CHAPTER SEVEN

FINANCING WATER PROGRAMS

In general, the operation and maintenance of drinking water and wastewater systems is financed from income generated by those who use the systems and/or through government subsidies. This section will deal first with financing for the maintenance and operations of water systems and then with sources of funds for planning and design of water supply and wastewater systems.

Community water supply programs in general can be totally or partially financed with locally generated funds. Since these programs distribute a commodity that can carry a price, if the fiscal management is sound such a program can usually meet the cost of operation, initial capital costs and the costs of capital expansion as the system grows. In contrast, the collection, treatment and disposal of wastewater do not involve the distribtuion of a product, but instead represent a service. Thus financing the operations of wastewater systems is more difficult.

Wastewater collection and disposal are not given high priority in the allocation of funds to public services. Water supply systems and other revenue-producing investments are preferred. Yet, as previously mentioned, water supply systems in the absence of appropriate excreta disposal programs can increase the health hazards to a community. Financing is required for all phases of a wastewater disposal project: conception, design, construction, and operation. The required feasibility studies, engineering, inspection, consultation, etc. are often best financed through a package that includes several financing sources.

A community with a water supply and/or wastewater system can attract new industries, commercial enterprises, tourism, and new housing developments. This increases the general economy and employment possibilities that benefit the entire population of the community. Thus, it might be argued that all taxpayers benefit even though the systems may serve only a part of the community. But complete equity in discerning the cost of providing the use and benefits of the works to each resident is seldom possible.

In the case of water supply systems with community taps or home taps, charges proportional solely to the amounts of water used are most equitable. Historically sewerage systems were paid for from general taxation. However, as wastewater collection systems have gained recognition as services to individuals as well as community responsibilities, a wider range of financing programs has been used.

A balanced program might incorporate three types of financing simultaneously: special assessments, taxation, and service charges. Special assessments are made against property owners who are adjacent to and who will benefit from lateral sewers. General taxation for the stormwater portion of combined sewers as well as for a proportion of the total cost of the system that can be said to benefit the community as a whole is common. Service charges, based on dwelling units, water use, number of water fixtures or some other appropriate measure, for wastewater collection and disposal from households and establishments is another common method.

This array of financing devices may be necessary in large cities where a wide range of industries and households are served. But, in smaller communities a single financing system that is simple in character and consistent with government practices will suffice.

Hazen (1968) has summarized the factors favoring each of these types of financing. In the frontage assessment system for laterals the property owner pays directly for having a sewer in the street to which he can connect his property if he so desires. The ability to connect is a convenience to the owner. It is worth a great deal and adds substantially to the value of his property.

Assessments based on frontage reflect not only the actual cost of the sewer installed, but also the owner's ability to pay. The wider the plot of land, presumably the better able the owner is to pay for the service. The assessment places the burden on the newcomers to the city who need the facilities, and not on those who may already have paid taxes over many years for citywide sewerage facilities. This is significant in the extension of existing systems but may be of little importance where a complete sewerage system is to be constructed at one time.

Factors favoring ad valorem taxes on all property exist when adequate sewerage and sewage disposal is a "public necessity." All property owners benefit from the existence of a sewerage system, even if they are not connected immediately. These benefits are twofold: (1) real estate values are greater in cities with sewers and other utilities, than in cities without these services. The mere existence of sewers will enhance the market price of property; (2) the householder who installs a connection to the sewerage system and gets rid of an unsanitary and inadequate privy, cesspool, or septic tank, may help his neighbor as much as he helps himself.

In most communities, especially those without wastewater treatment, the cost of sewerage is a function of the construction cost, not of the quantity of sewage flow from each house. The costs per house throughout the city are normally comparable, or at least of the same order of magnitude. Persons with large houses or large plots of land are normally better able than their poorer neighbors to pay more for sewerage. If ad valorem taxes are already collected for other municipal purposes, the tax rate need only be increased to provide the necessary sewer revenue, without separate billing and collection. State or federal grants in aid of sewer construction may be applied directly to reduce local costs without questions being raised as to equitable apportionment.

Factors favoring service charges to users exist where a service charge is already being made for water, increasing the rate by a fixed percentage for sewer service is simple and relatively "painless." Borrowing against this type of assured income is generally easier. In addition, service charges are particularly appropriate for meeting operation and maintenance costs, as both these costs increase approximately at the same rate as the population served.

Because service charges are likely to be widely adopted for meeting at least a portion of the costs of wastewater collection, treatment, and disposal, some further information on this type of financing is given here. Service charges are intended to recover the costs of the system from those users who benefit directly from it. The costs of providing benefits to the local community as a whole from improved sanitation or to a downstream community adversely affected by polluted receiving waters are more difficult to measure and, with currently available institutional arrangements, often difficult to recover.

Where water supply is metered and where the water and sewerage agencies are under the authority of the same government department, an increase in the water rate is easy to impose and to collect, and is generally fair. Failure to pay may be met by cutting off water supplies. Such dual dependence on the water meter may encourage better programs of meter reading and meter maintenance. This system may be inequitable where a substantial fraction of the water is used for sprinkling lawns or vegetable gardens. Such practices will often prevail over a well-defined area, and special allowances can then be made, based on the area watered. Another type of inequity may result where a large commercial or industrial user possesses a private water supply, but makes full use of the sewerage system. Metering of the private supply would then be appropriate.

The strength of the wastewaters from ordinary households can be expected to be fairly constant, so that the measurement of volume will be sufficient. However- with certain commercial and industrial establishments, such as laundries, dairies, food processing plants, tanneries and the like, the volume of the wastewater is not a true measure of the burden placed on the treatment plant. An additional charge to allow for the increased cost of treatment, as measured by solids and/or BOD, may then be appropriate. This charge can be based on selected samples collected on a 24 hour basis several times a year, or on known relationships between pollution load and output, or an intensive survey may be carried out and the annual charges determined in the light of the information obtained. (American Public Works Association, 1955)

In the absence of meters, a flat annual charge per dwelling unit or based on the number of water closets, sinks, bathrooms, or a combination of these fixtures in a house is useful. The volume of wastewater to be discharged can be expected to be approximately proportional to the number of drains provided.

A special method of charging appropriate to the circumstances may be adopted in each individual instance. The method should be equitable but above all, simple, to ensure a high rate of collection. In the few instances where low-income residents cannot be expected to pay a service charge but where community sewerage is provided, some government agency should pay for the sewerage on behalf of these residents. This agency may be the housing authority, or the welfare agency, or the municipality itself, even if the sewerage is under the jurisdiction of the municipality.

Local regulations for municipal borrowing vary from country to country. Bonds are widely used in industrialized countries, but less so in developing countries. Where used, three types of bonds may be sold when a municipality or other local uthority seeks to borrow money on the open market. The main types of bonds are assessment bonds, obligation bonds, and revenue bonds.

The special assessment bonds are short-term bonds designed to permit borrowing for a specific project serving only part of a community, such as lateral sewers that serve only the houses on a particular street. General obligation bonds are backed by the full faith and credit of the community, income generally being derived from ad valorum taxes on the property of the community. When the bonds are to be repaid over a period of years, they are called serial bonds. Revenue bonds are based on repayments earned from service charges paid by those who use the service.

The interest rates and the terms of loans, particularly general obligation bonds, depend on the financial status of the borrower. If a community or a nation has many debts outstanding and limited resources, the interest is likely to be very high, if a loan can be generated at all. The interest rate for revenue bonds depends, not on the indebtedness of the community, but rather on quality of project management. If it can be assumed with some confidence, based on previous experience with the community concerned or with the administrative practices of the country, that the project will be operated on a sound fiscal basis, the interest rate for revenue bonds may be low. If the fiscal integrity of the project is uncertain, the interest rate may be very high indeed. In general, the poorer communities have to pay the higher interest rates and can only obtain short-term loans. The desirability and necessity of high-quality management personnel becomes clearer when it is realized that it affects both the ability to borrow and the cost of borrowing.

For small communities in developing countries, capital costs are best met from loans or grants paid for out of the general taxation, either of the community or the nation, whereas operation and maintenance charges are best met by revenues collected from those actually using the system. The philosophy of this approach is that the capital works, including the main trunk sewers, pumping stations, treatment plant, and the like are constructed to serve not only those immediately connected but also those to be connected in the future. The entire community should therefore be charged for this investment for the future. The operation and maintenance costs, which need to be met both to preserve the capital investment and to serve those using the system, are appropriately met by the latter.

One type of financing may be used when the project is initiated and replaced by another over the years as the system is enlarged. During the early years, the capital costs may be met entirely from loans or grants charged against local or national taxation or even from international borrowing. Operation and maintenance costs may be met from revenue. However, as the number of users of the system increases, the revenue will increase and it will become possible to meet some of the fixed charges from revenue as well. If the project has been properly planned, a point should be reached where income will be adequate to meet all the annual charges and to generate a surplus that can be used for further extension of the system.

After a sewerage system with street laterals has been installed, householders may be reluctant to invest in connections. In small communities and in the poorer sections of large communities in developing countries, the cost of such connections may be high with respect to the value of the house to be connected. Yet it is just these houses that most need to be connected. The establishment of a revolving fund may provide the necessary encouragement, since such a fund gives householders an extended period in which to repay the cost. A system of partial grants towards the cost of house connections would provide an excellent incentive for the householder.

Early connection to a system on the part of the entire population accessible to it is important not only for sanitary reasons, but also because it will provide the income from service charges necessary to keep the project economically viable. The promise of 100 percent house connections is important to the lending agencies.

Wastewater collection enjoys a higher priority than wastewater treatment, as the health status of a community is improved even if the collected wastewaters are discharged untreated into a receiving stream or the ocean. if the receiving stream is large, or if the water below the community outfall has no immediate beneficial use, the priority given to wastewater treatment will be even lower. A further difficulty is that the direct benefits from treatment are often obtained downstream by communities other than those that pay for it. With many pressing and competing needs for funds, treatment has a low priority in a situation where little local benefit accrues from it.

Industrialized countries have just begun to'give serious attention to the problems of stream pollution, and many schemes are being used and proposed to promote the construction of treatment plants and provide sound methods of training. This problem will not be discussed in detail here, however, relevant references to these techniques are found in the Recommended Resources.

Funding Capital Costs

Sources of funds for the capital costs of engineering and construction of drinking water and wastewater systems may be public and private and can come from local, national, or international sources. Frequently it is necessary and desirable to finance projects through the use of more than one of these sources. The financing of projects in developing countries is markedly different from borrowing in industrialized companies. As previously mentioned local funds are limited, interest rates are high, rapid repayment is necessary and almost always there is an unfavorable balance of payments. Some equipment, supplies and personnel have to be brought in from industrialized countries in many cases, thus obtaining ready currency on favorable terms becomes a major problem.

Local financing may be accomplished in two ways: through the sale of bonds or the local direct contributions of labor and materials. The sale of bonds requires repayment that depends on local taxation and income generated by the project. In small communities selling bonds at reasonable interest rates may not be feasible. Financing through local contributions of labor and materials is one of the most effective means of achieving local participation and community cohesiveness. The construction of these systems is labor-intensive work that can be carried out with local labor if supervision is adequate. Where other necessary funds for a community project are to be obtained from a national source through loans or subsidies, an important consieration in establishing the priority to be given to such contributions is the extent of local participation. A community that is well organized and prepared to contribute a substantial portion of the total cost of its project is more likely to obtain the best possible terms and most favorable rates for borrowing funds.

In most developing countries, the financing of community wastewater and drinking water projects in most developing countries depends upon a national initiative in the form of subsidies or of loans. In general, the outright subsidy or grant is less satisfactory since it does not ensure continued support for an ever growing program.

National development banks may extend credit to local or provincial agencies for drinking water or wastewater projects. The development bank may extend credit for a portion or the total cost of the work, generally at relatively high interest rates and over short periods because of the local financial situation. In turn, the development bank may obtain its funds from international agencies or through bilateral loan agreements with industrialized countries at lower interest rates and extended over longer periods. The profit from these loans will help to increase the resources of the development bank and enable it to accelerate the construction program.

It has been recommended that countries in process of development interested in international loans for their water programs should apply for loans up to the amount of the external components of their individual projects if they want to follow a healthy financial policy (Hernandez, 1966). To use foreign exchange to pay the costs of local labor and materials is generally inappropriate and uneconomic, as public projects, such as water supply and sewerage, generate little revenue that can be used for repayment.

However, when international loans are available for financing sound water supply and wastewater projects, interested countries may be justified, under special conditions, in financing as much as possible of the project with such a loan in excess of the external component of the project that has to come from abroad. This constitutes an important secondary benefit of such projects to economic development, on the assumption that the country's international financing policy is a wise one.

Funds from international sources are generally not as readily available for wastewater projects as for directly productive projects that can add to the economic resources of the borrowing country, or for infrastructural projects that may lead to improved economic standards that in turn may assist in the development of productive projects. Another important factor in determining the availability of loans is the ability of the borrower to repay them; this in turn depends on whether the administrative and fiscal practices of the borrower are sound or not. Bilateral loans from industrialized countries may be an exception to this rule, however, where the social value of a project is clearly established and such assistance is consistent with the foreign policy objectives of the lending country.

One of the main objectives of all international assistance programs is so-called "institution-building." Training of local staff often is, or should be, explicitly provided for in loan and grant agreements. This training can be provided on the job but, for key engineers and administrators, specialized postgraduate educational program designed for personnel from developing countries should be used. The International Courses in Hydraulic and Sanitary Engineering at Delft, Netherlands, and the International Program in Sanitary Engineering Design at the University of North Carolina, among others, have provided such specialized training.

Since foreign aid policies vary from country to country, and are highly fluid, such policies cannot be discussed in any detail. Many industrialized countries plan to use their national resources for assisting developing countries through contributions to established international lending agencies such as those mentioned below. Drombach (1971) has reviewed the relationship between foreign aid and water supply and sewerage projects.

The World Bank (International Bank for Reconstruction and Development) and its associated International Development Association, are possibly the most active in making loans for wastewater collection and disposal. A questionnaire developed by IBRD is given to all organizations seeking loans or credits for sewerage projects. Although the purpose of the questionnaire is to provide guidance in preparing feasibility reports for the World Bank, the information requested is much the same as that required by any of the other international loan agencies. The IBRD has an excellent staff of sanitary engineers and economists who can assist in developing and evaluating projects.

The current interest rate on World Bank loans (February 1974) is 7.25 percent on the disbursed balance of the loan, with an annual commitment charge on the undisbursed portion of 0.75 percent. The interest rate charged by the Bank varies from time to time, depending upon the cost of current borrowings. A grace period (during which repayment of principal is not make) is granted for the construction period plus a certain time thereafter, usually six months to one year. Interest is payable during the grace period either from the loan account itself or by the borrower from his own funds. The loan amortization period depends on the individual project, but has customarily been from 15 to 30 years for water supply and sewerage projects.

The Bank usually limits its loans to the foreign exchange costs of the project. These are normally defined as the costs of foreign goods and services directly imported for the project and the foreign currency costs of locally provided goods and services to the extent that these costs can be readily ascertained. Local currency costs may be financed in special cases, as determined by the economic requirements of the country and not by the project needs. Funds may be made available in various currencies and must be repaid in the same currencies. However, as far as the project is concerned, the funds are available in "hard" currencies and must be repaid in such currencies.

IDA finances the same general types of projects as the Bank, selected according to the same standards, but on terms that place a much lighter burden on the balance of payments of the borrowing country. The development credits extended by IDA to date have been for a term of 50 years, with a 10 year initial grace period. There is no interest charge, only an annual service charge of 0.75%. These favorable terms are available only to the country; the funds are loaned to the project by the country on terms similar to those for conventional bank loans.

Regional Development Banks include the Inter-American Development Bank, which has the longest history in this class, the Asian Development Bank, and the African Development Bank. The offices of the Inter-American Development Bank are staffed with qualified engineers at the headquarters in Washington, D.C. and in each country of the Americas. Loans are made to Member Governments, their political subdivisions, and private entities. Loans are made for specific projects, including projects that are parts of national or regional programs. The Bank may also make or guarantee loans to national development institutions to permit them to lend smaller amounts to communities within the country. Repayment of loans from Ordinary Capital Funds must be in the currency lent, which is generally U.S. dollars; in general, lending policies are not unlike those of IBRD. The Bank fund for special operations, the Social Progress Trust Fund, begun in 1961, provides special resources for projects in the fields of education and health, including water supply and wastewater collection and disposal, which can be repaid in local currency.

Up to 1969, $452 million in loans had been made for water supply and sewerage projects costing, in all, some $1000 million. Of a total of 1641 systems assisted by the Fund, up to 1968, only 99 were for wastewater collection, although the proportion of such systems is increasing (Inter-American Development Bank, 1969). Loans may be made to national governments either through their national banks, which finance a wide range of projects, or through specialized banks or funds. One successful technique has been a "revolving fund;" this is initially created by a bank contribution to the central government and is kept operating through repayment of loans and the accumulation of interest from each loan. Such a revolving fund provides a sound basis for applications for loans by the national government to bilateral or international agencies interested in supporting such projects.

The Inter-American Development Bank can make combined loans from its Ordinary Capital and Special Operations Funds for water and sewerage projects in accordance with the economic status of the population concerned. It generally finances 50 percent of the cost of a project, including the whole of the external component and some of the local component. It also makes pre-investment loans for water and wastewater projects that are to serve as a basis for subsequent construction loans.

The United Nations Development Program finances pre-investment studies for research and development, for institution building, and for training projects in many fields, including water supply and wastewater disposal. If governments desire, WHO will help to prepare requests to UNDP for such financing of activities for which it is responsible, but the project document itself must always be submitted by the government concerned and meet the relevant UNDP conditions. If the request is approved, the funds are made available, usually subject to the appointment of an international agency as "Executing Agency;" in the case of water supply and wastes disposal projects, this is normally WHO.

Depending on the priority given to the project and its size, and whether or not it has been included in the overall country program of UNDP assistance, approval may be given by the Administrator or Assistant Administrators of the Program. Government counterpart contributions are usually called for whenever UNDP financing is provided. These may be in kind— e.g., the provision of local staff, office accomodation, transport, and locally available equipment and materials— and sometimes in cash in the local currency.

In general, pre-investment studies carried out with UNDP funds do not include detailed final engineering design or construction works. The objective is to produce a "bankable" project that will attract investment from an international, regional, or bilateral source. The Executing Agency will, if so desired, assist governments in obtaining loans for construction purposes, and the lending agencies themselves welcome the pre-investment studies as a basis for loan agreements, particularly in countries where experienced engineering consultants are short and outside expertise has to be called upon.

Where WHO has been appointed the Executing Agency for a UNDP-assisted project, the pre-investment survey is normally entrusted to a firm of internationally experienced consultants, slected from a list previously cleared by the government concerned. These consultants may include engineers, management specialists, economists, hydrogeologists or such other specialists as may be called for by the nature of the project. Their terms of reference are derived from the approved government request (Project Document) to UNDP, which in turn may have been prepared with the assistance of a WHO team consisting of an engineer, an administrator, an economist, and any other specialists appropriate to the problem. Such a team may be financed by WHO or UNDP, but the government normally provides such facilities as office accommodation and transport, and at times, secretarial services.

International banking agencies, in coming to a decision on the granting of a loan, are likely to be influenced not only by the desirability of the project and the efficiency of its design, but also by the institutional arrangements made for its future management, by the financial arrangements made for its future management made for loan repayment, and also by the experience of the undertaking or organization in servicing and repaying similar loans in the past. All these points are included in the pre-investment study, so that, in many cases, it is regarded as an almost indispensable preliminary to securing an international loan of this nature.

Other international agencies, such as UNICEF and the World Food Program, also provide assistance, particularly for smaller projects. Additionally U.S.A.I.D., C.I.D.A., O.D.M., and several national governments (Sweden, France, Japan, Germany, and others) offer assistance which should be investigated. As international support for developing countries grows, new programs will undoubtedly be initiated.

CHAPTER EIGHT

SOLID WASTE

Those substances defined as solid wastes include "all non-gaseous, non-liquid wastes resulting from the wide range of community, industrial, commercial, and agricultural activities." (Gilbertson, 1969) Management of solid wastes is of concern throughout the world; increasing populations, industrialization, and consumerism contribute to the problem.

The need for sanitary methods of solid waste disposal in developing countries is evidenced by commonly occurring open garbage piles, often also containing nightsoil. This situation creates potential hazards in both rural and urban areas. The hazards tend to increase as the volumes of solid wastes increase; this occurs with increasing urbanization and industrilization.

Generally, domestic wastes are comprised of garbage from food preparation, wastes from house sweeping, animal wastes, and ashes from fires used for cooking or heating. In towns, this category is expanded to include wastes from more specialized or concentrated activities, such as schools, markets, hospitals, and tourist facilities.

Agricultural wastes include animal manures, crop residues and animal carcasses. Industrial wastes may include a variety of materials specific to particular industries. Many of these wastes are inert and not harmful to health, while others may include highly toxic substances. Generally, it should be the responsibility of the individual industry to properly dispose of toxic wastes. Other wastes most typically found in urban areas include those from construction, storm drains, street cleaning, abandoned vehicles, and nightsoil.

Garbage is defined as putrescible animal and vegetable wastes resulting from handling, preparation, and consumption of food. Rubbish is defined as nonputrescible solid wastes (including ashes) composed of both combustible and noncombustible wastes, such as paper, tin cans, wood, glass, crockery, etc. Refuse includes all putrescible and nonputrescible solid wastes (except body wastes) including garbage, rubbish, ashes, street cleanings, dead animals, abandoned automobiles, and solid market and industrial wastes.

It is well known that solid wastes, particularly those of animal or plant origin, attract insect and rodent pests and disease vectors. Flies, for example, often breed in solid waste. Their disease-transmitting potential has been discussed in the section on wastewater and excreta. Furthermore, organisms associated with fecal contamination are commonly detected in solid wastes, particularly where nightsoil is disposed with refuse, often where sanitary awareness and practice are inadequate. For example, a study by Bhoyar, et. al. (1973) indicates that both Ascaris lumbricoides and Trichuris trichiura are commonly present in city refuse and that their prevalence is highest in samples from slum and low income areas, and lowest or nonexistent in samples from high income areas.

Nonorganic solid wastes can indirectly contribute to the disease picture. For example, the Aedes mosquito is known to prefer nondegradable cans and

and similar objects for breeding (Almeida Machado, 1973). Therefore, increased disposal of these containers increases the reproductive potential of these disease vectors, transmitting yellow fever and dengue.

Industrial wastes create additional potential health hazards. Included in this group are radioactive wastes, explosives, and highly toxic and pathological materials, The increasing industrialization requires careful monitoring of new and old industries and their waste by-products.

Secondary health hazards can result from the disposal of solid wastes. For example, open or otherwise uncontrolled incineration of solid wastes results in air pollution. Additionally, improperly situated dumps or landfills may promote water pollution as leachate flows from dump to water source.

In rural areas, the organic content of refuse is relative higher than in urban areas, because it contains animal waste, cattle dung, or stable refuse. All of these contribute to the fertilizer quality, but must be properly treated. In rural households, particularly in scattered rural areas, the refuse dump is often in the backyard, near the location used for defecation. In such cases, domestic animals aid in the decomposition of organic materials, however, unless precautions are taken to sanitarily compost, particularly if human feces are included, the disease breeding potential of these dumps is tremendous. Composting is most commonly recommended under these conditions, with alternating layers of house refuse, garbage, and animal manure between thin layers of earth, straw, or ash. Composting is discussed in detail in a later section.

As population density increases, it may become profitable to dispose of solid wastes communally. Here individual storage mechanisms must be established with some means of collection and transport to the disposal site. This situation will be discussed in combination with urban technologies. In urban and semiurban areas, the three basic operations that are planned for are: storage collection, treatment, and disposal. Techniques in these three categories relevant to rural, semiurban, and urban areas are discussed below.

Storage of solid wastes at households is a simple procedure involving disposal of all refuse in a bin or can that is adequately covered to prevent pest invasion. In some situations household refuse is carried to communal storage bins. These must be made easy to operate, yet sufficiently secure when closed to prevent infestation. Openings should be within the reach of children for dumping.

The type of material from which the bin is made should be impermeable to leakage and easy to clean. Pickford (1977) discusses the advantages and disadvantages of metal versus concrete bins. Concrete is more difficult to clean while metal tends to retain a layer of refuse unless removed from the site and cleaned under careful supervision. Either one is more acceptable than open dumps. One successful type of communal container is made in Lagos (Pickford, 1977). It is a metal box with easily sliding panels. The container is removed by a special vehicle, emptied, and cleaned, while another clean container is put in its place.

Collection methods should avoid spillage around the refuse bin. Additionally, the collecting truck should have an adequate capacity, suitable cover, facilities for unloading with ease, maneuverability to negotiate narrow and winding roads, and proper heights for loading.

Vehicles chosen for collection should be relatively simple and smaller than those used in developed countries. Vehicles should require as little maintenance as possible, and should, when possible, be of a similar type, so that maintenance will be easier. Maintenance should include daily washing and periodic painting to prevent corrosion.

One method for optimal collection recommended by Pickford is a relay system whereby wastes in trailers may be hauled by tractors, thus requring fewer tractors. Double handling or transfer loading should generally be avoided due to the increased potential for health hazard. However, if distances to the disposal site are sufficiently great (over 20 kilometers), it may be more efficient to transfer the collected wastes into layer vehicles for final transport to the disposal site (Pickford, 1977).

Treatment and Disposal

Pickford (1977) recommends the following considerations be made in planning refuse treatment and disposal facilities:

- The quantity and character of the refuse, and likely changes in these.
- Amount and quality of land available for final deposit.
- Constraints on the temporary and ultimate use of possible tipping sites.
- The health of the public and refuse workers.
- The need to restrict the use of mechanical equipment in developing countries.
- The need for compost due to the soil structure and the type of agricultural activity.
- The potential use of power or heat resulting from incineration.
- The costs of possible methods.

The three basic methods of refuse treatment disposal practiced throughout the world and recommended for use are: composting, sanitary landfills (controlled tipping), and incineration. The comparative costs and benefits of the three methods are discussed by Gilbertson (1969). He suggests that the sanitary landfill is the least expensive if land is readily available and reasonably priced. The benefits of the sanitary landfill are: (1) it requires no secondary disposal once the site has been filled, (2) size and moisture content need not be regulated, and (3) the landfill site may be reclaimed for recreational use once it has been filled. In comparison, composting and incineration are more costly for community use, requiring size and moisture regulation of the waste materials. The primary benefit of composting is the production of a reusable compost which can be applied to soil as fertilizer. The primary benefit of incineration is that little land is required. Each of these three methods is discussed here in greater depth, stressing applicability to conditions in developing countries.

Composting has been used extensively in many parts of Asia as a means of converting refuse and nightsoil to reusable fertilizer. Decomposition of organic matter is controlled in a warm, moist environment by the action of various microorganisms. During this process, sufficient heat is generated to destroy most pathogens.

Generally, manual composting is recommended for developing countries. However, whether the benefits outweigh the costs is questionable. Some experts claim that the value of compost fertilizer is not worth the cost of treatment (Pickford, 1977). However, with the addition of nightsoil, the fertilizing potential of compost is much greater. Another argument against composting is the sale of compost does not cover the cost of plant operation and that in areas with already rich soil, there is no need for compost. These factors must be evaluated regionally.

Factors that must be considered in the operation of composting facilities include the following:

- Moisture content— this must be regulated to between 40 percent and 60 percent for optimal operation.
- Termperature— this should not exceed 70 degrees centigrade.

- Wind— wind tends to lower temperature and moisture content on the windward side of heaps. Water addition may be required to compensate for wind.
- Flies— flies may be controlled by turning the outside of windrows to the middle. This may be required as frequently as every day if flies are creating a nuisance.

(Pickford, 1977)

The method of composting used in developing countries generally involves the formation of windrows, long piles of refuse approximately two meters high. Typically, the refuse in turned by hand or tractor shovel every few days. This process may occur on open land or on a concrete floor which will control leaching of pollutants to the water table.

Pickford (1977) discussed two composting methods developed in India: the Bangalore method and the Indore process. Good compost is produced by the first method after six months and by the second method after four months. In larger cities with large volumes of compost produced, it may become necessary to incorporate a greater degree of mechanization including tractor shovels for turning, and a conveyor belt to remove stabilized compost.

The sanitary landfill method (or controlled tipping) is a method of disposing of solid wastes on land by compacting them to the smallest practical volume, and covering them with soil daily, such that health hazard and environmental contamination are eliminated. Most types and sizes of waste may be disposed in this manner. Pickford (1977) describes the benefits of this method:

- Limits odor emission.
- Prevents light refuse being blown away by the wind.
- Prevents the emergency of fly larvae.
- Prevents the breeding of flies.
- Allows rat control to be easily applied.
- Reduces the risk of fire.
- Makes the tip less attractive to birds.
- Provides good condtions for the biological degradation of organic matter in the tip.

Dumping, the principal operation of a sanitary landfill, can be accomplished with a shovel, or a small bulldozer, or a tractor loader-shovel. Exhibit 1 displays methods applicable to rural and urban areas. If very large objects are present, these should be crushed, however, in developing countries, scavenging is widespread and anything salvagable will probably already be removed. If refuse is composed of putrescible material, it should be covered as soon as possible. Otherwise, the refuse should be covered each day. A 60 cm layer of packed earth is recommended as final covering.

A critical consideration in construction and operation of a sanitary landfill is the prevention of leachate from the fill contaminating the groundwater. Pickford (1977) recommends three ways to prevent leaching:

1. Where the underlying strata are fissured, a layer of sand or gravel may be put at the bottom of the tip. This acts as a filter. Biological degradation of organic matter and natural reduction of bacteria occur.
2. An impermeable barrier may be put at the bottom of the tip. Clay or plastic sheeting covered by a protective layer of sand are suitable. The leachate should be collected and discharged to sewer or special treatment facilities. Alternatively, it can be pumped and sprayed on the surface of the tip to control dust.

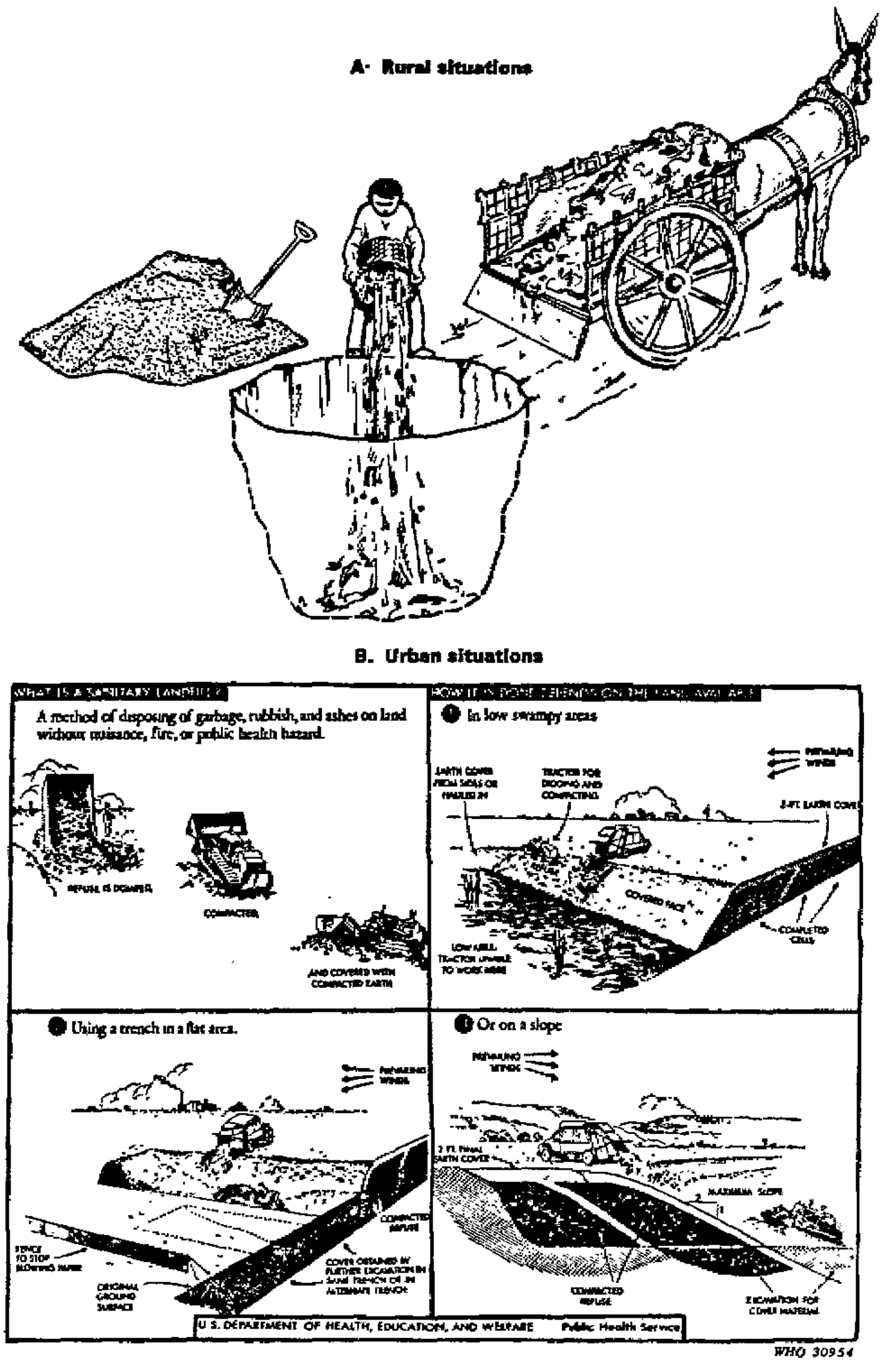

Exhibit 1: Sanitary Landfills (Source: Rajagopalan,1974)

3. The cover may be impervious to prevent rain reaching the tipped waste. Clay can be used. The surface must be given a slight fall and vegetation should be encouraged to reduce run-off and dessication. Drying cracks and settlement of tip material often destroy the impermeability of the cover. If the seal is maintained, gases given off during stabilization of refuse will be trapped. The cover may be lifted as a dome and then fractured.

Considerations for the choice of cover material are discussed by Pickford. First of all, any inert material may be used and advantage should be taken of local activities in the choice of cover.

On natural low-lying or desert sites, a shallow trench can be dug for the first section of the tip and material stockpiled. Cover is then obtained by excavating ahead of tipping until the whole site has been filled. The stockpile from the first trench is used to cover the last section of tip. Near large towns and cities, builders are often very willing to dispose of solid construction waste on refuse tips.

Inert industrial wastes may be available. If coal is used at local electricity power stations large quantities of ash may be available. At Sekondi and Kumasi in Ghana, sawdust from local mills provides an excellent cover. A smooth, even surface has been obtained. Stabilized material from old tips makes a satisfactory cover.

Nairobi has no difficulty in finding sites or cover. Generally, abandoned quarries are taken over. More than enough cover is delivered by contractors who are given a free tip for excavated material obtained during construction work. This is mainly black cotton soil and is stockpiled near the quarry. At large tips refuse is received throughout the 24 hours. Cover is moved from the stockpiles by day-shift workers using a tractor-shovel.

If the land to be filled is marshland, care should be taken to dump into shallow waters. Anaerobic decomposition and resultant odors are thereby minimized. The use of these types of lands should only be chosen when dry land alternatives are not available.

The planner must establish the optimal distance of the landfill from the community, balancing costs of transport and protection of public health. This determination must be based on local geographic factors as well as attitudes of community members. Pickford (1977) recommends the following management operations that may allow for siting close to built up areas: "Windblown refuse should be controlled by fences or by raising an embankment around the site. In windy weather refuse should be tipped at the end of the tip away from houses in bays formed in windless weather. The entrance should be attractive. Vehicles, and especially their wheels, should be cleaned before leaving the tip. Plant trees or shrubs, or raise embankments as a visual screen. Start tipping near to roads and work away so that the tip face cannot be seen by the public. Keep the completed tip tidy, putting it into temporary use as soon as possible. Plant grass, shrubs, or flowers. Inspect frequently for infestation by insects and vermin and take corrective action."

Incineration is a long-practiced method throughout the world. However, the process results in a great deal of smoke pollution unless properly controlled, and the technologies and expertise required to effect that control are very costly. Where land is available, incineration should not be performed. Only where land is scarce and money is readily available should this method be considered.

Other processes that may be considered for incorporation into the solid waste treatment and disposal process include spearation, pulverization, and compaction. Each of these provides certain benefits, however costs are also increased.

Separation or salvage, is often practiced by scavengers in developing countries. It may be beneficial to employ pickers to collect reusable materials thereby reducing the volumes to be treated and recycling nondegradable materials. The benefits to be gained from this process are highly variable and must be assessed on an individual local basis.

Pulverization homogenizes the wastes to be disposed before either composting, landfilling, or incineration. The increased cost of equipment must be weighed against advantages which include: reduced voids in landfill, easier control in tip, less fire risk, less attraction of insects and rodents, less cover required, biological decomposition is quicker, therefore reuse is accomplished faster. (Pickford, 1977)

High pressure compaction of refuse increases the density of collected materials. Transportation costs may be lower due to the decrease in volume. However, increased costs of compaction must be weighed against the decrease in transporation costs.

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