CHAPTER SIX

WASTEWATER AND EXCRETA DISPOSAL

World Health Organization assessments of the extent of sanitary facilities in the developing countries indicate that excreta disposal systems are particularly inadequate. In fact, within the developing world, 86 percent of the rural population lack an adequate water supply, and 92 percent lack adequate excreta disposal facilities. Of the urban populations, only 28 percent have water borne sewerage facilities and 27 percent have no sanitation facilities of any kind (Feachem, McGarry, and Mara, 1977).

The emphasis of the WHO and other agencies in improving sanitation for the developing countries has been primarily on the delivery of community water supply systems. Studies in this area indicate that without the accompanying improvements in excreta disposal, the disease potential of water supply systems may actually be enhanced, particularly in areas where enteric diseases are endemic. This enhancement of disease potential is accomplished through the increased availability of contaminated water to greater numbers of people. Because of this fact, the World Health Organization now stresses the importance of providing adequate means of excreta or wastewater disposal in the developing countries.

This exemplifies a common problem associated with the development process: in the course of the establishment of improvements for the protection of health, further hazardous conditions are produced. These conditions then necessitate further technological intervention. This issue is a reflection of the interrelationships between the various subsystems of environmental health.

The primary waste materials of concern in this section are excreta and all other organic wastes produced in households, agriculture, and industry. The term "wastewater" includes all or any combination of the above waste substances. The focus of this chapter shall be on the various methods of collection, treatment, and disposal of excretory material primarily.

Typically, feces are deposited either on land or in water. Aquatic systems are a primary disposal medium, possessing self-purification properties capable of decomposing and dispersing organic materials. However, the increasing load of organics corresponding to increasing populations has overloaded the natural cleansing mechanism of many aquatic systems. Soil as a disposal medium also provides certain benefits. Feces dry and decompose in the soil, thereby replenishing certain basic nutrients needed for plant cultivation. This natural process, however, has become impractical with population growth since deposition must, of necessity, occur in close proximity to human settlements, thus attracting rodent and insect pests. In both cases, it is evident that these basic methods of deposition directly into the environment are inadequate. Furthermore, basic disposal methods used in many countries are also inadequate, being improperly constructed, maintained, and utilized.

Studies of environmental health conditions in many rural areas of developing countries indicate that indiscriminate defecation on land, improper maintenance of simple latrines or pit privies, and inconsistent use of these facilities are common occurrences. Closely associated are the problems related to the attraction of insect and rodent pests, and the overflow of fecal material into the water supply system. Additional organic load on the water is promoted by laundry and bathing habits, as well as the defecation by domestic and wild animals in the water.

Deposition of excretary material on land presents a number of potential hazards through direct contact with the feet, attraction of pests and vectors to the area, transmission to food crops, and particularly contact by children and domestic animals (WHO, 1972). Certain intestinal parasites are most typically contracted by stepping on dried feces. Ascariasis, trichuriasis, and ancylostomiasis (hookworm) are contracted in this manner. Other diseases of fecal origin that may be contracted from soil include cholera, salmonellosis, bacillary dysentery, typhoid, paratyphoid, and amoebiasis.

Flies are typically attracted to excretary material. Flies not only harbor numerous disease organisms in their systems, but may also function as intermediaries, carrying pathogens on the surfaces of their bodies from feces to a food source. Furthermore, foods themselves may serve as intermediary media for the transmission of certain enteric diseases, particularly as a result of the use of feces directly as fertilizer. Wastewaters also serve as breeding sites for numerous disease vectors such as Culex pipiens, the vector of filariasis.

Chemical substances originating from fecal materials are primarily organic and may be classified as either lipids, amino acids, cellulose, hemi-cellulose, lignin, protein, or ash. Although these breakdown products of plant and animal tissue do not typically produce disease, they do as a group, produce certain adverse effects on the environment, particularly the aquatic environment. High levels of organic matter in water stimulate the growth of microbial populations which, in turn, utilize the dissolved oxygen available in the water. Depletion of sufficient quantities of dissolved oxygen, accompanied by high levels of organics, eventually lead to conditions of eutrophication in certain aquatic systems. Eutrophication, of course, does constitute a health hazard in that the water supply eventually becomes unfit for human consumption.

Although toxic chemical substances do not originate in excrement, they may be found in association with excretary materials and, once associated, often become concentrated. For example, chemicals used in households, agriculture, and industry enter the sewers and/or the water supply. Conventional treatment methods do not remove many chemicals. Therefore, reuse of these wastewaters for irrigation or fertilization will cause further accumulation of potentially toxic chemicals. Additionally, food crops, and in some cases, animals, then accumulate these chemicals at high levels.

This potential for accumulation of toxic substances inherent in the reuse of waste materials should not, however, preclude their reuse. Here again, consideration must be given to a number of interacting factors that influence the ultimate health impact of a given wastewater source. These must be assessed on an individual basis, considering the types of technologies utilized, ultimate use of the recycled waste, particular chemical hazards encountered in that locality, and local priorities where trade-offs must be made.

Assessment of Wastewater and Excreta Disposal Techniques

In the assessment of existing wastewater or excreta disposal projects, a wide range of technologies are being used. A census of existing facilities by region, along with available regional information in the areas of area description, medical and sanitary data, resources available, and ongoing surveillance work is important. The data needed in each of the four specific areas werr discussed generally in the Assessment and Planning chapter. Data needed to assess the quality of specific technologies and their surveillance are listed in the technologies section of this chapter.

In scattered rural areas primary concern should be for the provision of individual (privy) facilities that are sanitary and regularly used. Assessment would include determining whether: (1) facilities are properly maintained, (2) local contamination of soil or water supply might be attributed to malfunctioning or location of the facility, (3) odor and insects are controlled; and (4) facilities are sufficient for the population and its expected growth.

In densely populated rural areas, semiurban, periurban, and urban areas, individual systems may operate along with community disposal systems. Assessment should include similar factors, with additional attention to the functioning, capacity, and quality of the community system. Certain alternatives are discussed at length in the Technologies section.

In the assessment of existing excreta disposal systems of the individual and community types, a set of data should be collected that would be useful for assessing capacity and for planning changes in a system. The parameters and data sets of potential use in such an assessment are listed below.

Waste Clasification:
- Domestic (type, age, mode of delivery)
- Industrial (type, age, mode of delivery)
- Agricultural (type, age, mode of delivery)
- Combination (type, age, mode of delivery, realtive percentages)

Waste Characteristics
- Volume (minimum, average, maximum daily)
- Concentration of organic materials (BOD_5, BOD_u, COD)
- Solids (special industrial wastes; total, settleable, suspended, dissolved, total volatile, and fixed solids)
- Nutrient concentrations (nitrogen, phosphorus)
- Color materials (suspended, dissolved)
- Toxicity (BOD reduction rates, bioassays, and specific aquatic microorganisms)
- pH (minimum, average, maximum)
- Quality of tap water (mineral analyses)

Hydrology and Meteorology
- Evaporation (average, seasonal variations)
- Rainfall (average, seasonal variations)
- Air and water temperatures (average, seasonal average, average hottest month, average coldest month)
- Groundwater (average depth, permeability of formation)
- Percolation rates (preferably measured with waste to be treated)
- Wind (strength and direction for time of day, seasonal average)
- Cloud cover (percentage of daytime, season, and year)

Light
- Solar radiation (minimum monthly, average annual, seasonal variations)

Topography
- Soil characteristics (ease of excavation, embankment use, percolation, compaction)
- Flood stages (high-water marks)
- Availability of contour map
- Location of houses, industries, agriculture
- Streams (drainage of all types)

Regulations, public health data
- Potential odor problems
- Potential insect problems
- Community data (local zoning restrictions, effluent and stream standards, ownership of lands, location of waterworks)
- Health regulations (effluent and stream standards, coliform bacteria standards, special quality regulations for drinking water and food processing, bathing water criteria; wildlife, recreation, fisheries regulations; and prior appropriated rights to wastewaters)

Use of Effluent
- Groundwater supplementation
- Surface water supplementation
- Immediate irrigation
- Industrial reuse
- Development of wildlife
- Recreational use

Wastewater Quality Analyses and Criteria

Sampling of wastewater quality, particularly after treatment, is an important practice. Standardized methods of determining wastewater and receiving water quality have been developed in many countries, e.g., those published by the American Public Health Association, American Water Works Association, and the Water Pollution Control Federation in 1975. This section describes the methods used for the determination of water quality, and states the precision of the determination and the significance of each analysis in the assessment of quality. The Recommended Resource section lists some of the more important reference manuals in the field of wastewater quality. Simplified laboratory procedures for wastewater examination, published by the Water Pollution Control Federation in 1968, should be particularly valuable in developing countries.

The suspended solids are those removed in filtration through a standardized fine medium. They are classified as fixed and volatile, the latter being the material that is organic in nature and expected to be amenable to biological degradation or incineration; the fixed solids are essentially inert materials. The suspended solids can further be classified on the basis of their settleability. Those that are settleable should normally be removed in large measure in sedimentation tanks of one type or another, whereas the nonsettleable suspended solids require some additional treatment, either chemical or biological, to remove them from the wastewaters. The suspended solids content is important in design and disposal, because it determines the sludge handling requirements of the plant, including those for dewatering and drying the sludge as well as for its final disposal.

Dissolved solids are the solids in the filtrate obtained after removal of the suspended solids. They represent the salts in solution, including the mineral salts from the water supply. Dissolved solids are important mainly where wastewaters are to be reused after treatment. The dissolved solids remain unchanged by most conventional forms of treatment.

The accumulation of local analytical data is important for planning a water quality control program. Where a laboratory is not yet available, the laboratory facilities of the public health or public works agency or of a local university could be used. Specific analyses made in the absence of a sewerage system are discussed in the technologies section of this chapter.

In a community or region where a sewerage system already exists, the best method of determining wastewater quality is by the analysis of the wastewater itself. Samples for such an analysis must be taken over a 24 hour period, as a definite proportion of the flow, and for at least one full week. This procedure should be repeated during different seasons if seasonal variations are to be expected in rainfall, temperature, or population. Such an analysis, when related to the population tributary to the sewer system, can help to establish the per capita contributions of waste to the system so that population equivalents for that community or region can be established.

The Biochemical Oxygen Demand (BOD) is a measure of the organic matter present in wastewater. It is determined by measuring the amount of oxygen absorbed by a sample of the wastewater in the presence of microorganisms during a specific period, generally five days, at a specified temperature, generally 20 degrees centigrade. While it is customary to determine BOD at a temperature of 20 degrees centigrade in tropical countries, a higher temperature may be selected in order to avoid the cost of incubators that would require both heating and cooling units. A BOD at 30 degrees centigrade, for example, would be appropriate in parts of the world where ambient temperatures tend to be high. It is also appropriate, where high temperatures are used for standard BOD determinations to reduce the duration of the test from five days to perhaps four or even three days, thereby reducing the required incubator capacity, as samples would then have to be stored for shorter periods. The BOD, the primary measure of the strength of wastewaters, is also an indicator of the expected effect on receiving streams caused by reducing their oxygen content. In general, the degree of treatment provided by the wastewater treatment plant is selected so the BOD of the effluent will not be such as to reduce the oxygen level in the receiving waters below that necessary to enable the best use to be made of them.

The Chemical Oxygen Demand (COD) is also a measure of the strength of wastewaters; it is a measure of the oxidation requirements of a sample under prescribed conditions, as determined by using a chemical oxidant. This indicator is generally useful where industrial wastes are important. In any given system, a relationship may exist between COD and BOD, but this will vary markedly from one city to another.

Coliform organisms, including Escherichia coli, provide presumptive evidence of the presence of pathogens, both bacterial and viral. Since human feces contain about 1×10^{12} coliform organisms per capita per day, all sewage is heavily contaminated with these organisms.

The pH is a measure of the acidity or alkalinity of the wastewater. Where industrial wastes are present, the pH indicates whether there is a need for pretreatment in order to prevent interference with conventional waste treatment processes. Generally speaking, the pH of domestic is near neutral.

Dissolved Oxygen (DO) can be important in the operation both of sewerage systems and treatment plants. Water supplies are normally saturated with oxygen, but this is rapidly depleted when organic wastes are added to the water. In temperate climates, where the sewers have adequate slopes, the wastewater may reach the treatment plant in reasonably good condition, although the oxygen level might be quite low. In warm climates and where the sewers have flat slopes, however, so that velocities are low, solids are deposited, and the water takes a long time to reach the treatment plant, the wastewaters will probably become completely devoid of oxygen and septic. Septic wastewaters are more difficult to treat and give rise to odors, both in the sewerage system and at the treatment plant. The DO level of wastewater is highly variable and not at all stable. The objective in managing raw wastewaters is therefore to maintain sufficient dissolved oxygen to prevent anaerobic conditions, a trace generally being sufficient. In treated effluents, a level of one or two mg/liter as contrasted with saturation values of about ten mg/liter is desirable.

Where there is a need to disinfect treated wastewater effluents, the chlorine demand is an important index of quality, since it is a function of the strength of the waste. The higher the degree of treatment, the less the chlorine demand of the effluent is likely to be.

Wastewaters contain significant concentrations of nitrogen and phosphorous. Conventional treatment does not reduce their concentration significantly. Ordinarily, they are not troublesome in the receiving stream, nor will they be troublesome where wastewaters are to be reclaimed for irrigation or industrial use. Where wastewaters are to be discharged into relatively clean bodies of water, such as lakes or estuaries, however, these nutrients may enrich such waters to the extent that excessive algal growth will be stimulated and the receiving waters may be harmed because of the enrichment (eutrophication).

Where industrial plants discharge into the sewerage system, many chemicals may then enter the system that interfere either with treatment processes or with the quality of the receiving waters. For example, copper accumulates in sludge digestion tanks and interferes with the digestion process.

Grease may cause serious difficulties in the management of wastewaters, particularly where it is intended to reclaim the wastewater or to use the sludge. In the absence of discharges from particular commercial or industrial undertakings, the amounts of grease normally found in wastewaters are not troublesome. However, oil, grease, and gasoline from filling stations may cause difficulties, and separators are then required. Detergents may also be troublesome, particularly where wastewaters are to be discharged into turbulent streams so that foam is likely to be a nuisance. Many countries have outlawed the use of the so-called hard detergents that are not readily removed in treatment processes, but even excessive amounts of "soft" detergents may be troublesome where treatment is not adequate. These detergents emanate from households. Other special difficulties may be caused by industrial wastes. Special precautions may be necessary.

Technologies for Excreta Collection and Disposal

Any system of excreta disposal must take into consideration the habits and priorities of the people with respect to defecation and other practices. Traditionally, the industrialized nations have been willing and able to spend large sums of money for a system that will remove human wastes such that the average citizen need have no direct contact with excrement. In the less industrialized nations, however, funds are more limited and, furthermore, individual citizens are not often willing to pay such a high price for excreta disposal. Nevertheless, the need for some form of sanitary excreta disposal is considered to be crucial to the elevation of the health status in the developing countries. The planning and implementation of progeams, therefore, may very well involve a variety of compromises both from the economic and technological standpoint and from the public health standpoint.

Traditionally, recommendations for technological alternatives have been geared towards developed country alternatives. These are often unsuited to the climate, terrain, personnel availability, degree of technological advancement, and economy of the developing country. The objective here is to propose and evaluate intermediate technologies that may be feasible for the developing country.

The excreta disposal and treatment subsystem may be subdivided in numerous ways: rural vs. urban; community vs. individual; and water-carriage vs. nonwater-carriage. Most appropriate for this document is the rural vs. urban delineation and the relevant technologies, with additional consideration to high density rural or peri-urban areas that are becoming more common in the developing areas.

The technologies for handling of excreta are typically characterized as either collection, treatment, disposal and/or reuse. It is within this framework that those technologies most applicable to either rural or urban communities of developing countries will be discussed. In many cases, these processes are combined. Any excreta disposal system should be designed with consideration of the following factors proposed by Wagner and Lanoix (1958):

- Surface soil contamination
- Groundwater contamination.
- Surface water contamination.
- Contamination of excreta by flies or animals.
- Handling of excreta.
- Odors or nuisance.
- Complexity and expense in construction and operation of the system.

The pit privy is widely used throughout the world. It requires a minimum of attention to location and construction to safeguard against soil and water pollution. It is simple in design, can be built from local materials in most cases, and is easy to maintain, requiring minimal upkeep. Additionally, the pit, if kept covered, will not attract flies and, even if left open, fly infestation will not be great since the pit is always dark and housed in a superstructure. Odors are negligible and no handling of the feces is required. A key advantage of this method is that it is inexpensive to construct and can be constructed by a local family without assistance and with locally available resources. The lifetime of the pit privy is five to fifteen years, depending upon the capacity and utilization of the pit. In spite of all these benefits, experience has shown many failures in the effectiveness of the pit privy (McGarry, 1977). This has been attributed primarily to the lack of accompanying education of local peoples in the use and maintenance of the pit, and to the fact that local people did not participate in either the decision-making process or the actual construction of the facility (Shelat & Mansuri, 1977). Clearly these drawbacks are associated with the lack of success of many rural technology programs.

The bored-hole latrine is similar to the pit privy, having an identical outhouse superstructure and functioning on a similar principle. The major difference is that the bored-hole latrine pit is of smaller diameter and greater depth. Its life is considerably shorter (1-2 years), thereby requiring frequent construction. However, the unit is generally easier to construct than is the pit privy, if appropriate equipment is available. An important consideration is that soils be free of rocks and stones that might facilitate contamination of groundwaters. This type of facility is recommended for emergency or temporary situations.

The following points should be examined during a sanitary survey of pit privy and borehole latrine installations:

- Size of the pit or hole in relation to the number of users;
- Local subsidence that might indicate caving in;
- Precautions against surface flooding;
- Cleanliness of set; use of hole covers;
- Absence of foul smells;
- Presence of flies;
- Defects of the superstructure, doors, floors, ventilation, etc., and
- Age of pit or hole, level of sludge, and dispersion efficiency.

The physical facility of a pit privy or bored hole latrine will be similar to that presented in the following illustration. The following planning factors should be considered in developing such a latrine or in the assessment of an existing facility.

- Is it located more than 6 meters from dwellings and 30 meters from wells?
- Is a cover provided for the floor slab opening?
- Is tamped earth mounded around the privy for drainage and fly seal?
- Is there an impervious floor base to prevent emergency of larvae?
- Is the pit lined for 1/2 meter at top for strengthening?
- Is the pit volume sufficient for four or more years service?

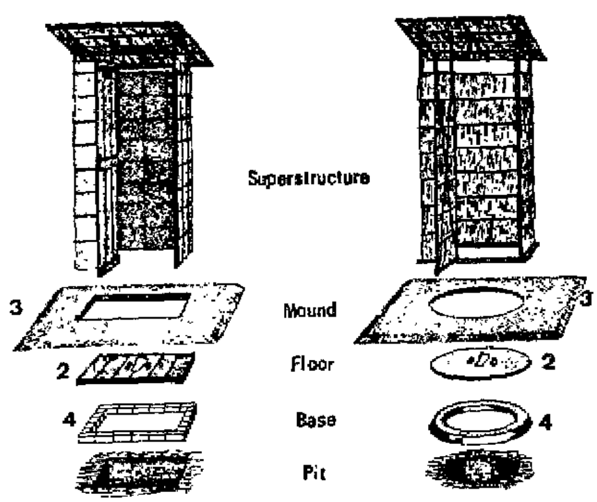
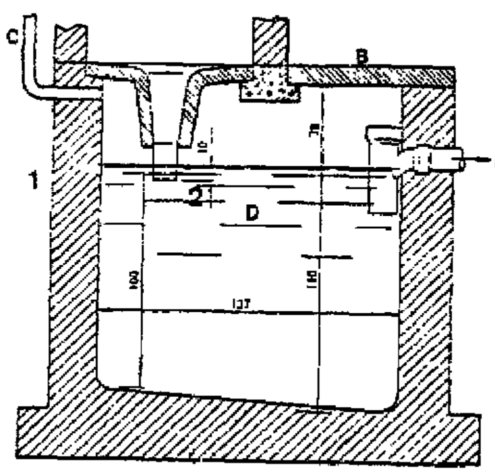


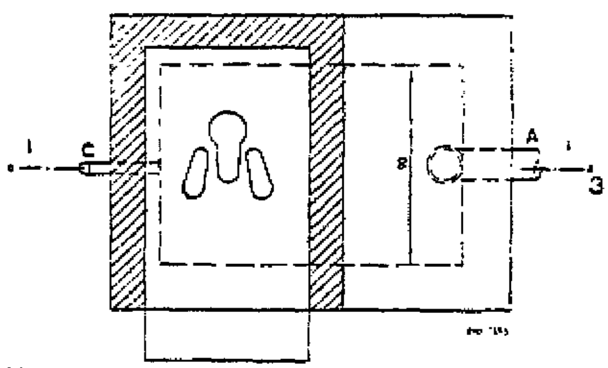
Figure 1: The pit privy

The aqua privy is a modification of the septic privy. It consists of a tank filled with water and a chute extending to it from the latrine floor. Feces and urine are decomposed anaerobically in a similar manner to the septic tank. If the facility is properly constructed and maintained, it will satisfy the aforementioned seven selection criteria. Additionally, it is a permanent installation which, although requiring operation and maintenance daily, is relatively simple and inexpensive. The aqua privy may be placed nearer a dwelling than other methods, since there are essentially no odors and it will withstand greater abuse than the pit privy.

This type of facility requires regular maintenance for it to satisfy the above advantages. The disadvantages of the aqua privy include a high initial cost, the need for sanitation and health education to promote proper maintenance, a water requirement (although small compared to water-carriage methods), a daily operation and maintenance requirement, and the fact that it cannot be used in cold climates. Maintenance of the aqua privy requires periodic desludging which may make it less suitable for rural areas.

Figure 2 depicts a family-type aqua privy. The figure shows how the drop-pipe provides a water seal barrier. Below the figure is a checklist of planning and assessment considerations.





Measurements shown are in centimetres.

A = Outlet to soakage trench or soakage pit

B = Removable, reinforced concrete cover slab

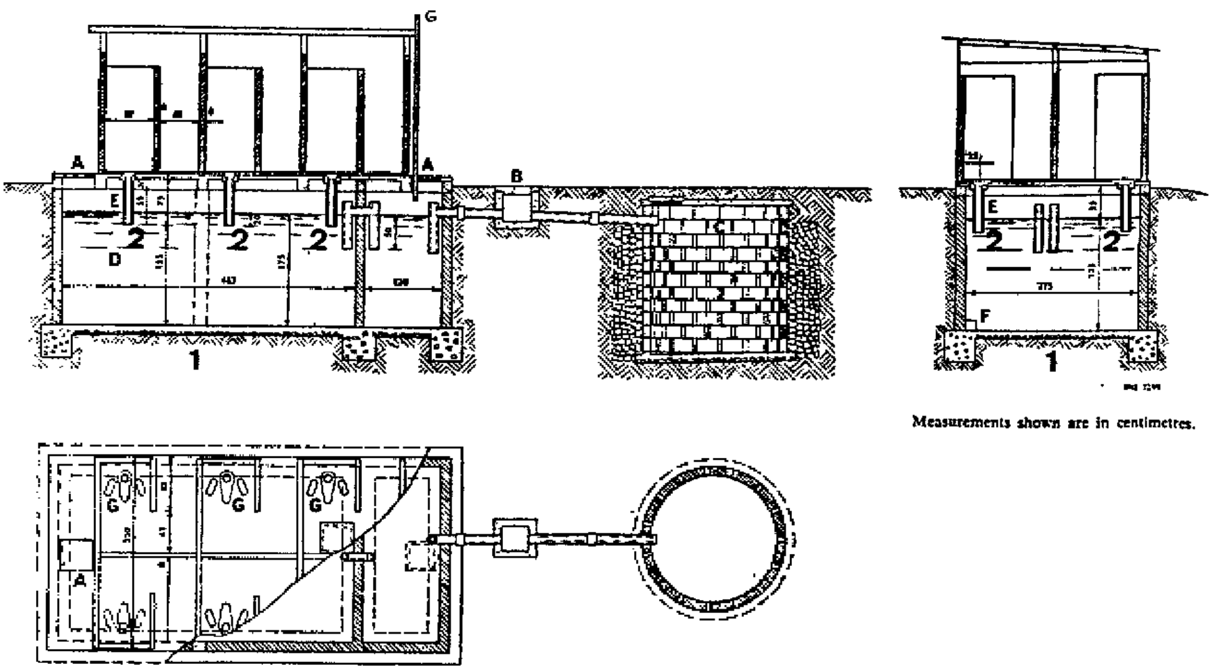
C = 2.5-cm diameter pipe ventilator

D = Capacity of tank : 1340 litres (295 imp. gal.)

Check list

1. Is the concrete tank of watertight construction ?
2. Does the drop pipe extend below water outlet level ?
3. Is there a seepage pit or subsurface percolation for discharge ?

Figure 2 Family-Type Aqua Privy



* Reproduced by permission of the United Nations Relief and Works Agency for Palestine Refugees in the Near East.

Check list

1. Is the concrete tank of watertight construction ?
2. Do the drop pipes extend below water outlet level ?

A = Inspection manholes, 40 × 40 cm
B = Inspection box, 40 × 40 cm
C = Soakage pit or soakage trench
D = Capacity of tank : 22.3 m^3
E = Drop pipe 10.5 cm in diameter
F = Opening 15 × 15 cm in partition wall
G = Ventilator pipe

Figure 3 Institutional-Type Aqua Privy

Source: Rajogopalan (1974)

Applicability and effectiveness of the aqua privy depends also on certain sociocultural considerations. For example, although the aqua privy has been very successful in Asia where anal cleansing with water is commonly practiced, it has been highly unsuccessful in certain parts of Africa (McGarry, 1977). The problem described by McGarry occurs in parts of southern and eastern Africa where sticks, mudballs, and stones are typically used for anal cleansing. In the situation, water is not consistently added to the latrine. The water level sinks, and the water seal is no longer in effect. This then leads to fly breeding, odors, and generally unpleasant conditions. The planner must, therefore, consider local sociocultural factors when making judgments.

The water-seal latrine or pour-flush unit is a modified version of the pit privy, the aqua privy, or other methods. It consists of a concrete slab into which is incorporated a bowl. It may be installed over any type of pit or tank. A small amount of water (1 liter) is required to flush waste materials into the pit and maintain a water seal. The water seal excludes flies and prevents odors from escaping. Additional advantages of the water-seal latrine include the fact that it may be constructed close to the house, that it is safe for children, and that it is simple and relatively inexpensive to construct.

The principal disadvantages of this type of installation are that water must be available year round, health and sanitation education programs must be used to teach proper use and maintenance, local soils must be permeable, and use is precluded in freezing climates. Additionally, construction costs are generally higher than for the pit privy, however, they are less than for the aqua privy.

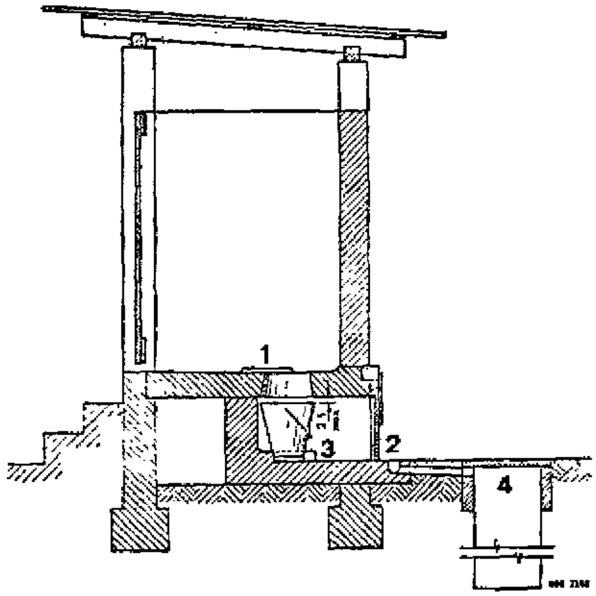
The following check list would be of use in carrying out a sanitary survey of flush-type latrine installations:

- Water provided in the latrine in a container, with a can having a mouth one liter wide for flushing.
- Capacity of chambers in relation to number of users.
- Cleanliness, absence of flies.
- Efficiency of water seal.
- Effectiveness of ground absorption.

This system of excreta disposal is also referred to as box and can privy, conservancy system, pail latrine, or earth closet in English-speaking countries, and as tinettes in French-speaking areas. The basic mechanism of this method consists of a bucket in which excreta are deposited and removed for emptying and cleansing at regular frequent intervals. Some types possess a mechanical device for releasing earth, sawdust, or ash to cover the excreta. Figure 4 depicts a bucket latrine and planning and assessment factors to consider.

The trench latrine and "feurillee" are two methods functioning by essentially the same principle: a relatively shallow pit is excavated, and the user must throw a sufficient quantity of soil over the feces deposited at each use. Additionally, an iron sheet is to be placed over the hole when not in use. Problems associated with this method may be easily projected. If the user does not throw soil in the pit and keep it covered, significant hazards may result. Soil pollution, especially by worm larvae, may result. Fly breeding in enormous numbers, and access of flies and animals to uncovered or lightly covered feces, ground and surface water pollution, and easy access to and scattering of the material by rodents and other animals increase hazards.

The principal benefit of this method is that it is very inexpensive to build and maintain. However, its disadvantages appear to be too costly. This method, if used at all, should only be used as a temporary installation (McGarry, 1977; Wagner & Lanoix, 1958).



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Check list

1. Is a latrine seat cover provided ?
2. Is the chamber door self-closing and flytight ?
3. Do the guides position the bucket correctly ?
4. Are a drain and a soakpit provided for wash wastes ?

Figure 4 Bucket Latrine

The overhung latrine consists of an outhouse superstructure and a latrine floor built on top of wooden piles above the banks of some body of water, either seawater or fresh water. These are found around seaports and fishing villages in various parts of the world, particularly in Asian fishing villages where they may constitute one of the only alternatives; for example, where huts are raised on stilts above mudflats or shallow water, far from solid earth.

Under these conditions, certain requirements should be met. The receiving water should be of sufficient year-round salinity to prevent human consumption, and the latrine is installed over such water depth that the bed is never exposed at low tide or during the dry season. Every effort should be made to provide for dilution and carrying away of floating solids from the village. Stream flow should be 14 liters per second per family for adequate dilution, and the walkway, piers, squatting openings, and superstructure are made structurally safe for adults and children.

Further factors of concern with respect to the utilization of overhung latrines include relatively long survival rates of pathogens in fresh and brackish waters; the universal habit of prolonged contact with water in bathing and fishing; and the possibility of stimulating or encouraging more widespread use of this method further inland and upstream, thus emptying into smaller, freshwater bodies of water.

The PRAI (Planning Research Action Institute), type of latrine, developed in India, is a relatively low-cost method easily converted to the bucket or basket type latrine, thereby eliminating the nuisances associated with daily handling of nightsoil (Shelat & Mansuri, 1977). Additionally, water use, where soil is porous, is relatively limited. This method is recommended for use in India for small village communities (Shelat & Mansuri, 1977).

Urban Excreta Collection Technologies

Generally, recommended methods for collection of excreta from urban areas involve water carriage. This is primarily due to the lack of sufficient space in cities for sanitary location and maintenance of latrines. Additionally, where these privies and latrines are found in cities, they quickly become overused, creating highly unsanitary conditions. This situation leads ultimately to the need for some form of water-carriage collection method. Industrialized countries have often, in the past, recommended the traditional sewerage system as the "best" solution, not considering other alternatives that may be more suitable for developing countries in terms of cost-effectiveness.

If the objective is to supply adequate facilities for all inhabitants in an area, then trade-offs may be required, taking into account social, economic, and health considerations. Although the level of technical effectiveness may be lower than with the most advanced methods, it may be more beneficial to provide a system that people can afford and that they are capable of running and maintaining on their own. Numerous trade-offs may be required and it must be stressed here that the choices must be made by the individual governments. For these purposes, governments are encouraged to enlist the aid of, not only engineers, but environmental health and social science experts whose combined efforts may greatly affect the ultimate choice. Furthermore, it may be necessary to perform pilot studies to assess advantages and disadvantages.

McGarry (1977) proposes the following methods as potential wastewater collection solutions for the developing urban community; the septic tank; the aqua privy; the aqua privy-sewerage system; and the vacuum truck and vault.

The septic tank is a large covered settling tank into which raw sewage is led. Wastes entering the system may be of excretory or household origin. The process of sedimentation occurs within the tank; the sludge settling to the bottom for further decomposition. The liquid and lighter floatable solids flow out of the tank for final disposal. Within the tank, the remaining solids undergo anaerobic decomposition. Typically, a septic tank may operate for periods of one to four years before cleaning out of the remaining solids is required.

Upon leaving the tank, the liquid effluent is filtered through soil, sand, or small stones. During this stage, aerobic decomposition is occurring. This process occurs in subsurface pipe or trench systems, however, alternatives may be necessary where groundwater levels are near the surface.

Wagner and Lanoix (1958) highly recommend this method for small communities and rural areas. McGarry (1977), however, describes a number of disadvantages in the use of septic tanks for developing countries. They are relatively expensive and therefore their use will typically be restricted to the wealthy. They require large areas of land for percolation; the area becomes less available with increasing population. Soils must be highly permeable and when they are not, effluent becomes a serious health hazard. Finally, the temptation of a municipality to rely on individual ownership may later result in higher costs when increasing population necessitates reversion to more efficient methods.

The following check list will be of use in carrying out a sanitary survey of installations comprising septic tank latrines:

- Location of the latrine for optimum use;
- Availability of adequate water supply;
- Adequacy of the number of seats for the number of users;
- Efficiency of the water seal as provided; quantity of flush-water required;
- Cleanliness of the seats in use; user proficiency;
- Absence of foul odors and flies;
- Structural defects, broken doors, cracked floors or walls, bad ventilation, defective manhole covers;
- Average detention time provided by septic tank;
- Age of tank, frequency of sludge removal, quantity and quality of sludge;
- Effluent quality and quantity; content of suspended solids;
- Effluent discharge point; efficiency of distribution and dispersion in trench; adequacy of absorption surface; and detention time provided by stabilization pond.

The aqua privy has been discussed in the section on rural collection methods. It may also be applied to the urban community with the same advantages and disadvantages. The restrictions on applicability of the aqua privy to the urban community of a developing country are similar to those mentioned for the septic tank. Desludging may be effectively accomplished by vacuum trucks.

An alternative system that compensates for some of the major drawbacks of the aqua privy, the aqua-privy sewerage system, has been developed and applied in Zambia (McGarry, 1977). This system allows for disposal of all household wastes. Initial settling takes place in the tank, and the liquid then passes out to a sewer system. This system, however, is much less complex than a conventional sewerage system due primarily to the reduction in solids facilitated by initial sedimentation. This factor results in reduced costs for pipes, trenching, and pumping.

As previously mentioned, insufficient flushing of the system with water following defecation may result in breaking of the water seal. Although this concern is still valid, steps may be taken to preclude this eventuality. For example, several aqua privies may be linked in series so that the liquid effluent from the first flows to the second, etc. This system may also be linked initially with a communal washing facility. In this manner, the water seal is assured.

Costs for establishing and maintaining the aqua privy-sewerage system are highly variable. One proposed means of reducing costs is by sharing of the tank between two to four families (McGarry, 1977). McGarry discusses the relative costs of such a system with the conventional sewerage system: "In comparison to conventional sewerage, this system sets the costs of installing a tank on the property with its associated appurtenances and periodic tank desludging requirements against the benefits of shallow pipe trenching, low or nil pumping, and essentially no additional water needed to maintain the water seal. This system holds considerable promise where a capital intensive passive technology is deemed necessary. However, care should be taken to assess relative costs on a case by case basis as both this and the conventional sewerage systems' costs are highly sensitive to local conditions."

The vacuum truck and vault system has been widely used in various parts of Asia. A vault is used for storage of nightsoil and small amounts of water from anal cleansing. The fixture within the house may be a flush bowl or a squat plate, both using small amounts of water for flushing. At periodic intervals, trucks or carts will collect the contents of the vaults. These contents may then be transported to a treatment or reuse site, such as a fish pond.

The principal disadvantage of the vacuum truck and vault method is that it does not accommodate household wastewaters other than excrement. Additionally, sanitation is maintained by a water seal and therefore cultural habits may preclude its safe use.

The advantages of this method include the facts that it is a relatively inexpensive community system both in terms of installation and maintenance, that it is labor intensive, that the bowl and vault may be locally manufactured, and that the system is extremely flexible, allowing for rerouting at any time (McGarry, 1977).

There is little doubt that the conventional sanitary sewerage system is the most effective method available for collecting wastewaters. However, that degree of effectiveness is often not necessary, nor can many local communities afford to install and maintain it.

The sewerage system begins with a household plumbing system composed of a flush toilet and pipes leading to connections with the community pipes and to the street sewers. As sewage passes through the system, the pipes become larger in diameter and manholes are located periodically for inspection and maintenance. Pipes are constructed such that the force of gravity is utilized whenever possible to move the sewage along at a sufficient velocity. Wherever necessary, pumping stations are employed to counter upward slopes. Typically, the sewerage system leads ultimately to a treatment facility of some sort.

Okun and Ponghis (1975) propose that developing countries should consider conventional sewerage systems for the more urban areas. The level of urbanization at which this becomes practical however, must be decided on an individual basis. And the degree of industrialization is also a critical factor; pollution from commerce and industry may influence the ultimate choice.

McGarry (1977) proposes that sewerage systems are not practical for developing countries, since they require high capital investment and relatively little labor and maintenance. Additionally, he claims that even where sewerage systems have been planned or constructed, they rarely serve the entire population in that urban center, but rather only the wealthier areas. Consequently, outlying areas are often neglected and sanitation facilities postponed to some time in the future.

Nevertheless, rapidly industrializing areas may need to consider the sanitary sewerage system as the only means of dealing with high levels of industrial pollution. In that situation, Okun and Ponghis (1975) have provided an excellent document on planning of conventional wastewater systems (collection, treatment, disposal, reuse) for developing countries. The next section discusses alternative technologies for wastewater treatment that are particularly relevant to densely populated rural and semiurban areas.

In an appraisal of existing sewerage facilities, the WHO recommends that the regularity of sewer cleaning operations should be checked. The sewerage system should be inspected to ensure that no breaks, blockages, or overflows have been left unattended.

The investigation should determine whether there has been any misuse of storm overflows to discharge sewage from overloaded systems, and the condition of the watercourses or drains that might receive such discharges should be inspected. The working routine of the main pumping stations and any substantions should be investigated, taking into account the total quantities pumped (as against the water supplied), to detect any abnormality in the operation of the system.

The quality of the treated sewage effluent as discharged into watercourses should be tested to ensure that it conforms to the quality standard as assumed in the design. If the watercourse is used by communities in and near the area, effective disinfection of the treated effluent should be arranged to cover any period of emergency. If raw sewage is discharged into a watercourse or lake through an outfall sewer, it can become a potential "risk zone" during an epidemic. An outbreak of cholera would contaminate the receiving body of water with the cholera vibrio, and if there is a constant supply of the contaminating discharge this organism may remain in the water for an indefinite period. The use of the contaminated water lower down, for irrigation, bathing, washing, and drinking, may spread infection. As an emergency the possibility of interposing an oxidation pond ahead of the outfall point should be fully investigated.

In any case, emergency chlorination of the sewage effluent should be arranged to destroy pathogenic organisms before they enter the watercourse. Large doses may be used, up to 30 mg/liter, with the object of maintaining a level of free residual chlorine of 0.2-0.5 mg/liter. If raw sewage is discharged into the sea, it is necessary to prohibit public access to the beach in the vicinity during an emergency. If treated sewage is so discharged, it is better to disinfect the treated effluent for the duration of an emergency.

Wastewater Treatment: Conventional and Alternative Technologies

The sanitary collection, treatment, and disposal of human excrement in small communities may be provided by single facilities. However, with increasing populations and crowding, it becomes necessary to transport these wastes to larger facilities designed to accommodate and treat greater quantities of wastewater. This section discusses current wastewatee treatment technologies of potential use to densely populated areas of developing countries where a collective treatment facility is warranted.

The processes that take place in wastewater treatment may occur in a series of separate stages or may be incorporated into one or more stages. Okun and Ponghis, 1975, have broadly classified the various treatment stages into the following: Preliminary treatment, primary treatment, intermediate treatment, secondary treatment, and tertiary treatment. These shall be briefly discussed in terms of the processes occurring in each. However, it must be stressed that many of these stages are not necessary nor recommended for developing countries. Following this brief description, those technologies of relevance to developing countries shall be described in greater detail.

Preliminary treatment is performed initially to remove coarse solids from wastewaters and thereby prevent obstruction or damage to the workings of the treatment plant. Included in this process are screening, grit removal, and flotation. In those instances where wastes are being discharged directly into a large receiving body of water with only preliminary treatment, some form of disinfection is typically performed.

Primary treatment involves, basically, sedimentation. It is capable of a 35 percent BOD removal and 60 percent suspended solids removal when designed for maximal removal of settleable solids (Okun & Ponghis, 1975). This level is aimed for where no further treatment is performed.

Sedimentation is accomplished by a variety of methods including the sedimentation tank, the Imhoff Tank, and the stabilization pond. The latter two methods perform additional functions as well as sedimentation; the Imhoff Tank functions as a sludge digester and the stabilization pond is multifunctional and shall be discussed later in this section.