods by Sylvester, et al., is presented in a matrix of weight assigned criterion (Table 26). Based upon final ratings method number one, the recycling and holding tank, was the most preferable for public rest areas.

This discussion of the decision making process seeks to show that any evaluation of worth is a subjective process. In order to seek limited objectivity in the sense of "freedom from particular biases," the decision-maker may be asked to follow some reasonable form of limited objectivity to delineate and formulate his preferences relative to specific decision making and the system alternatives available. Lack of "complete objectivity" may be the weak point of this concept. Yet, "complete objectivity" would require a random selection techniques, which could hardly be regarded as judicious to a decision-maker choosing between alternatives, especially if this decision is to be imposed upon his community or his elective choice.

Modelling efforts which have not demonstrated a degree of intervention for the decision-maker have been unacceptable and may have led to the rejection of otherwise preferable choices. Regardless of these speculations of the correctness of the evaluation of worth, in the final analysis, one cannot repudiate the fact that where alternatives exist, the decision-

Table 26. Comparison of Wastewater Disposal Methods+

+from the Sylvester, et al., "Rest Area Wastewater Disposal Study"

DISPOSAL METHOD	Simplicity	Provides Entire Treatment and Disposal Required	Treatment or Disposal Effectiveness, in Practice	Aesthetic Qualities, in Practice	Effect of Weather Extremes	Accommodate Load Fluctuations	Accommodate Extreme Loadings	Suitability for Use in Most Rest Areas	Cost	Corrosion; Vandalism; Hazards	Acceptability to Regulatory Agencies	Local Pollution Possibility	Summation Criteria Ratings	Rating
Chemical Toilet	7	5	8	1	5	4	4	1	7	2	6	6	56	5*
Holding Tank (Dry)	8	4	6	2	8	5	7	7	8	5	7	7	74	3*
Septic Tank System	6	8	4	3	7	6	5	4	4	8	8	4	67	4
Ponds (evaporative)	5	7	9	5	4	8	8	5	5	7	9	5	77	2
Recycle & Holding Tank	4	6	10	8	6	7	6	8	6	6	10	8	85	1
Physical-Chemical Treatment	2	3	5	7	3	2	3	3	2	3	4	3	40	7
Biological Tr't (Package)	3	2	7	6	1	3	1	6	3	4	5	1	42	6
Proprietary Processes	1	1	3	4	2	1	2	2	1	1	3	2	23	8
Weight assigned criterion	8	8	10	8	8	8	8	8	8	8	10	8	100	

*These methods are unsuitable for most major rest areas.

maker must make a choice. His task is to ensure he assesses all factors in such a manner that the true conceptual worth of all alternatives if revealed. An outline of the procedure is as follows.

Formulating Procedure

Establishing Overall Objectives

Once a decision situation is cited and several meaningful alternative actions have been defined, the first step in formulating an evaluation is to specify what is desired, that is, listing the objectives, goals, missions, or purposes. These represent the overall performance objectives.

Generating Subcriteria

After listing overall performance objectives, describe in detail what they mean. This is accomplished by a process of repeated conceptual subdivision. Each objective is divided into one or more lower level factors. During this process it may be necessary to revise either the objectives or the number of criterion.

Selecting Physical Performance Measure

The next step is to select a single physical performance measure for each lowest level or sublevel factor without violating the character of each objective. A way to insure this is to reverse the process by trying to identify the objectives from the measures. By this process, the subjective-worth structure of a decision maker and the objective physical world of alternatives are closely related. When quantitative measures of worth are assigned to various situations, great care must be taken in designing the assessment procedure. Relationships between assigned numbers must faithfully reflect perceptions of the relative worth of each factor to

the objectives of the real worth environment.

Formulating Scoring Functions

Scoring functions are formulated to establish specific worth relationships or values between each lowest-level criterion and its associated performance measure. A scoring function is a mathematical rule that assigns a unique-worth score or utility score to every possible value of some physical performance measure. It transforms raw performance, measured in terms of whatever physical unit is appropriate to the performance measure under consideration into a worth of performance. This is measured in terms of the worth scoring or utility. This, in effect, serves to bridge the physical characteristics of the alternative with a worth structure. It also serves to smooth values of raw performance which can be measured only by approximate ranges. To insure consistency in the scoring conventions the following ground rules are applicable:

1) The outputs of all scoring functions will be in terms of worth point or utility point.
2) Positive numbers (+) will be assigned to situations evaluated as possessing positive worth, that is, toward which a positive preference is felt.
3) Negative numbers (-) will be assigned to situations evaluated as possessing negative worth, that is, toward which an aversion is felt.
4) The worth scale is bound by plus one and minus one. (+1, 0, -1). All real numbers between the range are allowable. Plus one will be used only where complete satisfaction is to be accomplished

for the job objective. Conversely, minus one will be used only where worth is logically possible in terms of the stated job. Zero will be assigned to situations toward which indifference or neutrality is felt.

5) Two situations will be assigned equal worth numbers if and only if they are evaluated as possessing identical worth, that is, a decision-maker feels indifference in choosing between them. A higher worth number will be assigned to situation "A" rather than situation "B" if and only if situation "A" is thought to possess more worth.

6) Situations evaluated as partially successful in accomplishing positive objectives will be assigned according to their proportional or percentage accomplishment of the stated objectives with numbers between zero and plus one. Conversely, numbers between zero and minus one will be assigned to situations evaluated as partially successful in accomplishing negative objectives according to their proportional or percentage accomplishment of the stated negative objectives.

7) The entire range of logically physical performance should be covered when formulating the scoring functions. Most scoring functions will be formulated in terms of mathematical formulas and/or graphically characterized mathematical curves. However, some will be assigned without the aid of either formulas or groups.

8) All scoring functions will be formulated by means of a single, uniform, and replicable procedure. The process is divided into two sequential stages. The first stage contains a series of

questions designed to determine the general nature and shape of the functions. The second stage of the scoring process consists of a function of the general nature and shape identified in the first stage.

Assigning Weight and Indexing

The last steps in the evaluation procedure are to combine worth scores assigned on the basis of separate performance criteria or mission requirements to a single, overall index of worth and to adjust the effective weight for each physical measure to derive a utility index to aid the decision maker.

A weighting function is a conceptual device that recognizes both the existence of multiple objectives and the differential importance of satisfying them. At the beginning, all the factors subsummed under a given high-level criterion are ranked following the descending perceived order of importance. Then, starting with the most important pair of subfactors, successive pairing comparisons are made between contiguous subfactors. The decision maker is asked to indicate the degree of perceived relative importance of the two. A value of one is assigned to the topmost factor, then the second is compared to the first and its importance evaluated in terms of ratio or fraction. The third subcriterion is then compared to the second, and again a relative importance is assigned. Successive paired comparisons are quantified in this manner until the list is exhausted. The weights are then summed, each divided by the total, and are reported as normalized weights.

The indexing of these worth points must then be resolved with the adjusted effective weight for each physical measure to derive a utility

index for decision making. This simply involves multiplying the worth of each criterion by its corresponding adjusted effective weight for each alternative. The sum of these products is the utility index for the alternative. The alternative then with the highest utility index indicates the preferred alternative.

CHAPTER VI

COST-EFFECTIVENESS GUIDE

This guide has been prepared as a reference or aid for use in selecting appropriate wastewater treatment systems in developing countries. It is not intended to supplant the need for engineering or health consultants in the actual selection of appropriate facilities. Its particular value should be found in waste problem areas where conventional systems have not been successful and for areas of unserved population not amenable to sewerage. It is intended to encourage environmentally sound policy planning in developing countries.

To prepare the guide the sewerless alternatives were reassessed in light of the previous findings that were presented in Chapters I through V of this report and evaluated in a cost-effectiveness format. Some reiteration of previously presented information also was necessary in the guide in order to perform the final evaluations. From the review of sewerless alternatives the material on the systems was divided into two sections: 1) manufacturing cost analysis and 2) alternative costs and effectiveness.

Since the obvious purpose of any guide is to lead, steer, or engineer a way to avoid or overcome difficulties some basic assumptions had to be made. Objectives were then set forth before proceeding with

the presentation of the sewerless alternatives.

Basic Assumptions

Sewerless treatment systems occupy part of the waste disposal facilities market in several countries. The manufacturers are actively marketing their respective products where ever they can. Marketing emphasis is taking place in developing and developed countries.

Unexpectedly high costs are occurring from the extention of higher waste discharge standards for community waste treatment facilities. In particular, communities under 50,000 population are sometimes experiencing costs with conventional treatment systems which are higher than residents can or are willing to pay for such services.

Extention of conventional systems into areas under 10,000 population has sometimes required 100% financing of some extremely high cost projects while consideration for less costly replacement alternatives continues.

Survey results have shown that centralized collection systems are not sufficient motivations for new industrial development in smaller communities. Many industries are required to treat or pretreat their wastewater prior to discharge into local facilities or streams. With smaller community facilities, in particular industrial treatment, standards are beyond the capability of conventional waste water treatment systems.

Changes have taken place in the last four years in the U.S. to lead national and international environmental policy makers and engineers to explore new and unusual methods. Traditional approaches have been proven to not always be appropriate or cost-effective in

diverse applications.

Changes have taken place in the last five to seven years to lead international engineers and health officials to seek alternate technology because the rate of sewerage construction has fallen behind world population growth.

Since over 200,000 sewerless units have been sold in the last ten years in the U.S. Sewerless systems have demonstrated their effectiveness, appropriateness, and acceptability to a large segment of the population. (Because of regulations and lack of recognition it would be arbitrary to limit the systems in their effectiveness evaluation).

Reluctance among federal officials to accept new technology in on-site units will fade as their public acceptance increases. That reluctance has obviously lingered in part because of the difficulty in administrating federal grand funds on a regional basis to individuals.

Growing state responsibilities in the functional application of federal program grants and surveillance activities should also increase the potential for on-site facilities funding.

The higher unit costs from low volume production of on-site systems and the lower capital investment requirements for current manufacturing operation are limiting growth of market. Presently the sewerless systems are being merchandised for vacation homes, isolated residential areas, industries, and public transportation carriers (such as railroads and airplanes). These markets are usually financed by private lending institutions or other agencies than those that traditionally finance conventioanal wastewater treatment type activities.

These basic assumptions are highly conditioned by U.S. practices. In summary with exclusive reference to developing (third world) countries it could be assumed.

1) That sewered and centralized sewage treatment may not be the solution to all needs in every city or community.

2) This is particularly true of the needs in large African and Asian cities, such as, Binh Dinh, Tiapi, etc, where 6-7% of the cities have sewers.

3) An alternative to the sewerage system and central plant concept is the on-site treatment plant. This may vary from hydraulic and biological systems to those requiring energy.

4) The selected alternative may not be constrained by lack of energy as AID and other programs have sought electricity as a social good.

5) Non structural solutions should include at least three management approaches in the analysis of on-site alternatives.

    a) Private enterprise

    b) Private enterprise for unit construction and public for installation and management

    c) Public management and process manufacturing.

6) Mixed strategies in on-site selection maybe the solution, that is, both on-site and aggregate systems from various levels.

OBJECTIVES OF THE GUIDE

Setting forth a list of the objectives for the guide has served for the most part to synoptically present the goals set for the entire study.

The overall goal was to produce a cost-effectiveness analysis of sewerless systems. Within this activity other goals were imperative to insure that the finished product was compatible with AID's mission of health and socio-economic benefits for developing countries.

Manufacturing

Perform a cost engineering analysis on a represnetative sample of the sewerless systems to determine cost breakdowns.

Project the current production costs of those systems to a higher production level for comparision with conventional treatment systems cost in the alternative Costs and Effectiveness section.

Relate the costs of low and high level production to developing country rates.

Alternative Costs and Effectiveness

Prepare a cost-effectiveness analysis of sewerless systems.

Display sewerless systems vs conventional systems in a format for the comparison of alternatives of production, operation and maintenance, and time.

Field-Site Selection Model

Prepare a field site selection model considering technical, economic, social, political, and cultural factors which might effect acceptance or utilization of sewerless methods.

MANUFACTURING COST ANALYSIS

Manufacturers have been contacted throughout the project for cost data, brochures, and operational manuals on their products. They were again contacted by letter for their input prior to the completion of

this report. From the responses a representative group of manufacturers were approached with the following explanation.

List of Representative Group of Manufacturers

Incinolet	Research Products Dallas, Texas	214/358-4238 Dr. Blankenship
Destroilet	LaMere Walworth, Wisc.	414/275-2171 Robert Ward
Clivus Multrum	Clivus Multrum USA Cambridge, Mass.	617/491-5821 Abbey Rockefeller
Toa Throne	Enviroscope, Inc. Corona delMar, Calif.	414/257-1830
Ecolet	Ecolet Milwaukee, Wisc.	414/257-1830 Pam Krawczyk
Bio Flo	Pureway Corp. East Moline, Ill.	309/755-2116 Jerry Guinn

Explanation Given with Questionnaire

What we are trying to do is develop a production function for various types of units. We'd like to be able to compare these different types on more than one level, such as cost, so that we can better approximate the results of field applications. In other words if selection is made only on cost then some units which might be otherwise be very successful would not be considered. Conversely, if a selection were made of the least expensive unit, that unit might be very unsuccessful when applied in a field situation.

Using the following questionnaire the representative group of manufactureres were asked for specific information about their products to upgrade previous data or answer new questions (Table 27). Their

information was than used to produce the cost table (Table 28).

Table 27 Cost Questionnaire

1. Company Name and Spokesman
2. Standard Domestic Unit Name and/or Number
3. Unit cost for one domestic unit in U.S. dollars.
4. Is unit price all inclusive?

Wholesale	Retail
$_____	$_____

5. Are there distributorships on how do you market?
6. What are the savings in cost if a larger number of units were ordered?
7. If more units were ordered than the number required for the minimum wholesale price, would there be a further reduction in price.
8. What kind of quotes have you been able to give in the past for various numbers of units?
9. What is the cost breakdown for the general categories of materials, labor, fixed costs, and other expenses?
10. Have you ever contemplated manufacturing in another country?
11. If the units are marketed or manufactured outside the U.S., in what countries?
12. What type of financial arrangements have been made for foreign sales?

Table 28. Cost Table of Sewerless Manufacturer

Incinerating	List	Wholesale	1000-5000 Volume prod./unit
Destroilet	$599	$449 ($345)	$360 ($277)
Xpurgator	$1,044*		
Incinolet	$799	$552 @ 30% profit	$351 @ 30%
"Carefree"		($457)	($270)
"Carefree" kit			$200
Composting			
Clivus	$1,685		$200
Community Prod.		$605	
Toa Throne	1045	$732	$697
Ecolet	736*		
Mull-Toa	795*		
Bio Loo	795*		
Biological Toilet			
Mod A	980		
Mod 75	1400-1700*		
Bio Flo.			
#512	402		

* It is felt that large scale production should provide a figure of 30-40% less for these systems. This level to date has not been attempted.

Ref. 1972 Census of Manufactures	Labor Total	% Prod. (Wages) Labor	Value of Shipments [1]			% Prod. by Large Companies*
			% Material	% Value [2] Added	% Value Added Less Labor (Overhead + Profit)	
HseHld. Cook. Equip. 3631 **	.22	.15	.57	.44	.22	71
HseHld. Refrig. & Freezers 3632	.18	.14	.55	.46	.28	100
HseHld. Laundry Equip. 3633	.16	.13	.51	.50	.34	100 (20 Co.)
Elect. HseWares and Fans 3634	.22	.15	.46	.56	.34	32
HseHld. Vacuum Clrs. 3635	.21	.15	.38	.64	.43	100
HseHld. Sew. Machine 3636	.34	.26	.23	.78	.44	71
HseHld. Appl. 3639	.18	.12	.53	.50	.32	76
Misc. Plastic Product 3079	.25	.17	.45	.56	.31	5

* Percent of shipping accounted for by 50 largest companies

** Four-digit codes are Product Groups from either companies or establishments

Table 29. Labor, Material, and Overhead for Certain Product Groups Shipped by Large Companies

[1]Value of Shipments -- Net selling values, f.o.b. plant, after discount and allowances and excluding freight charges and excise taxes.

[2]Value added by Manufacture -- Value added by manufacture is derived by subtracting the total cost of materials (including materials, supplies, fuel, elevtric energy, cost of resales and miscellaneous receipts) from the value of shipments (including resales) and other receipts and adjusting the resulting amount by the net change in finished products and work-in-process inventories between the beginning and end of the year.

These values were placed on the manufactured shipments from industries producing similiar product groups.

Projected Production Levels

Under current production levels at low volume demand the two incinerating units, or units 1 and 2 (Table 30 & 31), were found to closely resemble the vacuum cleaner manufacturing industry (Table 29). In the interview with the manufacture of Unit 2 the plant manager described their assembly operation to be very labor intensitive similiar to that of a sewing machine. The interview of the Unit 1 manufacturer produced a description of an assembly operation similiar to that of a vacuum cleaner. Based upon the cost breakdowns indicated for parts of Unit 1 and 2's operation, Unit 2 was allocated slightly higher labor and overhead cost (because of northern U.S. location) than Unit 1.

Projections of high production levels was estimated for both Units 1 and 2 to be similiar to that of the electric housewares and fans manufactureres. This similiarity was assumed on the basis of component parts of the units. Unit 2 was again allocated a higher percentage for labor cost based upon their labor intensive statement

Table 30 Incinolet in Estimated High Production

Unit I Retailing at $800/unit

	low production volume $/unit	Manu. Costs (%)	Manu.Costs incl.profit (%)
Materials	200	47	36
Labor	125	29	23
Fixed Costs	100	23	
	$425	100%	
@ 30% profit	127.50	all other	41
	$552.50		100%

New Retail at $500/unit

	high production volume 1000-5000 units $/unit	Manu. Costs (%)	Manu. Costs incl.profit (%)
Materials	159	59	46
Labor	60	22	17
Fixed Costs	50	19	
	270	100%	
@ 30% profit	81	all other	37
	351		100%

Table 31 Destroilet in Estimated High Production

Unit 2 Retailing at $599, Install $150-200 = $650-700

	low production volume $/unit	Manu.Costs (%)	Manu.Costs (%)
Materials	148	43	33
Labor	108	31	24
Fixed Costs	89	26	43
	345	100%	100(+)%
@ 30% profit	104		
	$449		

all other

Retailing at $449

	Volume Wholesale 25-30 $/unit	Manu.Costs (%)	Manu.Costs incl.profit (%)
Materials	137	49	38
Labor	76	27	21
Fixed Costs	74	27	
	$277	100%	
@ 30% profit	83		
	$360		

all other 41(+)
100(+)%

Retailing at $360

	high prod. volume 1000-5000 units $/unit	Manu.Costs (%)	Manu.Costs incl.profit (%)
Materials	119	55	44
Labor	59	27	22
Fixed Costs	38	18	
	$216	100%	
@ 25% profit	54		

all other 34
100%

and the higher number of component parts required. A higher profit margin potential was shown for Unit 1, especially, if fixed costs could be reduced further.

The evaluation of Unit 3's low and high production volume was much more difficult to formulate based upon the information provided (Table 32).

Assuming that the high volume would produce cost structure similiar to that of other misc. plastic products (Table 29) the manufacturer's highest discount rate for 1000 to 5000 units was used. Utilizing in over-all operating cost structure for misc plastics and allowing for a 30% profit level Unit 3 was provided with the estimated manufacturing costs shown in the final example of Table 32.

Working backwards from that high production estimate the volume wholesale and low production volume costs provided by the manufacturer were used as final unit costs allowing for: a suitable profit margin, an increase for materials costs due to reduced price quantity breaks, and an increase in fixed costs for the overhead allowance. This resulted in the low and moderate volume production figures as shown. The manufacturing costs for low and moderate (volume wholesale) production showed a percentage distribution somewhere between the Electric Housewares and Fans Industry and the Household Laundry Equipment Industries in group costs.

Table 33 contrasts the LDC unit costs to that of developed countries. By substituting such a ratio then adjustments can readily be made for the comparison of waste treatment systems.

Table 32. Toa Throne in Estimated High Production

Unit 3

Retailing at $1045

	low prod. volume $/unit	Manu.Costs (%)	Manu.Costs incl.profit (%)
Materials	406	60	46
Labor	160	24	18
Fixed Costs	114	17	36
	680	100%	100%
@ 30% profit	204		
	$884		

Retailing at $952

	Volume wholesale 500-1000 $/unit	Manu.Costs (%)	Manu.Costs incl.profit (%)
Materials	337	60	46
Labor	146	26	20
Fixed Costs	80	14	all other 34
	$563	100%	100%
@ 30% profit	169		
	$732		

Retailing at $806

	high prod. volume 1000-5000 units $/unit	Manu.Costs (%)	Manu.Costs incl.profit (%)
Materials	307	59	43
Labor	144	28	21
Fixed Costs	65	13	all other 35
	$516	100%	100%
@ 35% profit	181		
or	$516		
@ 30% profit	155		
	671		

United States

Unit Cost + C_1X^n (Capital, including profit)

C_2X^m (Labor)

C_cX^p (Materials)

C_4S^q (Fixed) Costs

$\mu C_1 = C_1X^n$

$\mu C_2 = C_xX^m$

$\mu C_3 = C_3X^p$

$\mu C_4 = C_4X^q$

So, $\mu C = C_1X^n + C_xX^m + C_3Xp = C_4X^q$

For developing countries, (LDC's) substitute:

$$C_2X^m \frac{LDC}{DC} = \mu_1$$

unskilled

$$C_3X^p \frac{LDC}{DC} = \mu_2$$

skilled

So, $C = C_1X^n + C_2X^m\mu_1 + C_3X^p\mu_2 + C_4$

Table 33. Unit Cost Formula for Developed and Developing Countries (LDC)

Developed Country Rates

Figures 29-40 contrast the low and high production rates in units per dollar for Total Cost, Materials, Labor, and Fixed Costs. Figure 41 shows the manufacturing costs for all three units with volume production.

Related Costs of Low and High Level Production to Developing Countries

Utilizing the manufacturing cost data developed for three sewerless systems, Tables 30, 31, and 32, the potential savings in developing country application was sought. The low and high production levels showed obvious and traditional reductions in costs. The production systems can be anticipated to behavior in a similar manner to other industries such as that of ewing machines, appliances, and miscellaneous plastic products.

The third column in Tables 30, 31, and 32, is the manufacturing costs including profit at different levels of production which is comparable to statistics from the Census of Manufacturers, Table 29. The relationship of the third column percentages, to those of other industries in Table 29 can be determined by comparing the Materials to the % Materials under Value of Shipment, the Labor to the Labor Total, and all other to % Value Added Less Labor. For example, Unit 1 with a low production level showed manufacturing costs at 36%, 23%, and 41%. This cost distribution is similarly found in the production of the Household Vacuum Cleaner Industry, 3635, at 38%, 21%, and 44%.

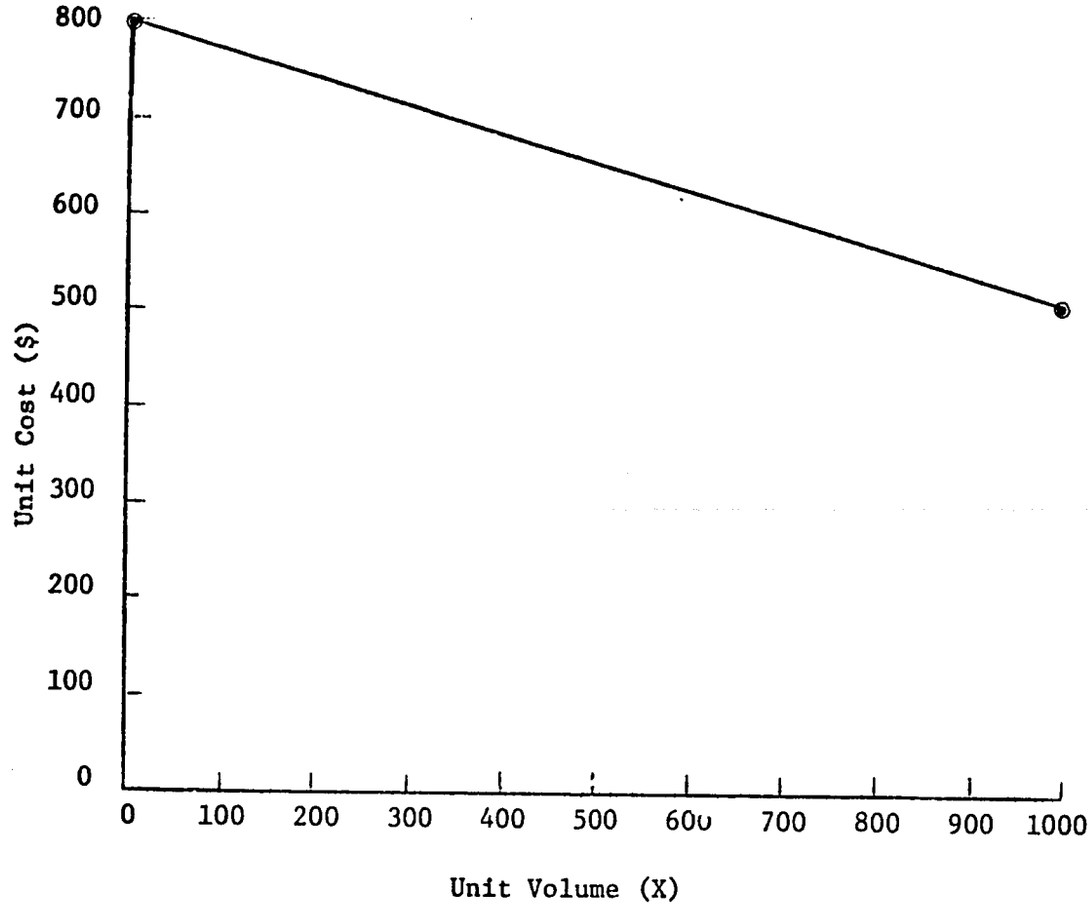


Figure 29 Unit 1 Cost Reduction with volume

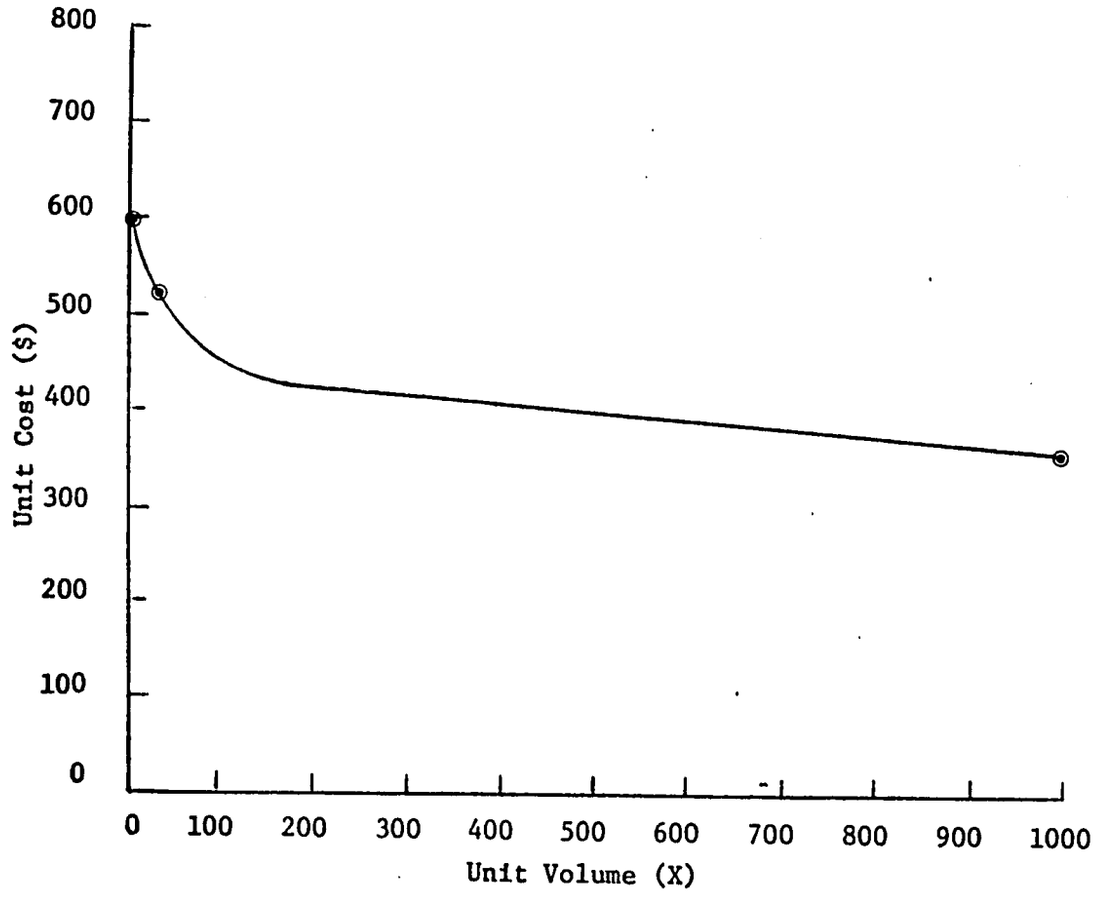


Figure 30 Unit 2 - Cost Reduction with volume

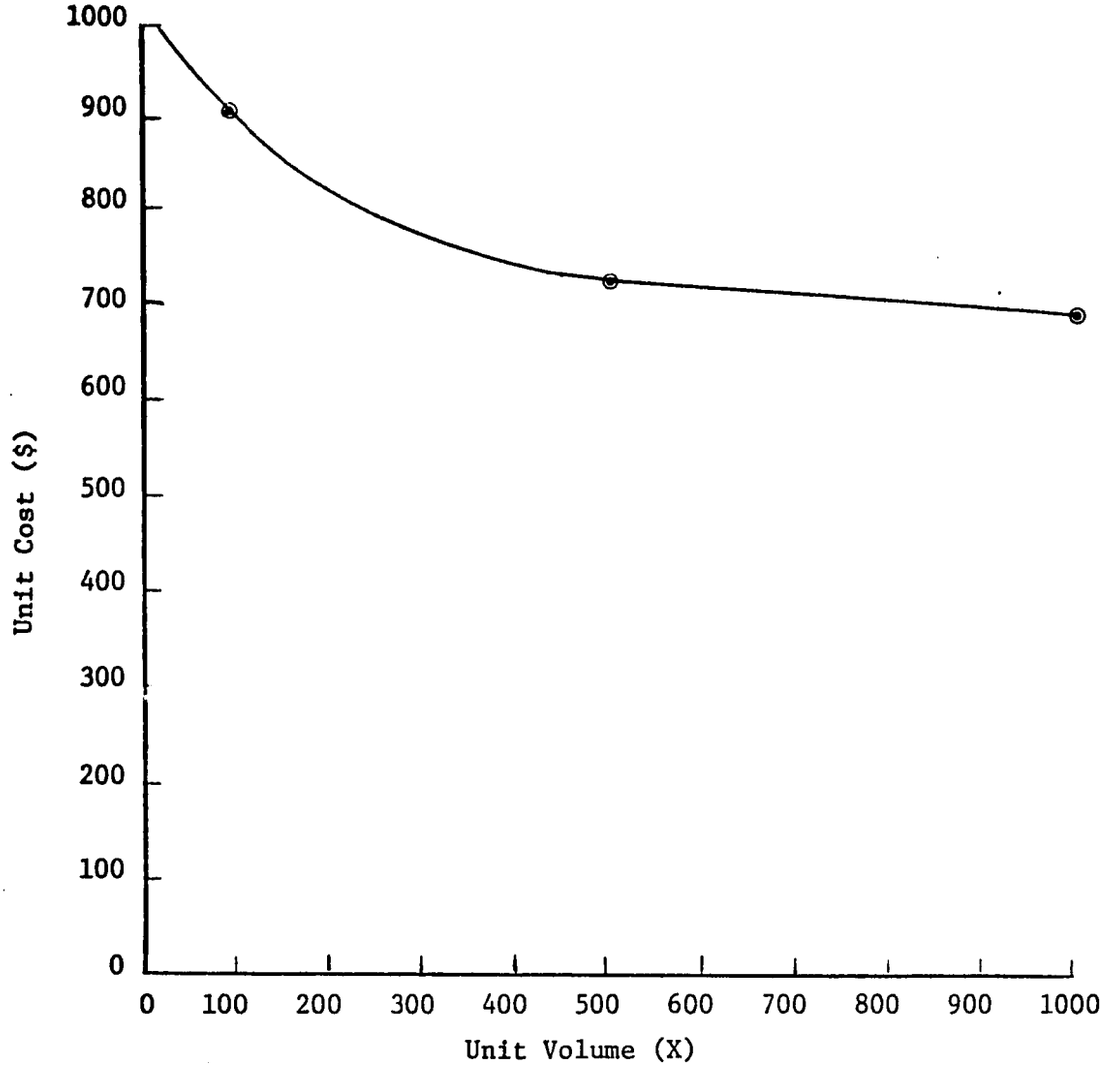


Figure 31 Unit 3 Cost Reduction with volume

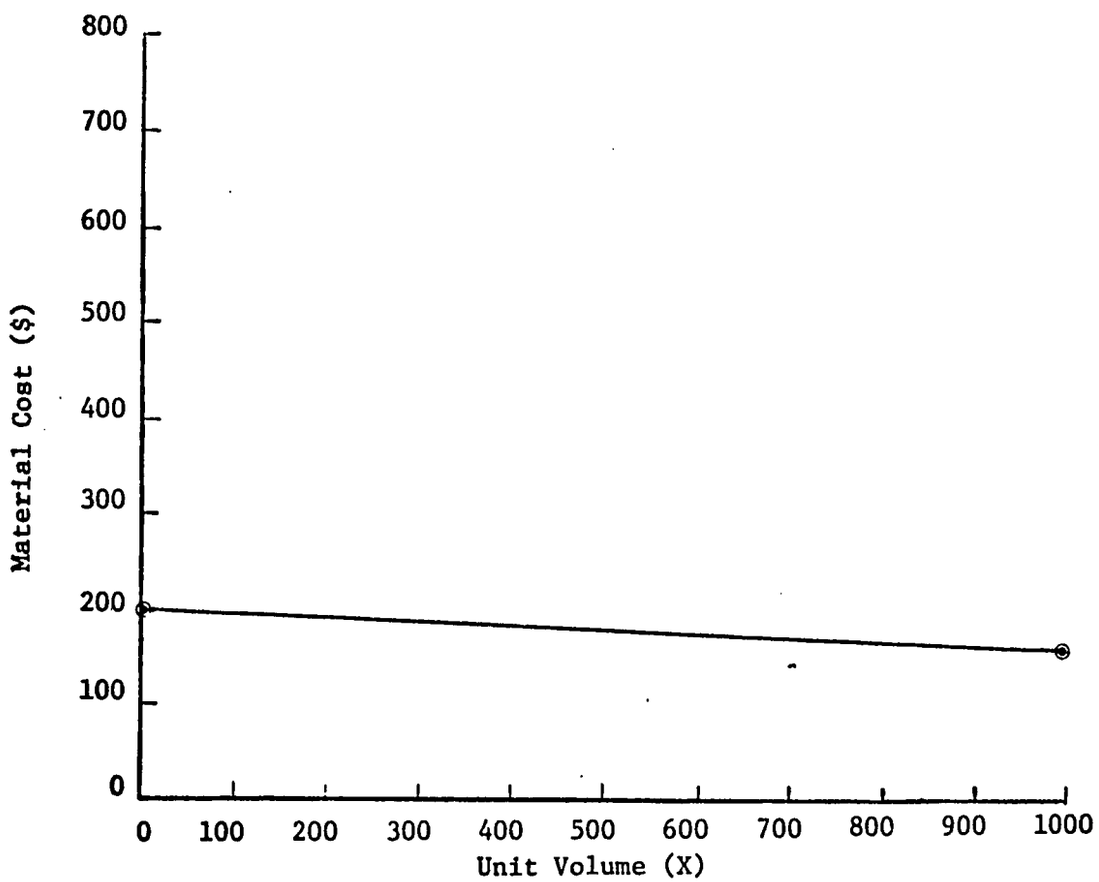


Figure 32 Unit 1 - Materials with Volume

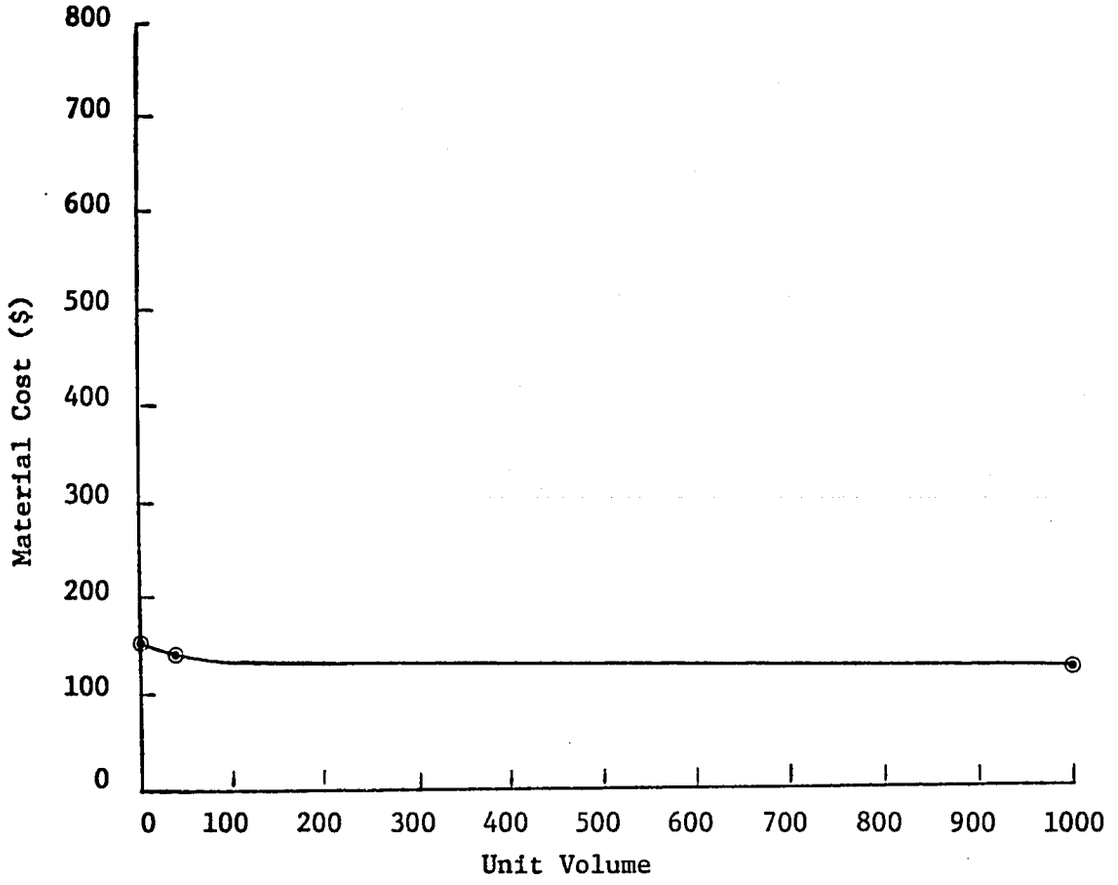


Figure 33 Unit 2 - Materials with volume

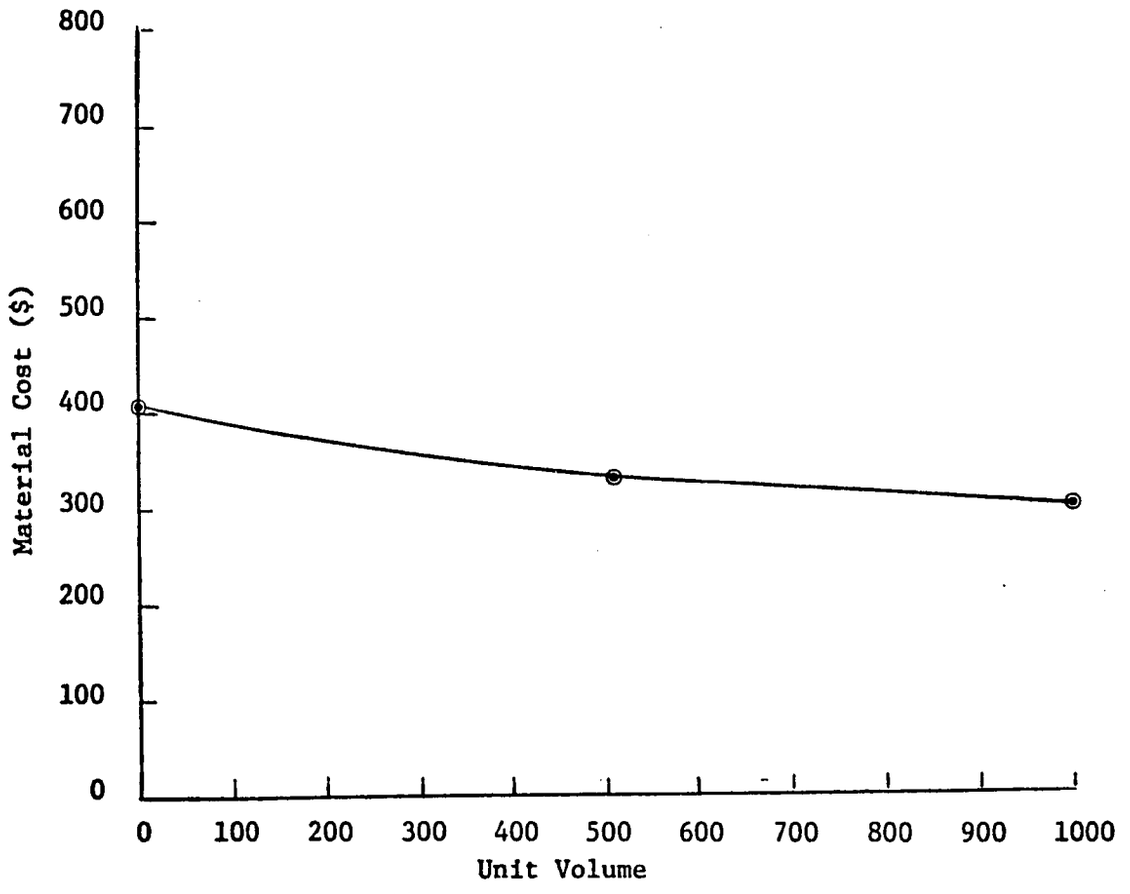


Figure 34 Unit 3 - Materials with volume

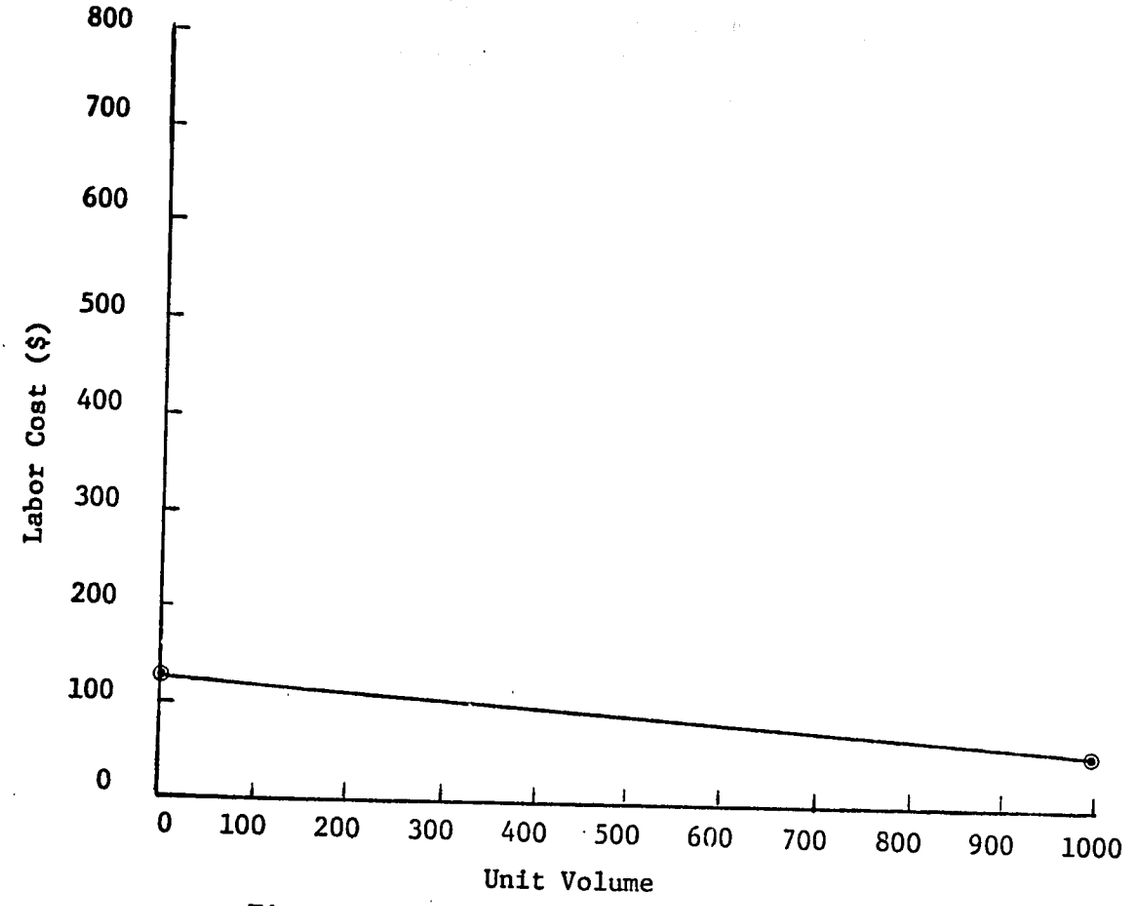


Figure 35 Unit 1 - Labor Costs with volume

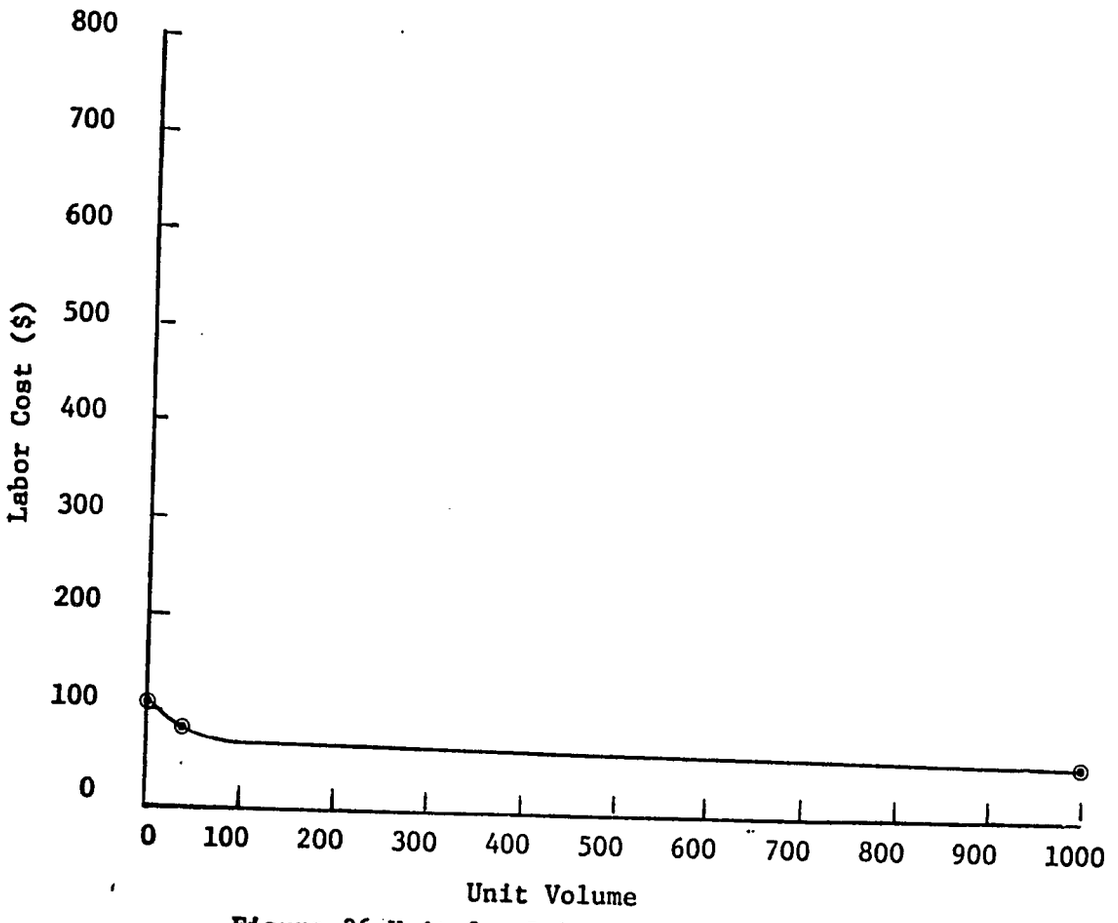


Figure 36 Unit 2 - Labor Costs with volume

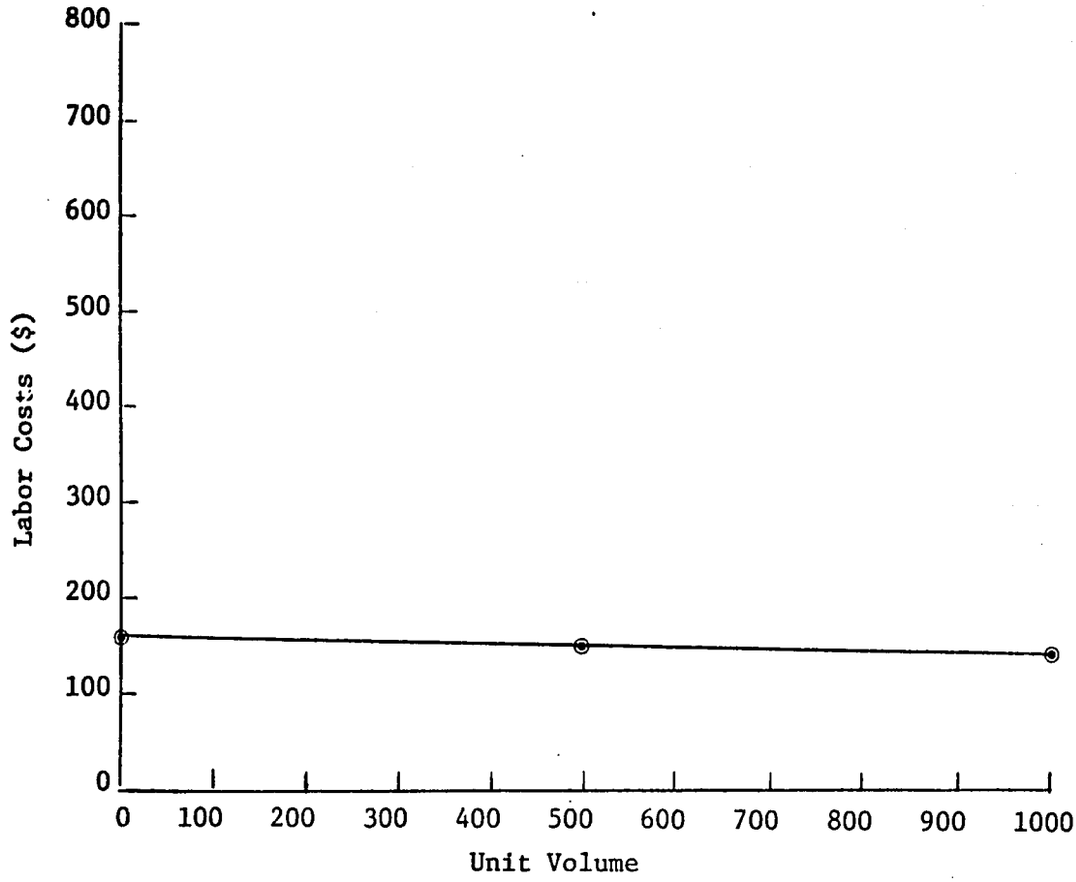


Figure 37 Unit 3 Labor Costs with volume

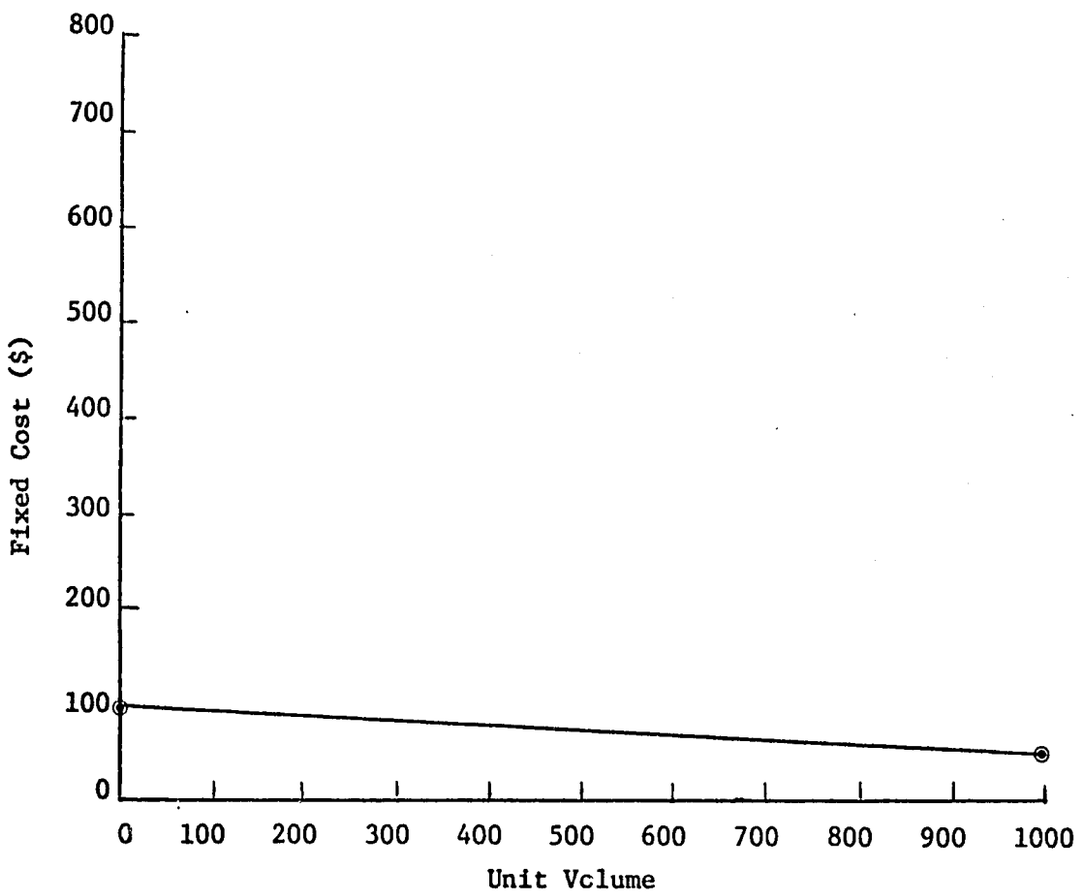


Figure 38 Unit 1 - Fixed Costs with volume

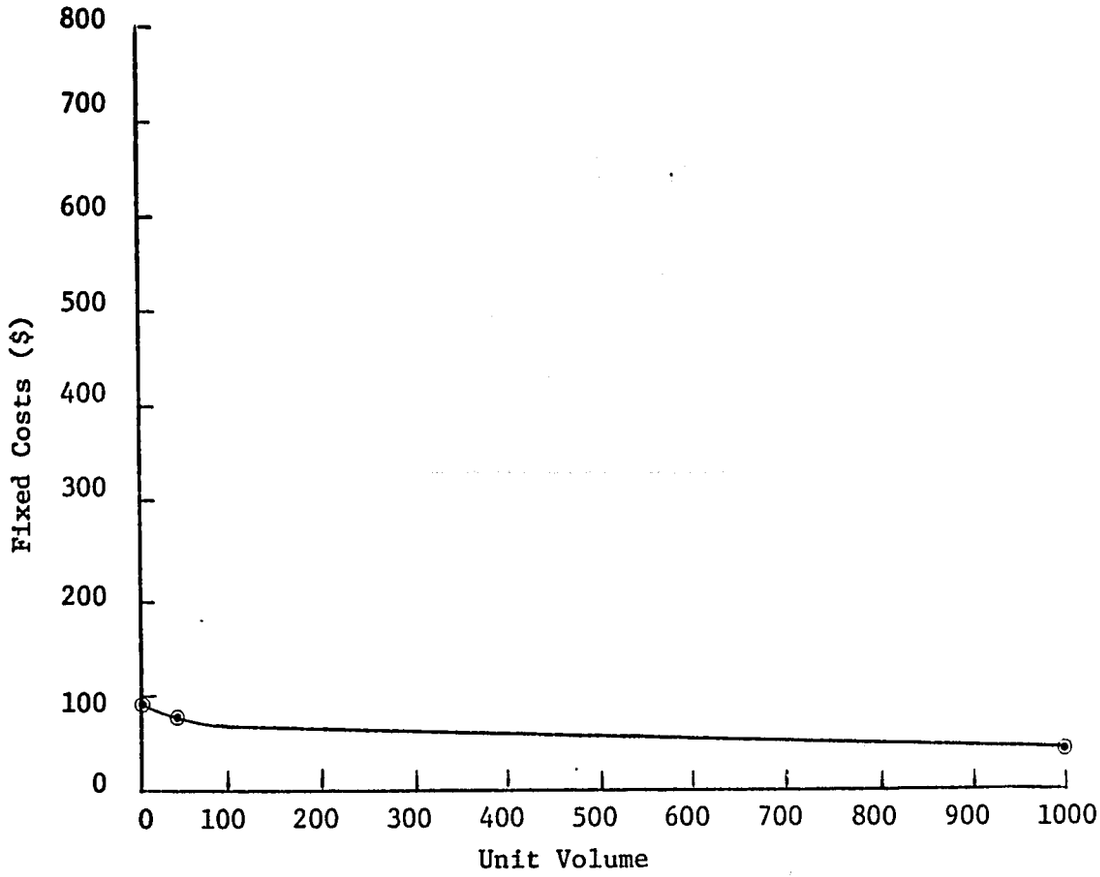


Figure 39 Unit 2 - Fixed Costs with volume

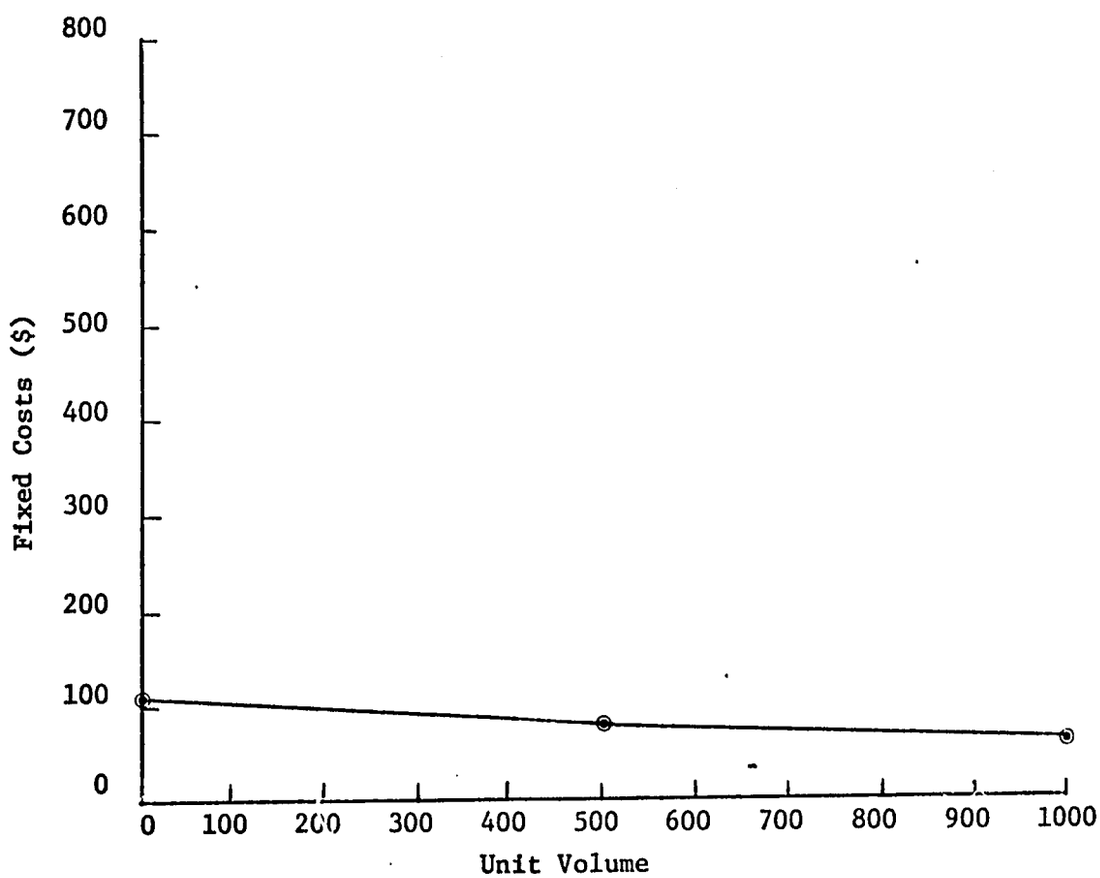


Figure 40 Unit 3 - Fixed Costs with volume

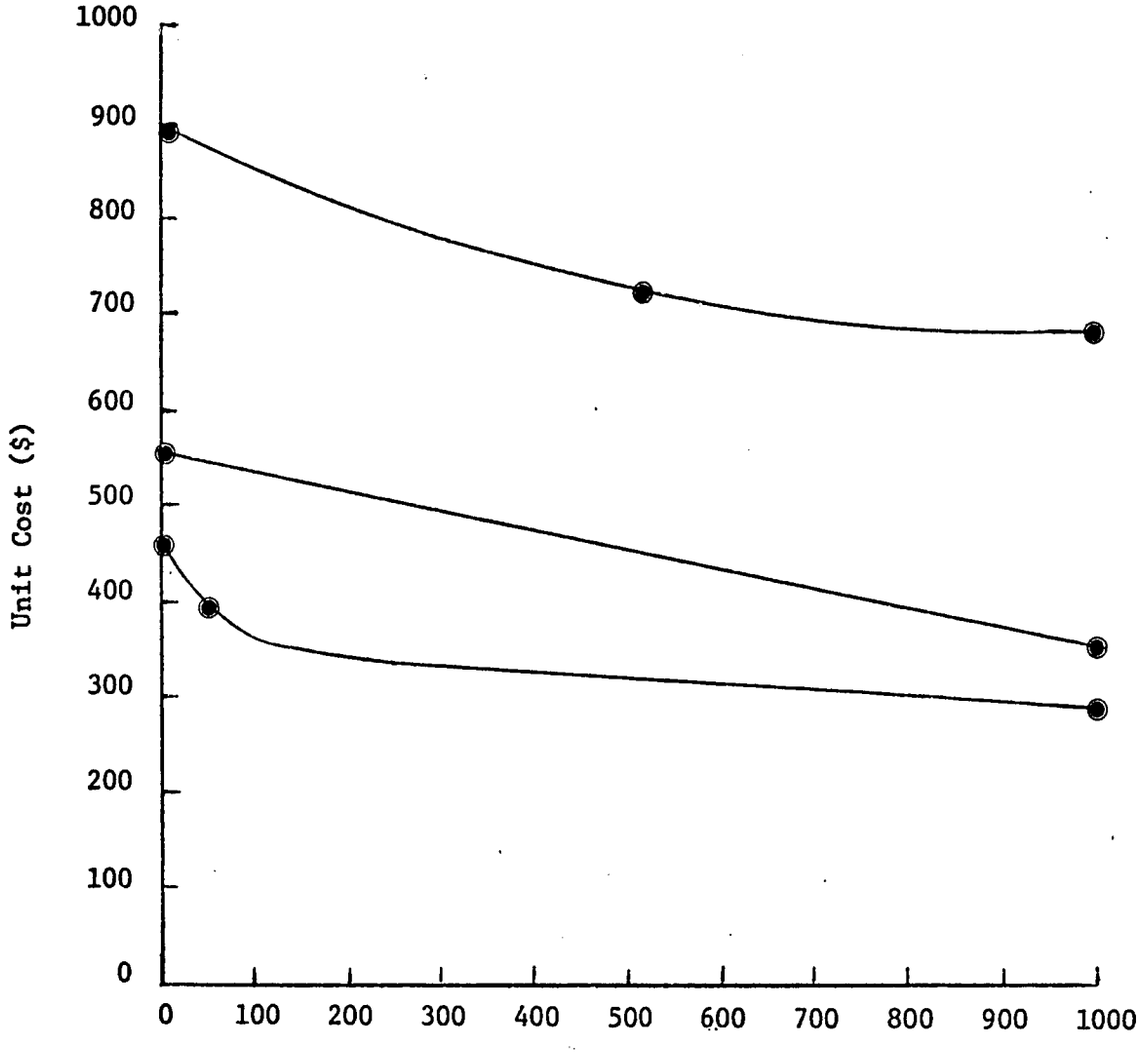


Figure 41 - Manufacturing Costs with Volume Production

By stepping up the level of production though Unit 1 showed a different cost picture. Manufacturing costs at a higher volume produced a new retail sales of $500 per unit with a percentage breakdown of 46, 17, and 37%. This is comparable to that of 46, 22, and 34 percent for the Electric Housewares and Fans Industry 3634.

The manufacturing process for the incinerating system exemplified in Unit 1 and the number and types of material-parts components showed a great similarity to that of the Electric Housewares and Fans Industry. Such similarity could have been expected. The fact that the cost breakdown of Unit 1 was so close to that experienced in the Housewares and Fans Industry is encouraging though for future development of the Unit 1 Industry.

The other two units, Units 2 and 3, showed the same sort of pattern when their levels of production was also stepped up.

A review of industry wages which were available for five countries was developed, Tables 34, 35, and 36, to provide the following comparison of Developing Country Rates. Taking the previously established costs and the production level projections the relative labor rates was substituted for U.S.costs. Some in-country substitution of materials would be possible but dependent upon in-country resource requirements.

Table 34. SELECTED LABOR STATISTICS FOR FIVE COUNTRIES AND UNITED STATES

Reference Yearbook of Labour Statistics 1976
International Labour Office, Geneva

1975	INDUSTRY		AGRICULTURE		CONSTRUCTION	
	(unit)		(unit)		(unit)	
Malawi	Kwacha/month	38.83	Kwacha/month	10.74	Kwacha/month	33.06
Bolivia	peso/month	1,709.44		N/A	peso/month	1,609
Puerto Rico	$/hour	2.56		N/A		N/A
U.S.	$/hour	4.81	$/month (1974)	423	$/week	254.88
Korea	Won/month	38,378	Won/day	1,255	Won/month	61,590
Syria	lb/week	82.22	lb/day	5.95		N/A

N/A = Not Available

Table 35. Comparable Wages in U.S. Dollars Per Month*

MALAWI	Kwacha/month	$/month (.87K/$U.S.)
food	43.7	50.2
textiles	41.68	47.9
transp. equip.	144.23	165.8
metal prod.	49.69	57.1
chem. prod.	108.48	124.7
rubber prod.	55.61	63.9
elect. mach.	68.68	78.9
BOLIVIA	**peso/month**	**$/month (20p/$)**
food	1,786	89.3
textiles	1,642	82.1
metal prod.	1,347	67.4
transp. equip.	1,451	72.6
chem. prod.	1,780	89.0
rubber prod.	1,554	77.7
elect. mach.	1,289	64.5
PUERTO RICO	**$/hour**	**$/month**
food	2.60	450.6
textiles	2.15	372.6
chem.	3.64	630.8
metal prod.	2.95	511.2
elect. mach.	2.81	487.0
transp. equip.	2.87	497.4
plastics	2.56	443.6
U.S.	**$/hour**	**$/month**
food	4.57	792.1
textiles	3.40	589.3
Ind. chem.	5.93	1027.8
metal prod.	5.04	873.5
transp. equip.	6.07	1052.1
elect. mach.	4.58	793.8
plastics	4.35	753.9
KOREA	**Won/month**	**$/month (484 Won/$)**
food	40,124	82.9
textiles	33,393	69.0
metal prod.	38,406	79.4
elect. mach.	37,896	78.3
transp. equip.	51,098	105.6
plastics	46,420	95.9
chem.	79,132	163.5
SYRIA	**lb/week**	**$/month (3.7 lb/$) (4.33 wk/mon.)**
food	70.21	82.1
textiles	79.91	93.5
chem.	87.07	101.9
plastics	63.74	74.6
metal prod.	79.21	92.7
elect. mach.	80.60	94.3

*Census of Manufacturers

1975 Reference Yearbook of Labour Statistics 1976 Int'l Labour Office Geneva	MALAWI	PUERTO RICO	BOLIVIA	UNITED STATES	KOREA	SYRIA
food	50.2 / .063	450.6 / .569	89.3 / .113	792.1 / 1.00	82.9 / .105	82.1 / .104
textiles	47.9 / .081	372.6 / .632	82.1 / .139	589.3 / 1.00	69.0 / .117	93.5 / .159
metal prod.	57.1 / .065	511.2 / .585	67.4 / .007	873.5 / 1.00	79.4 / .091	92.7 / .106
elect. mach.	78.9 / .099	487.0 / .614	64.5 / .081	793.8 / 1.00	78.3 / .098	94.3 / .119
transp. equip.	165.8 / .158	497.4 / .473	72.6 / .069	1052.1 / 1.00	105.6 / .100	NA / NA
plastic ① rubber ② prod.	63.9② / .085	443.6① / .588	77.7② / .103	753.9① / 1.00	95.9① / .127	74.6① / .099
chem.	124.7 / .121	630.8 / .614	89.0 / .087	1027.8 / .100	163.5 / .159	101.9 / .099

$/Month/%/1.00 U.S.

Table 36. Comparison of the Relative Labor Rates to the United States Rate

N.A. = Not Available

Developing Country Rates

Substituting labor rates for U.S. rates based on the rate developed (Table 36) for the electric machine industry and the plastic production industry the following reduction in costs could be provided by in-country manufacture and/or assembly (Table 37).

	Malawi	Puerto Rico	Bolivia	U.S.	Korea	Syria
Electric Machines						
Unit 1	$12.38	$76.75	$10.13	$125	$12.25	$14.88
Unit 2	$10.69	$66.31	$ 8.75	$108	$10.58	$12.85
Plastic Production						
Unit 3	NA	$94.08	NA	$160	$20.32	$15.84

Table 37. Labor Cost/Unit for Low Production Volume

Therefore production in Korea of Unit 1 would result in a 14% savings in labor alone. The production of Unit 3 in Korea would result in a 13% savings.

High production volume of Unit 3 would show a greater reduction in price in developing countries due to the raise in labor costs per unit when volume is increased. Units 1 and 2 would show the greatest overall reduction in price though at the higher production level.

Retail Price equivalents for Units 1,2, &3, would then become as demonstrated in Table 38.

	Unit 1	Unit 2	Unit 3
Malawi	$687.38	$501.69	NA
Puerto Rico	$751.75	$557.31	$979.08
Bolivia	$685.13	$499.75	NA
U.S.	$800.00	$599.00	$1045
Korea	$687.25	$501.58	$905.32
Syria	$689.88	$503.85	$900.84

Table 38. Retail Equivalents at Developing Country Rates

Therefore production in Korea of Unit 1 would result in a 14% savings in labor alone. The production of Unit 3 in Korea would result in a 13% savings.

High production volume of Unit 3 would show a greater reduction in price in developing countries due to the raise in labor costs per unit when volume is increased. Units 1 and 2 would show the greatest overall reduction in price though at the higher production level.

COST-EFFECTIVENESS

Alternative Costs and Effectiveness

At this point based upon the data accumulated, the probability of conventional and sewerless systems being considered concurrently for U.S. application has been narrowed to smaller towns and to more difficult (costly) projects. It would also be offered a potential consideration in lower density population areas, such as urban/suburban fringe. From the experiences of the manufacturers, the evaluations of Federal funding

agencies, i.e., the U.S. Environmental Protection Agency (EPA), and Farmers Home Administration (FHA); and health officials a community of less than 1.7 percent population per acre can yield a probable site for alternative conventional vs. sewerless systems.

In a survey of communities under 50,000 population, 258 facility plans for 49 states were analyzed by EPA in 1976. Results of the cost per household, in Table 39, showed that only about 5% of the new facilities cost under $100 per year. This compared to about 50% under $100 for older facilities. In other words about 95% of the new facilities are costing over $100 per year as compared to about 50% formerly, or about a 45% increase in the households which will be expected to pay above $100 per year.

Cost/Household	258 Facilities	83 New Facilities
$=US Dollar	(%)	(%)
$100+	40	75
$200+	10	20
$300	>0	>0
under $100	All other (50%)	All other (5%)

Table 39. Cost/Household yr in EPA Analysis of Facilities Plans in Communities Under 50,000 Population

A breakpoint of 50,000 population or less was shown in the survey to be significant in the facility siting of conventional projects. User charges for wastewater services were often too high to be met by the residents. "(Costs for communities under 10,000 were much higher than the larger communities surveyed.)"

Charges were as shown in Table 40.

User Charge/Month	Community Size
$12 - 20	< = 10,000
$20 - 30	Some
<$12	All Other

Table 40. User Charge per Month by Community of 50,000 Population or Less

Over 1.5 percent of the U.S. median family's annual income of $13,000, or approximately $195.00/year/household could be required for payback. This would be equivalent to $16.25/mo. in user charges. From these results the present EPA guidelines were promulgated and published in the Federal Register for the cost-effectiveness analysis of conventional vs. sewerless treatment systems (Chapter III, Figure 5).

Cost Comparisons

Jim Kreissel of EPA produced the following cost estimates of on-site and water-saving alternatives (Tables 41 and 42). An FHA official verified that present on-site alternatives of spetic tank and discharge combinations could produce costs varying from $800 to $3,000 per site. The easier sites (or cost-justified) were described as completed while the remaining communities were viewed as lacking resources to support conventional facilities. The marketing of any new systems which would require a $20/month/user household fee was viewed as extremely desirable and capable of financing with community acceptance. It should be noted that the average septic tank installation costs approximately $150-200 with an average lifetime of 5 years under proper conditions. Costs on the sewerless systems under mass production would be $\leq$ to the $195/year.

TABLE 41

ON-SITE ALTERNATIVES
COST ESTIMATES

ALTERNATIVE	SOIL	CAPITAL COST $	O/M COST $/YR	TOTAL $/YR
Septic Tank - Conventional SAS	Good	975	10	85
	Fair	1288	10	109
	Poor	1600	10	134
Septic Tank - Pressurized Distribution (Dosing) - SAS	Good	1317	35	134
	Fair	1641	35	159
	Poor	1964	35	194
Septic Tank - Alternating Beds	Good	1700	10	141
	Fair	2326	10	189
	Poor	2950	10	238
Septic Tank - Mound	--	3500	35	305
Septic Tank - (ET) Evapotranspiration	--	4000	10	319
Septic Tank - Sand Filter-Disinfection	--	3415	150	421
Aerobic Unit - Pressurized Distribution (Dosing)	Good	2347	122	326
	Fair	2671	122	351
	Poor	2994	122	376
Aerobic Unit - Sand Filter-Disinfection	--	3395	207	492
Aerobic Unit - Disinfection	--	2645	147	374

TABLE 42

WATER SAVINGS ALTERNATIVES

COST ESTIMATES

ALTERNATIVE	SOIL	CAPITAL COST $	O/M COST $/YR	TOTAL $/YR
Large Biological Toilet + ST-SAS	Good	2900	20	244
	Fair	3200	20	268
	Poor	3500	20	291
Small Biological Toilet + ST-SAS	Good	1900	90	237
	Fair	2200	90	260
	Poor	2500	90	283
Incinerator Toilet + ST-SAS	Good	1650	180	308
	Fair	1950	180	331
	Poor	2250	180	354
Low-Flush Toilet + ST-SAS	Good	1400	96	210
	Fair	1700	96	234
	Poor	2000	96	257

ST = Septic Tank

SAS = Soil Absorption Systems

A comparison of the essential components for operation for conventional treatment, PW1-PS12, (from the Lower-Cost Methods Study) and for sewerless treatment, PS 13 and PS 14, (from the May 1977 AID Interim Report) are presented in Table 43. The advanced sewerless treatment was further developed in Table 43, SS1-SS7. The sewerless, SS2-SS6 of the series, uniformly do not require groundwater, i.e., specific soil conditions, but do require minimal chemicals. Maintenance supplies in one form or another are required.

A comparison of the production process requirements (of costs and facility requirements) and the life expectancy of the system was developed in Table 44. This included both conventional and sewerless treatment, PS and SS, respectfully. Under "costs" the lending level was addressed. Three divisions were specified: state, in-country, and international loans. Under "facility required" the types of treatment applicable for the five community sizes were designated. Under "life" the projected life, assuming proper operation and maintenance, was also designated. There could be variations within this dependent upon a variety of factors such as siting, engineering design, and community acceptance.

Effectiveness Measurements

There are many measurements of effectiveness which can be used to determine the most appropriate waste disposal treatment systems in any size community. Usually in the past this determination has been made on economic measures alone, or on the basis of the most units for the least cost. Unfortunately, an economic system will not necessarily provide

Table 43. Water & Sewage Treatment Processes With Essential Components for Operation.

	Treatment Methods \ Process Requirements	Process Number	Manpower Operation			Resources Required				
			Unskilled	Skilled	Professional	Operation Equipment	Process Materials	Maintenance Supplies	Chemical Supplies	Groundwater Availability
WASTE PROCESSES	No Treatment	PW1	●				●			●
	Primary-Conventional	PS1	●							
	Primary-Stab. Pond	PS2	●							
	Sludge-Conventional	PS3	●	●			●	●	●	
	Sludge-Advanced	PS4	●			●	●	●	●	
	Sludge-Combined (Imhoff)	PS5	●			●		●		
	Secondary - Standard Filter	PS6	●	●		●		●		
	Secondary - High Rate Filter	PS7	●	●	●	●	●	●	●	
	Secondary - Activated Sludge	PS8	●	●	●	●	●	●		
	Secondary - Extended Aeration	PS9	●	●		●		●		
	Disinfection	PS10		●		●	●			
	Aqua Culture	PS11	●							
	Dilution	PS12	●							
	Individual	PS13	●							●
	Individual (adv)	PS14		●		●		●		●
SEWERLESS	Septic	SS1	●	★	★	●		●		●
	Incinerating	SS2	●	★	★	●	●	●		
	Biological	SS3	●	●	★	●	●	●	●	
	Composting	SS4	●	★	★	●		●		
	Vacuum	SS5	●	★	●	●	●	●		
	Oil Base	SS6	●	★	★	●	●	●	●	
	Aerobic	SS7	●	★	★	●		●		●

★ Consulting or Part time

Table 44. Production and System Life

Treatment Methods	Process Requirements	Process Number	Costs: State Funds	Costs: In-Country	Costs: Intrn'l Loans	Facility Required: Village	Facility Required: Unsewered Community	Facility Required: Sewered Community	Facility Required: Suburban	Facility Required: Urban	Life: Temporary	Life: Short Term	Life: Long Term
Conventional	No Treatment	PW1	●			●	●		●		●		
	Primary-Conv.	PS1	●					●	●	●			●
	Primary-Stab.	PS2	●					●	●	●			●
	Sludge-Conventional	PS3		●				●		●			●
	Sludge-Advanced	PS4		●				●		●			●
	Sludge-Comb. (Imhoff)	PS5		●						●			●
	Secondary-Standard Filter	PS6			●					●			●
	Secondary-High Filter Rate	PS7			●					●			●
	Secondary-Activated Sludge	PS8			●					●			●
	Secondary Extended Aeration	PS9			●					●			●
	Disinfection	PS10		●	●			●	●			●	●
	Aqua Culture	PS11	●			●	●						●
	Dilution	PS12		●			●		●		●		
	Individual	PS13	●	●		●	●		●		●	●	
	Individual (adv)	PS14	●	●			●	●	●	●			●
Sewerless	Septic	SS1	●	●		●	●	●	●			●	●
	Incinerating	SS2	●	●			●	●	●	●		●	●
	Biological	SS3	●	●			●	●	●			●	●
	Composting	SS4	●	●		●	●	●	●	●		●	●
	Vacuum/Pressure	SS5			●		●			●			●
	Oil Base	SS6			●				●	●			●
	Aerobic	SS7	●	●			●	●	●			●	●

the most acceptable solution. The economic approach does not take into consideration other factors which affect the eventual success of a project. Such other factors (often sociocultural in value) are always compatible to the assignment of consistent monetary values that are repeatable or comparable.

Another measurement of effectiveness has been the regulatory requirements of effluent standards and the cost of meeting those standards for various systems. Criticism of this measurement rests with both the determination of the standards and the provision for alternative systems. Standards have often had to be arbitrary since their application has needed to be diverse. Alternative systems have often been inhibited by field data, engineering design, and equipment availability, also.

Various schemes have also been proposed to measure effectiveness. The acceptance of these has varied dependent upon their particular application and dissemination. Table 45 is an example of low to high values.

The difficulty with considering any measurements other than cost has been in the failure to identify a comparable measure for comparison. Most criteria which would allow for effectiveness measurements as input are not directly quantitative so that a ratio of + or - 0 cannot be developed for cost/effectiveness. These criteria are usually qualitative in nature which requires indirect comparisons or an alternate value system to monetary costs.

Human waste disposal in developing countries has often been handled with the same reasoning that was used in Great Britain and Northern Europe until the 1800's, namely, dilution is the answer to pollution. Removal of wastewater from the human environment has been the effectiveness criterion.

Table 45. Alternative Toilet System Characteristics[1,2]

Toilet System	Similarity to Conventional		Approximate Resource Requirements				Final Product Disposal	Scheduled Maintenance
	Appear.	Use	Water	Power	Fuel	Other		
Composting Separated	Low	Low	None	Low	None	None	Soil Amendment	Periodic Residue Removal
Non-Separated	Low	Low	None	Mod.	None	None	Soil Amendment	Periodic Residue Removal
Incinerating	Mod.	Mod.	None	Low-High	Low-High	None	Refuse	Weekly Ash Removal Periodic Unit Cleaning
Recycle	Mod.-High	Mod.-High	None	Low	None	Pumping	Treatment Plant or Land Disposal	Annual Servicing and Accumulated Solids Pumping
Low Flush/ Holding Tank	High	High	2 qts. / Use	Low	None	Pumping	Treatment Plant or Land Disposal	Semi-Annual Tank Pumping

1 The characteristics shown may vary considerably depending on the individual unit and/or application in question.
2 Siegrist, Robert."Segregation and Separate Treatment of Black and Grey Household Wastewaters to Facilitate Onsite Surface Disposal,"Small Waste Management Project, Univ. of Wisconsin, Madison, Wisc., November 1976.

Once the residents of developing countries have been supplied with piped, treated water then the removal and treatment of wastewater has often been only of primary importance with the occurrence of health incidences. As previously stated in earlier chapters the significant reduction (60%) of incidences together with the higher costs of conventional sewerage and treatment to an established community has limited the applicability of present-day, developed-country conventional wastewater systems. The new sewerless technology with reduced water-use and sewerage requirements does show advantages for greater cost-effectiveness measures over the conventional systems, creating new cost-effective alternatives.

If one were to assume then that a sewerless waste treatment process does meet the basic requirements (health, etc.) of waste disposal alternatives, this assumption becomes an adequate criterion for effectiveness. The quality of processes are therefore equal to the requirements, namely removal and treatment, in any application.

So, here cost of on-site versus off-site can be compared without prejudice. This comparison could then be favorable to U.S. purchase as described. The residual question relates to LDC comparisons. This relationship in Table 46 describes the cost-effectiveness comparison of SS1-SS7, while Table 47 compares the cost of SS1-SS7 to that of conventional technology.

Process Number

Community Size	Capitol O&M	SS1	SS2*	SS3*	SS4*	SS5	SS6	SS7
	Village	975/10	NAP	736/90	800/10	NAP	NAP	NAP
	Unsewered Community	975/10	500/180	736/90	800/10	SI/96	NAP	2347/122
	Sewered Community	975/10	500/180	736/90	800/10	NAP	NAP	2347/122
	Suburban	975/10	500/180	736/90	800/10	SI/96	2000/100EST	2347/122
	Urban	NAP	500/180	736/90	800/10	SI/96	2000/100EST	NAP

Costs in U.S. Dollars

Total Capital Costs over O&M Costs per Year
with High Production Savings for SS2 and SS4

* Does not include auxiliary gray water system

NAP - Not Applicable

EST - Estimate

SI - Site Intensive

Table 46. Cost-Effectiveness Comparison

of Seven Sewerless Systems

Process Number

Community Size	SS/PS	SS1	SS2	SS3	SS4	SS5	SS6	SS7
	Village	985/NAP (+)	NAP	826/NAP (+)	810/NAP (+)	NAP	NAP	NAP
	Unsewered Community	985/NAP (+)	680/NAP (+)	826/NAP (+)	810/NAP (+)	SI/NAP (+)	NAP	2469/NAP (+)
	Sewered Community					NAP/ (-)	NAP/ (-)	
	Suburban	(+)	(+)	(+)	(+)	SI/NAP (+)		
	Urban	NAP/ (-)				SI/ (-)		NAP/ (-)

Costs in U.S. Dollars

= Ratio of SS/PS Costs

NAP - Not Applicable

SI - Site Intensive

(+) - Sewerless Favorable

(-) - Conventional Favorable

Table 47. Cost-Effectiveness Comparison of Sewerless Systems vs Conventional Systems