CHAPTER XV. REGULATORY AND ECONOMIC INSTRUMENTS FOR SOLID WASTE MANAGEMENT

A. Introduction

This section presents an overview of major strategies and policy methodologies employed in solid waste management in developing countries and in industrialised nations. The strategies and policies of concern are those that are designed to facilitate the control of pollution, especially those related to the improvement of solid waste management. Although the examples presented in this section deal with experience gained in industrialised countries, the message conveyed is applicable to developing countries with very minor modifications.

In industrialised countries, the strategy for protecting and enhancing the quality of the environment calls for direct regulation, reinforced by the "command-and-control" approach. In essence, the approach consists of the implementation of systems for monitoring and for the enforcement of the regulations. Usually, the implementation of the approach is by way of the application of regulatory instruments such as standards, permits, and licenses, and the control of land and water use. The approach more or less affords the regulators some degree of predictability regarding the achievable pollution reduction. Despite allegations regarding economic inefficiency and difficulty of enforcement, command-and-control strategies have been of significant assistance in the fulfilment of objectives of environmental policies.

In an attempt to endow control measures with increased flexibility, efficiency, and cost effectiveness, in some instances, industrialised countries are resorting to a mechanism that is based on economic motivation, i.e., economic incentive. The incentive is the empowerment of potential polluters to select the particular means of control that is economically favourable to the potential polluter. The rationale for the innovation is the assumption that if properly implemented, reliance upon economic incentives is attended by several advantages. Among the postulated advantages are the following:

1. promote the use of cost-effective means for achieving acceptable levels of pollution control;

2. encourage the development of pollution control expertise and technologies in the private sector;

3. provide a source of revenue to be applied by the government to pollution control programs; and

4. lighten the burden that otherwise would be placed upon the government with regard to the collection and analysis of the extensive data involved in determining the feasible and appropriate level of control for each and every facility or product.

Supposedly, the need for governmental involvement and regulation can be materially reduced through recourse to economic instruments, because those functions would be accomplished by the economic instruments according to market mechanisms. The reality is that, in practice, the need for conventional monitoring and enforcement, and other forms of direct government involvement, has not been materially lessened by economic instruments.

Thus far, applications of economic incentives have been quite limited and, as yet, there is no instance of a significant improvement in environmental quality that can be credited to economic incentives. Hesitancy to rely upon economic incentives is largely due to uncertainty regarding ramifications and possible undesirable outcomes. Moreover, implementing a suitable application is a difficult and complex undertaking. Finally, economic instruments could be used to complement direct regulation.

B. Responsibility for regulatory and economic instruments

Nearly every governmental and non-governmental agency becomes involved in or is affected by ramifications traceable to the selection of regulatory and economic instruments designed to fulfil pollution control and waste management objectives. The responsible level of government, the type of institution, and the mechanisms for enforcement are determined by the nature of the selected instrument. Usually, agencies at the national government level are entrusted with instruments that involve activities characterised by a very high degree of political consensus, maximum complexity, and risk. On the other hand, responsibility for instruments concerned with natural resources shared by two or more municipalities generally is given to state and local agencies. Policy instruments that deal with wastewater collection and treatment, drainage control, air pollution from both mobile and fixed sources, solid waste management, and groundwater contamination generally are consigned to the local government level. At times, authorities managing a particular watershed, waste generation area, or air basin may be given responsibility for pollution control. Occasionally, non-governmental agencies strongly influence the development and enforcement of pollution control regulations.

B1. NECESSARY conditions

The authority of the agency assigned the responsibility for implementing pollution control or waste management policies must be clearly delineated. It follows that the selected agency be endowed with the expertise, human resources, equipment, and financial resources needed to carry out the policies. In many developing countries, doing this with respect to waste management, pollution control, and enforcement would involve a substantial strengthening of human and financial resources and of organisational structure. Frequently, it even may happen that a new environmental agency or environmental unit must be established.

Available reports of evaluations of the application of regulatory and economic instruments in developing countries are few in number. Reports that are available mostly deal with information on the existence or non-existence of standards or other regulatory or economic instruments. They focus attention on the weakness of current institutions and personnel regarding monitoring and enforcement activities. The literature contains few citations regarding the successful application of regulatory and economic instruments to environmental management.

In a developing country, the basic challenge regarding the makeup of environmental programs is to decide upon an appropriate combination of instruments. Among the factors to be considered are social, political, economic, and environmental issues. Accordingly, considerations that should be taken into account in the planning of environmental strategies and the selection of policy instruments should include the following: 1) the successful application of economic instruments pre-supposes appropriate standards, accompanied by adequate monitoring and enforcement capabilities; and 2) even with the establishment of effective monitoring and enforcement capabilities, it is unlikely that economic instruments will replace traditional regulatory instruments. Nevertheless, if adequate enforcement mechanisms are in force, a highly effective approach to the attainment of waste management objectives is the imposition of direct charges.

B2. NEEDED research

Additional research on environmental management strategies is needed. In-depth studies should be centred on the evaluation of the effectiveness of various regulatory and economic instruments as, for example, practical aspects of initiating and operating an economic instrument and the circumstances essential to the success of the application. The scope of the study should be broad enough to include: 1) combinations of the most appropriate instruments, 2) approaches that take cross-media pollution effects into consideration, and 3) suitable minimum standards. Finally, research should be directed to the identification and establishment of monitoring and enforcement capabilities that would be appropriate in a developing country setting.

C. Useful regulatory and economic mechanisms

C1. REGULATORY mechanisms

C1.1. Standards

Most current standards were designed for and are used in industrialised countries. The development of standards is, as yet, in the early stages in non-industrialised countries. This disparity rapidly disappears during the transition from the developmental status to the industrialised status. Hence, the following presentation on standards deals mostly with those currently in vogue in industrialised countries. The variety of the standards in industrialised countries encompasses all phases of solid waste management. Thus, standards exist that are specific for each type of solid waste management activity (e.g., storage, collection, recycling, final disposition).

The rationale and the consequent objectives of all standards are: 1) protection of the public and of solid waste management workers, and 2) the maintenance and improvement of the quality of the environment. The scope of the standards includes all applicable technical and operational requirements. Additionally, the scope extends to all management, operation, and maintenance aspects of solid waste facilities. More recently, the scope of some standards has been expanded to involve waste minimisation, recycling, and resource recovery.

C1.1.1. Storage and collection

Technical and operational standards pertinent to storage and collection specify types and sizes of storage containers, locations for the containers, frequency of collection, and the amount and types of wastes to be collected. If the traditional manual mode of collection is replaced by the "automatic" or "semi-automatic" mode, the design of storage receptacles and the placement of the receptacles on the day of collection must be altered accordingly. Other applicable standards include specifications regarding the collection vehicle and the collection schedule. Standards pertaining to noise abatement during collection include noises associated with the collection vehicle and its operation. Examples are activation of the compaction mechanism and engine exhaust noise. A less frequently encountered specification is to the extent that the collection vehicle be covered, excepting during the loading and unloading operations. Another regulation calls for computerised air braking systems for trucks equipped with air brakes.

C1.1.2. Waste minimisation

A current trend is the reliance upon governmental regulation, legislation, and mandate as mechanisms for minimising the amount of waste destined for final disposal. The trend is prompted, in large part, by the rapid dwindling of available landfill capacity and, to a lesser extent, by an awareness of the need for resource conservation. Governments conserve the landfill capacity resource by specifying types and amounts of waste that are permitted to be landfilled [1,7]. Resource conservation is promoted through resource recycling and reuse, encouraged by way of government-backed incentives.

Regulatory measures related to storage and collection and intended for the promotion of recycling and reuse usually call for kerbside placement of storage receptacles on the day of collection. The measures also specify the number of containers and the types of materials that are placed in each container. The simplest configuration calls for two containers; one for recyclables and one for non-recyclables. Each of the other configurations has the following general arrangement: one container for non-recyclables and one container each for the separated components (e.g., ferrous metals, paper, glass, etc.).

One of the numerous strategies geared to resource conservation involves regulating the use of certain materials or energy resources such that the recovery of materials from the waste stream is facilitated. Applied in that manner, regulations can be designed to control and possibly prevent the use of certain materials, or discourage the use of a particular production method or treatment.

Governments may provide an incentive to recycle and reuse by way of requiring manufacturers and importers to use recycled materials. By so doing, the government advances the development of a market for recyclable materials and simultaneously may alleviate shortages of a particular material. However, application of these measures should be preceded by discussions with affected industries, and preferably with their cooperation.

C1.1.3. Final disposal regulations

All aspects pertinent to the final disposal of wastes are subject to regulatory control. Thus, a collection of technical and operational standards are in force that affect the siting, design, construction, operation, closure, and post-closure of solid waste disposal facilities. In the United States, these standards are covered in the Resource Conservation and Recovery Act (RCRA). RCRA exemplifies a regulatory course of action that, with suitable adaptation, can be successfully applied in most industrialised nations, as well as in developing countries. In other words, it is a useful model. A major feature of RCRA is its banning of the open dump -- open dumps must either be closed or be upgraded to the sanitary landfill level. In keeping with this directive, RCRA specifies a set of standards for sanitary landfills. Among the standards are some that affect the location of a landfill facility. Another standard calls for the installation of a leak detection system if the need for such a system exists. Other directives mandate the monitoring of groundwater, and the initiation of corrective action to remedy shortcomings that are revealed. Finally, RCRA gives legal standing to regulations that ban certain waste management practices and forbid the siting of certain types of facilities in sensitive environments.

In some countries in Europe, land disposal of solid waste is subject to the Landfill Directive of the European Union [7]. The directive sets forth the conditions under which solid waste can be disposed in landfills, including the biodegradable organic content of the waste, the maximum percentage of biodegradable waste that can be landfilled over the period 2006 to 2020, and other requirements.

C1.1.4. Permits and licenses

Safe processing, transfer, and disposal practices in solid waste management can be assured by way of the issuance of permits and licenses to the owners and operators of solid waste management enterprises. In industrialised countries, the permits and licenses address both design and operation of the solid waste facilities, and typically specify and are conditioned upon peak processing capacity; operating schedule; required controls of solid, gas, and liquid emissions from the facilities; as well as other requirements.

C1.1.5. Management programs

This aspect of solid waste management policy deals with the management plan or program that should be developed by solid waste management jurisdictions. Thus, each jurisdiction should be obligated to: 1) prepare a program for the storage, collection, treatment, and disposal of all household, commercial, and industrial waste expected to be generated within its confines; and 2) periodically update the program.

Examples of management programs include the following:

- Each province in the Netherlands is required to develop a solid waste management program that states the manner, location, and by whom wastes are to be deposited, treated, or recycled.

- In the United Kingdom, items covered in a program are: information on types and amount of waste expected to be generated or to be brought into the jurisdiction during the program, type of waste the authority will process, types of waste others are expected to process, method of disposal, sites and equipment being provided, and cost. Other programs may extend to measures for waste reduction and recycling.

- The French Environmental Protection Law passed in July of 1992 requires the development of departmental and regional plans for the management and disposal of waste [1].

C2. ECONOMIC mechanisms

An excellent stratagem for funding solid waste management systems is the imposition of fees or charges, the use of a deposit system, or the implementation of a subsidy program.

C2.1. Charges (fees)

Charges that may be levied to defray solid waste collection and disposal costs can be grouped into three categories -- user, disposal, and product.

C2.1.1. User charges

Charges in this category are those that are levied to defray costs associated with collection and treatment. Only rarely are they inflated sufficiently to serve as incentives. On the contrary, charges are assessed on the basis of total expenditures and ignore marginal social costs due to negative impact upon the quality of the environment.

Assessment of user fees can be modified such that they act as incentives to reduce the rate and amount of waste generation. The utility of such an approach is attested to by the extent of the reduction in waste generation that resulted from the implementation of a variable garbage can fee system in the State of Washington (Seattle) and in the State of California (San Jose and San Francisco), and the pay-per-bag systems in New Jersey, Pennsylvania, and Illinois. Experience in the United States demonstrates that combining programs for recycling newspaper and containers (glass, plastic, and metals) with the variable fee system markedly enhances the effectiveness of the latter in reducing the quantity of solid waste destined for collection or final disposal. However, attention must be paid to properly integrate the collection, processing, and disposal systems, structure the fees, and educate the public.

C2.1.2. Disposal charges

One of the typical forms of disposal charges is the “tipping fee”. The tipping fee is the charge levied at the disposal site. The amount of the tipping fee usually is a function of the weight of the waste to be disposed. For certain types of waste, the fee may be a function of volume. The magnitude of the charge also may depend upon the type of waste and the method of treatment prior to final disposal. In many cases, the landfill tipping fee for residues from composting facilities is lower than that for untreated waste. A charge is levied in Denmark on solid waste from households and industry; the charge is intended to serve as an incentive to recycle. In the United States, final disposition of certain troublesome wastes (e.g., tires, vehicle batteries, and used oil) may incur special charges. Another stratagem is the imposition of disposal surcharges to cover closure costs, or to finance pollution monitoring and control and/or resource recovery activities [2].

C2.1.3. Product charges

The rationale for product charges is largely anticipatory in nature in that they deal with future consequences rather than past or current consequences. As such, the rationale may be motivational, compensatory, or punitive.

The rationale is motivational when the fee is imposed to promote protection of public health and quality of the environment or to encourage conservation of resources.

The rationale becomes compensatory if the fees are designed to compensate for the loss that would attend the eventual disappearance of an essential resource. It also is compensatory if the imposed fees are to account for disposal cost over and above that of other wastes. In practice, product charges finance parts of the policy measure originally developed to deal with the negative environmental effects of the products on which the charges were imposed. The consumption of products will continue unless charge levels are raised considerably or regulations become more stringent.

The rationale assumes a punitive quality when the motivational and compensatory aspects fail to be effective or are not pertinent. Regarding the effectiveness of product charges or fees designed to serve a regulatory function, the general experience is that they have little impact in terms of incentive.

Among the categories of waste that have been and are being subjected to product fees are non-returnable containers, lubricant oils, plastic bags, automobile batteries, and fuels. The category of non-returnable beverage containers has been the major object of product fees. Usually, the collected fees are primarily used to finance the deposit-refund systems for containers (e.g., Finland and some states in the United States).

C2.2. Deposit systems

The utility of the deposit strategy as a regulatory device has been amply demonstrated. Traditionally, the deposit stratagem involved two steps: Step 1 is the imposition of special taxes, charges, or fees on certain consumer items (usually, returnable beverage containers). Step 2 is the recovery of the special fees, etc. by the purchaser when he or she returns the container for reuse or disposal. However, the scope of the strategy has been broadened considerably such that it currently includes not only containers but also several other types of items. The objectives of the deposit fee are the encouragement of recycling and the prevention of pollution.

Returnable beverage containers continue to be the items most frequently concerned. Thus, in the United States, several states mandate the application of deposit-refund systems to carbonated beverage containers (soft drinks and beer). These states report that of the total number of containers affected by the system, 80% to 95% are returned for recycling [6]. Apparently, the monetary incentive (US$0.05 to US$0.10 refund/container) is sufficient to induce the desired compliance. The application of the deposit-refund system is not confined to the United States. Deposit-refund systems have been very successful in Finland, in that about 90% of the containers are returned. Doubling the deposit charged for aluminium beer cans increased the quantity of cans returned from 70% to more than 80% in Sweden [3].

The deposit-refund concept has been expanded to include items other than reusable beverage containers. Suitably modified deposit-refund systems are being successfully applied to the recycling of automobiles and automobile batteries. For example, a deposit-refund system applicable to hulks of cars and vans was mandated in Norway in 1978. Under the system, the refundable fraction of the deposit is larger if the discarded hulk is returned to an officially designated site. The return rate in the mid-1990s was greater than 90%. Revenues are used for refunds and for financial assistance for collection, transportation, and dismantling facilities.

Mandatory deposit systems for automobile batteries have been implemented in some states in the United States (e.g., California). In these states, every battery sold or offered for sale must have a deposit paid at the time of sale. The deposit is waived or returned if a used automotive battery is brought to the store.

Experience tends to indicate that deposit-refund systems work well, and apparently are more effective than voluntary return systems. A probable reason is that deposit-refund systems provide a tangible reward for performance. Deposit-refund systems are efficient in terms of administration, in that monitoring or other involvement by authorities is usually not required.

Most industrialised countries have in effect some form of deposit-refund system applied to glass beverage containers.

In terms of the efficiency of deposit-refund systems, there is a lack of quantitative assessments in which the costs of deposit-refund systems are compared to the costs of alternatives that have an equally beneficial environmental impact. Nonetheless, it can be assumed that, in some cases, the costs of household waste collection, transport, and incineration or dumping exceed the costs of the deposit-refund system [3].

C2.3. Subsidies

Very frequently, subsidies can be used to advantage in most phases of solid waste management. At one time in the United States, federal grants were made to states to subsidise the development and implementation of solid waste management plans, resource conservation, and resource recovery. Currently, some grants are available for training, research, and demonstration projects for energy and materials recovery, and for solid waste disposal planning.

In Denmark, subsidies for the development or installation of technologies that produce less waste or reuse waste materials are authorised by an amendment to the Act on the Re-use and the Reduction of Waste (1974). The Waste Disposal and Treatment Law enacted by Japan stipulates that the state subsidise: 1) various categories of local expenditures in accordance with policy provisions, 2) necessary expenditures for maintenance and repair of refuse disposal facilities, and 3) expenditures for the disposal of wastes caused by natural hazards or other factors. The Ministry of Environment in Finland subsidises the reduction of interest on loans made for the purpose of financing waste recycling investments.

Subsidisation can be in the form of preferential tax treatment on bonds issued by state (provincial) and local governments for the construction of pollution control facilities or the development of plants capable of incinerating municipal solid waste for the generation of steam or electrical power. In the United States, earnings on municipal bonds issued for that purpose presently are exempt from payment of federal and state income tax. Preferential tax treatment may be used to encourage industry to practice resource recovery. This approach has been used periodically in the United States and in Poland [4]. Other incentives include tax credits to industries that use recycled materials as part of their feedstock.

The market for recyclable materials can be stabilised through: 1) price supports for the establishment of materials banks; 2) the guarantee of an income from a recycling plant or facility (e.g., tipping fees or quantity of incoming material above a defined minimum level); and 3) the institution of investment grants, accelerated depreciation, and soft loans designed to encourage private enterprises to implement resource recovery activities [5]. The guaranteed income may be in the form of tipping fees, or of a guaranteed quantity of incoming material.

D. References

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CHAPTER XVI. FINANCIAL ARRANGEMENTS FOR SOLID WASTE MANAGEMENT

A. Introduction

As previously indicated, in most developing countries local governments have the primary responsibility to provide solid waste management services. Local governments must rely on a variety of financial resources to fund the services. In most cases, different resources are used to finance capital investments than to finance operating and maintenance costs. Furthermore, a mixture of resources may be used for financing of the various components of a waste management system (i.e., collection, transfer, resource recovery, and final disposition).

In this chapter, the various methods of financing solid waste management services are discussed. Issues pertinent to economically developing countries, such as financing services to low-income or marginal areas, are presented. For low-income areas, reducing the need for government financing through encouragement of greater self-reliance and community participation also is discussed.

The option of privatising solid waste management services, as a means of obtaining capital and implementing user charges for the services, also is discussed. In addition, key issues associated with municipal strengthening, as well as costs associated with publicly-owned versus privatised service, are presented.

B. Financing capital investment costs

In this section, four methods of financing capital investments are discussed: reserves, bonds, loans/grants, and donations [9-11].

B1. RESERVES

In this particular case, the solid waste agency receives and saves a portion of current revenues for the sole purpose of financing capital investments. Reserves also are known as renewal funds and usually are used for investments in equipment replacement or to extend the service capacity of existing equipment [1].

B2. BONDS

Another way to obtain financing for capital investments is to raise funds from private investors through the issuance of bonds [1].

Public ownership of a solid waste management system or facility generally results in one of three financing methods: general obligation (GO) bonds, revenue bonds, or lease revenue bonds. In each option, the community issues tax-exempt debt and guarantees repayment of the debt with credit of either the community or the project’s revenues combined with any other guarantee or insurance.

B2.1. General obligation bonds

This type of financing utilises the credit of the community as the credit pledge. Principal and interest payments for GO bonds can either be made from tax revenues or from the project’s revenues.

B2.2. Revenue bonds

This type of bond is repaid from the revenues generated by the project or system. The bonds are secured by legal documents specifying the responsibilities of each participant, as well as the flow of funds. Revenue bonds were popular in the United States for financing waste-to-energy facilities, where revenues were obtained through tipping fees and sales of energy. If the bonds for a facility of this type are secured only by the project's revenues, they will command a higher interest rate.

B2.3. Lease revenue bonds

In this type of financing, a public entity or a specially formed non-profit corporation issues tax-exempt revenue bonds to finance a waste management facility. The facility is then leased to the municipality. Security for the bonds is provided by the lease between the two entities.

In situations when projected revenues for a particular project are too limited or the risks are too high, it may be in the government's best interest to provide financial incentives to the private sector to encourage participation in new business development. When the government provides financial incentives, it either provides financing directly to the private sector or sacrifices potential tax revenues from the private sector. Tax exempt bonds are one example of a government financial incentive that leads to a potential loss in tax revenues.

B3. LOANS/grants

Ideally, most capital investments should be financed through the use of reserves. Nevertheless, in order to finance major capital investments, municipalities may resort to borrowings. Borrowings derive from loans with commercial banks, international development banks, and central government banks.

In some countries, capital expenditure by local governments is controlled by the central government. Each year, the central government sets a limit on the total capital expenditure that can be made. Projects are submitted to the pertinent agency of the central government for approval. Once approved, the local government can borrow either from a public agency or from the money market.

Several international lending institutions have been involved in financing solid waste management investments in economically developing countries. Some of the most active institutions include The World Bank, the Asian Development Bank (ADB), and the Inter-American Development Bank (IDB). The financings have covered replacement and expansion of the solid waste collection fleets, construction of transfer stations and purchase of transfer trucks, design and construction of sanitary landfills and purchase of landfill equipment, development of composting facilities, and others. The majority of the financings of solid waste management projects have been included as part of development bank loans for large urban development projects.

Borrowings for major solid waste management investments may be financed through the project or through general obligation financing. In project financing, the financial viability of the project is compared with the revenues that the project is expected to generate. In general obligation financing, the credit of the local government secures the loan. For both types of financing, if future revenues are in doubt, it may be necessary for the central government to secure the loan. Most loans for solid waste investments are project financing.

It is possible to finance some costs that would commonly be considered recurrent operating costs within arrangements to finance capital investments. For instance, capital investment in solid waste equipment could include the acquisition of a large supply of parts that are used frequently. Loans from development banks commonly make allowances for purchasing spare parts within the equipment procurement that they finance. This is part of a policy to ensure that the equipment financed can be successfully utilised to provide service and, thus, improve the revenue generation of the service entity.

In most developing countries, the central government will more than likely continue to be the principal source of funding for major projects in solid waste management.

B4. DONATIONS

Municipalities in developing countries often have access to a variety of organisations that can donate funds, human resources, or equipment for environmental protection and solid waste management. The organisations can be either national or international. Some of them are willing to assist in solving a specific problem without any conditions, while others impose rather stringent and sometimes costly conditions. This option is purposely included as one of the last options for financing solid waste services because the authors have observed several ill-advised "donations" in which the donations have been encumbered with conditions such that they eventually become costly investments to the community. One such example is the installation of an incinerator for combusting residential wastes in a community located in a tropical country, where the wastes would have a very high concentration of wet organic matter. Another one would be the donation of a few used, compacting collection vehicles to a city that is located in hilly terrain and that has narrow, unpaved roads. The cost of operating and maintaining the "free" vehicle is oftentimes several times higher than operating a simple animal-drawn vehicle. It is important to emphasise, however, that not all donations are failures. There are countless positive experiences throughout the world. Unfortunately, the recipients of the donations must be cautioned to carefully analyse the advantages and disadvantages of accepting a particular piece of equipment or system before it is put into use in the community.

C. Financing operating and maintenance costs

C1. FINANCING methods

In developing countries, operating and maintenance (O&M) costs, also known as recurrent costs, can be financed by means of several methods. A brief discussion of each one of these methods is presented in the following section [9-11].

C1.1. General revenues

Local governments obtain their revenues from a variety of sources such as property taxes, fines, and license fees. Local governments typically use their general revenues to finance costs associated with labour, consumables, and spare parts (O&M). Since the revenues in most municipalities in developing countries often are insufficient to cover O&M costs for solid waste services, grants or subsidies from the central government are used to supplement local revenues. In some countries, municipalities receive a fixed percentage (on the order of 10%) of the country's general budget to complement their general revenue.

C1.2. Grants from central government

Theoretically, grants from the central government would only be justifiable for those cities that have national importance as centres of government, industry, and commerce (such as the capital).

The grants and subsidies would be justifiable as benefiting national economic growth. However, since central governments usually limit the ability of local governments to generate their own revenues, subsidies compensate for the lack of decentralisation.

C1.3. Sources of revenue

Unfortunately, a large number of local governments in developing countries have extremely limited sources of revenue. The amount of residential waste generated in developing countries is about one-third to one-half of that generated in industrialised countries. However, since their taxable income is so low, either a lower standard of service or a less capital-intensive system must be considered.

Ideally, a solid waste service organisation should be accountable for all costs, and the tax or fee paid should reflect the actual costs for the service. Property taxes are not suitable for financing solid waste services, unless it is clearly stipulated that a certain portion of the tax must be used to cover the costs of solid waste service. It is preferable to implement user charges, because these charges raise public awareness about the costs associated with providing the service. User charges have the tendency to make the service agency accountable. Furthermore, if the charge is related to the quantity of waste discarded, the charge may serve as an incentive for waste prevention.

One of the main problems associated with the implementation of user charges is that not everyone is willing or able to pay a user charge for solid waste service. Well designed surveys to determine both the willingness and capacity to pay should be carried out prior to the establishment of tariffs. Generally, the collection of user charges for waste services is extremely low. Some cities have tried to solve the problem of willingness to pay by attaching the user charge to the billing for a service for which residents are more willing to pay. For example, in the past in Lima, Peru, the user charge for solid waste was included with the electricity bill. In other developing countries, residents receive a single bill for water, wastewater, solid waste, and other services such as television and security, if applicable. Combined billing of services allows for reduced costs associated with the billing process, and leads to a high collection rate of the user charges. Furthermore, the addition of solid waste service charges has not led to a discernible reduction in the collection of user charges for electricity or water. In setting the tariff, consideration should be given to making allowances for cross subsidies. Large commercial establishments and high-income residential areas (which typically demand a high quality of service) would be charged a higher tariff than low-income areas.

In a large number of municipalities, the revenues that are collected for waste services generally are deposited into a general account. Once in that account, the funds are often utilised for a number of purposes other than waste management.

C2. COSTS of solid waste service

In order to generate sufficient revenues to cover the costs of solid waste service, a jurisdiction should have a thorough understanding of the actual costs associated with providing the service. Unfortunately, very rarely are the costs fully known. Budgets for departments of local government are based on projections from previous budgets and/or the need to pay salaries and purchase supplies. In order to determine the true costs for solid waste management, the costs incurred from several departments must be consolidated.

C3. RESPONSIBILITY for service delivery

Since activities associated with the delivery of solid waste services generally are decentralised in economically developing nations, it typically is extremely difficult to determine the full costs of the service. Accountability of, and responsibility for, service provision is also difficult to determine in a decentralised system. One of the best methods to resolve accountability is to establish a single entity responsible for all aspects of solid waste management. In order to obtain revenues, it is essential that this entity have the following: 1) equal status with other agencies in the local government that may be competing for a portion of the revenues, and 2) capability to assess and justify financial needs.

Assigning responsibility might be partially addressed by upgrading the status of a solid waste office, which is typically set up within another department having different responsibilities (e.g., Public Health Department, Public Works Department). The department chief would then have the opportunity to request some of the available revenues, as well as the professional staff necessary, to prepare the financial justification for budgetary needs.

Placing all solid waste activities within an independent organisation would assure accountability for the service. These types of organisations usually are autonomous. Generally, political leaders and members of the private sector are appointed to the Board of Directors. These organisations receive grants from the state and local governments. They also generate their own revenues through special charges and fines. Since these organisations are financially responsible and capable of generating their own revenues, it is considerably easier for lending organisations to work with them in obtaining financing and determining the means for cost recovery.

A study conducted in Latin America by The World Bank evaluated 16 semi-private solid waste enterprises. Although the enterprises were relatively accountable, the results of the study indicated that they were not financially independent. All entities received some type of government subsidy and most of them obtained only a small fraction of their revenue from service-related taxes or user charges [3,4].

D. Financing waste management services for marginal areas

In most economically developing countries, the urban poor usually live in marginal areas and squatter settlements. These areas are occupied illegally, and the settlers generally do not pay taxes to local jurisdictions.

In most cases, the marginal areas are not provided with water supply, electricity, wastewater collection, or solid waste services. The shortage of technical and financial resources is primarily responsible for the lack of basic services to these areas. As a result, those responsible for the management of solid wastes have the tendency to concentrate their efforts in high- and middle-income areas of the cities.

It is typically assumed that the residents of marginal areas are not willing to pay for solid waste services. However, the results of work conducted by the authors indicate that this may not necessarily be the case. In some countries in Latin America, the waste generated in low-income areas is collected by individuals outside of the formal collection system. The fees charged by these individuals are comparable to those charged by the formal sector. The level of user charge that has emerged throughout the urban poor areas in Latin America is on the order of US$3 to US$7/ dwelling/month.

D1. SERVICE alternatives

The lack of financial resources in economically developing countries does not allow for the provision of basic services to all segments of the population. In this section, alternatives are developed for providing solid waste services in low-income areas. Inasmuch as financial resources are limited, innovative solutions must be developed that take into consideration appropriate levels of service for different types of neighbourhoods and local conditions, as well as other factors.

D1.1. Public participation

A very practical and efficient alternative for providing solid waste services in marginal areas is to encourage public participation. In this particular case, the residents are requested to volunteer some of their time and effort and, thus, keep the outlay of financial resources to an affordable level.

Public participation can be accomplished by requesting that the residents of marginal areas transport their residues either to a conventional collection vehicle provided by the municipality or to a communal container located in a strategic location. In the first option, arrival of the collection vehicle is announced by means of a bell or a loud horn. In the communal container option, different types and sizes of containers can be used. The size of the container can range from half a drum (i.e., a drum in which the top half is cut off), to a whole drum (about 120 L), or to $\geq 1\ m^3$ containers. In any case, it is important that the containers be emptied by the collector at a fixed frequency and that they be located at convenient distances (i.e., generally not more that 100 m apart). In both alternatives, savings are realised through the reduction in the number of personnel in the collection vehicle.

Another option that has been used in marginal areas involves rigorous public participation initiatives. In this type of alternative, residents are requested to participate in workshops and public meetings in which they are instructed on the benefits of public health and solid waste management. In addition, residents are introduced to recycling processes involving the separation of organic and inorganic matter. The residents are then requested to treat their organic wastes onsite, and to segregate and turn in their dry recyclable materials to a local collection crew or to a neighbourhood recycling depot. The recyclable materials are sold, and the revenues from the sale of the materials are used to pay for the collection and processing costs.

In most cases, these projects have been funded by international development agencies, with the technical assistance of non-governmental organisations (NGOs). Experience thus far indicates that it is important that the technical assistance to the community be continued and maintained over a long period of time to assure a high degree of success.

D1.2. Micro-enterprises

Another viable option to providing collection services in marginal areas involves the establishment of micro-enterprises. In this approach, the full costs of providing the collection service to the particular area are borne by the residents of the area. As such, a small enterprise is established in which residents of the area are requested to participate. The members of the enterprise are trained in their different duties (from collection to basic bookkeeping). In order to keep the investment and operating costs to an affordable level, the enterprise provides the house-to-house service, while the municipality is requested to assist with the transportation of the wastes to the disposal site. Options of this type have been established in Latin American countries, with the assistance of NGOs. Experience thus far indicates that this type of organisation can be established successfully. The success of the enterprise depends upon a number of factors, including: financial arrangements, logistics and degree of cooperation obtained from the municipal government, level and type of technical assistance, and degree of dedication of the members of the micro-enterprise. The key issues associated with the micro-enterprise include establishment of tariffs; punctuality of payment (either by the municipality or by the householder); and level, type, and length of qualified technical assistance given to the staff of the enterprise.

E. The role of the private sector

The provision of solid waste management services is a very costly and difficult undertaking for many municipalities throughout the world. The level of cost and degree of difficulty associated with the service provide an opportunity for participation of the private sector. In general, the private sector potentially can play two key roles in the field of solid waste management. One important role is to increase the efficiency of the service and, thus, reduce the cost in existing waste management systems. The other key role for the private sector is to provide much needed sources of funds for capital investments. As previously indicated, solid waste management systems in economically developing countries tend to be extremely inefficient, providing relatively low coverage at a high cost, and oftentimes becoming an “employment agency” to a large number of unneeded labourers.

One of the potential benefits of privatisation of the service is the ability to recover the costs of service through the implementation of user charges. The implementation of user charges, or the increase to existing charges, generally is an extremely difficult political decision that can best be managed by allowing the private sector to impose them [5,7,8].

Privatisation, however, is not the total solution to the successful provision of solid waste management services. First of all, privatising some aspect of the solid waste service delivery or the entire system does not reduce or eliminate the responsibility of local government for the service. Furthermore, privatisation of services should not be interpreted as weakening of the local government. On the contrary, in order for local government to effectively privatise some of its services, certain areas of the government institutions must be strengthened. Only a local government institution having competent and qualified professional staff will be able to develop, negotiate, manage, monitor, and enforce a contract with a private entity [2].

The types of privatisation most commonly used in solid waste management include: contracting, franchise, open competition, and vendor/operator equity investment [7].

E1. CONTRACTING

In this case, a private firm, by means of turnkey contracting, may design, build, own, and operate a solid waste facility such as a transfer station, a resource recovery plant, or a sanitary landfill. In the 1980s, turnkey contracts became a popular means of financing resource recovery projects in the United States. Private ownership was encouraged through financial incentives established by the central and state governments. Some of the financial incentives included tax benefits and opportunities for accelerated depreciation [1]. A substantial portion of the waste-to-energy plants in the United States is privately owned.

Perhaps one of the better areas for the private sector to enter the waste management field is in the area of waste collection under contract with the local government. As a result, it is feasible for local firms with modest financial resources to enter into the business of solid waste collection. A study of privatisation in Latin America indicated that most of the firms were of a small to medium size, demonstrating that there were virtually no barriers to entry [3]. Additionally, as previously pointed out, the demand for collection service in many low-income areas in economically developing countries provides the opportunity for very small entities (micro-enterprises) to provide the service [6].

Privatisation is an appropriate alternative for providing much needed solid waste services in many countries. However, the service must be properly described, performance indicators established, costs delineated, an equitable contract developed, and monitoring functions well defined in order to receive the most benefit from the service. Therefore, contracting seems to be better suited for isolated activities (which can be evaluated easily) within the solid waste system, such as the operation of a landfill. In Buenos Aires, Argentina, private firms provide waste collection services and operate transfer stations and sanitary landfills under contract with CEAMSE, the government entity responsible for solid waste management. In Mexico City, a private entity operates one of the major landfills.

In the event that sufficient funds are not available for the acquisition of equipment or it is difficult to borrow the funds, it is possible to contract for provision of the equipment. For instance, some or all of the solid waste collection fleet can be leased from private firms. The firms can provide the vehicles only or the vehicles with the drivers, fuel, and even maintenance. One of the major disadvantages in this option is that the vehicles available for lease in developing countries often are not well suited for waste collection (particularly residential waste), since the majority of the equipment is used in the construction business. Since collection is one of the more expensive phases of the waste management process, the option of leasing vehicles should be carefully considered before it is implemented [6].

Another possibility for privatisation of collection services is to adopt a system that would consist of the following elements and functional relationships. The municipality would purchase appropriately designed collection trucks. The vehicles would then be leased to qualified contractors, who would be responsible for the operation and maintenance of the vehicles. In order to avoid the potential of poor operation and inadequate maintenance, the municipality can institute a rigorous monitoring program and provide the maintenance. On the other hand, operation and maintenance can be left up to the contractors, with the understanding that after a predetermined number of years the vehicles would be owned by the contractors.

If a municipality is considering privatisation of the collection system, it may be advisable to privatise a portion of the city and maintain public services in another. Under this system, the collection areas should be selected carefully so that they are comparable. The mixture of private and public services results in having both methods accountable to the users and, thus, encourages competition. Consequently, the public entity is motivated to provide efficient service, and the private organisation understands that efficiency and tariffs can be compared, as well as the fact that the municipality would still be able to take over the system if the service provided by the contractor is not satisfactory.

E2. FRANCHISE

In this option, the law empowers a municipality with the authority to give to a private entity an exclusive franchise, or right, to provide service to customers in various zones under the municipality's jurisdiction. In return for an exclusive franchise granted by the municipality, the private firm pays a franchise fee to the municipality. Under a franchise system, the firm is responsible for providing the service and can charge its customers to recover the cost of the service. In this situation, the municipality or local government maintains responsibility for supervising the performance of the private firms. Additionally, the municipality must maintain some degree of oversight and/or set limits on the type and level of tariffs.

E3. OPEN Competition

In economically developing countries, a municipality typically uses open competition in the private sector to secure maintenance and repair services for equipment used in the solid waste management system. In some cases, minor repairs are performed by maintenance personnel employed by the government. However, for major repairs of waste collection vehicles and other heavy equipment, the common practice is to request quotations from private garages and to grant the repair work to the lowest qualified bidder. Depending upon the size of the service area, it may be advisable to contract as well for the performance of minor repairs in order to economise on time and distance travelled.

Private collection through open competition is another viable option to municipalities in developing countries. This type of service provision is especially applicable in large urban areas where private collection firms are established. One of the advantages of this option is that through a well designed procurement process and a sound, as well as transparent, evaluation process, a municipality can select the most appropriate conditions for its particular situation and secure the lowest price. On the other hand, this alternative presents the possibility that an established firm may lose a contract and, thus, its investment and experience to one with little experience.

The alternative of open competition has been used several times by the City of San Jose, California in the implementation of its integrated mixed waste collection and recycling program.

E4. VENDOR/operator equity investment

This is an alternative for the private sector (the vendor or operator of a facility or system) to provide equity investment based on potential financial benefits (i.e., tax benefits). In developing countries, the equity investment varies from about 10% to 80%, or even 100%, of the project cost. The remainder of the funds generally is obtained by means of institutional loans. In some cases, the municipality guarantees a certain payment for the service (i.e., cost/Mg), and requires that the ownership of the particular process or system revert to the municipality after a certain time period.

F. Financing considerations and requirements

F1. SELECTION of financing method

In general, selection of the most appropriate means of financing a particular solid waste management project should be based on considerations of degree of risk or benefit and on the most cost-effective option to the rate payers. Essentially, a municipality should address the following three key issues associated with financing: 1) perform a thorough analysis to determine the financing method that results in the lowest tipping fee to the users, 2) identify the potential liabilities related to each financing alternative, and 3) determine the potential advantages and disadvantages associated with each alternative.

F2. VIABILITY of the project

At the risk of stating the obvious, one of the more basic requirements for financing, regardless of the type of method to be selected, is that the proposed solid waste management program be financially and economically viable. Viability can be thoroughly evaluated by developing and implementing a computer model and continually updating the model with current information. A good model allows the evaluation of several options or scenarios, and the impact of changes on the tipping fee. In addition to the development of a model, there are a few other key requirements that should be carefully explored and analysed before a final decision is made.

F3. RELIABILITY of waste supply

A reliable quantity of waste is a critical component of a solid waste project. The supply of waste should be available for the term of financing. A typical agreement involves a “put-or-pay” contract, signed by the municipality or solid waste authority, essentially guaranteeing delivery of a minimum amount of waste at a certain tipping fee. In the event that the municipality is unable to deliver the agreed minimum quantity, the municipality still has to pay the tipping fee for that minimum delivery.

F4. SERVICE agreement

Contracts should be developed and executed that clearly define the terms of the agreement. The various responsibilities of the parties involved should be delineated, such as acquisition of sites, permits, startup, operation, maintenance, and the terms under which payment for services will be made.

F5. SALES of materials and/or energy

Contracts should be in place with the entities that are going to purchase the resources that will be recovered from the waste stream. Ideally, these agreements would be made on a “take-and-pay” basis. A take-and-pay agreement simply means that the buyer must accept agreed-upon quantities of materials or energy, and pay for the resources regardless of use. This is particularly important when energy is produced. In the event that materials are recovered from the waste, then a minimum price per unit weight should be negotiated and included in the contract. The quality, or specifications, of the recovered resources also should be described in the contract, as well as a description of the method for adjusting the purchase price if the specifications are not met.

F6. AVAILABILITY of final disposal site

In the event that the project that is to be financed involves some type of resource recovery process, then provisions must be made to dispose of the residues. The residues would take the form of reject materials from a materials recovery process, or of combustion ash and waste that cannot be processed from a thermal treatment process. In addition, arrangements must be made to bypass and landfill the entire waste stream in the event of temporary shutdowns due to breakdowns, strikes, or other reasons.

F7. LEGAL authority

A legal authority should be clearly identified and established before financing is finalised. The legal authority acts as the responsible public agency for the project.

F8. PERMITS

All required permits should be obtained for the various solid waste facilities to be built and operated under the contract. Permits should be obtained from local, state, and national agencies, as appropriate.

F9. AGREEMENTS

Depending on the type of solid waste management project, some or all of the following types of agreements should be in place before the final financing process begins: waste supply agreements, construction contracts, operating agreements, end product purchase agreements, and financing agreements. Construction contracts should cover all aspects of construction, including:

timing and performance levels, technology to be used, and others. The contractor should have sufficient financial capabilities to guarantee the required performance of the agreements. Operating agreements should identify the operator of the facility, performance and operating conditions, and terms of payment. The financing agreements should specify items such as the requirements for reserve capital, debt coverage requirements, and terms of repayment.

F10. FINANCING process

The entity responsible for the financing must review in detail all aspects of the project and make sure that all requirements have been met. The review basically falls into three general categories: 1) evaluate the project's ability to secure financing, 2) develop and structure the financing, and 3) market the securities to finance the solid waste facility (if applicable).

F11. OWNERSHIP

Before final financing of a solid waste management is reached, the municipality must decide whether final ownership will rest in the public sector or in the private sector. The decision regarding ownership should consider the following items: expediency, risk assumption and allocation, control of the project, costs, and tax implications (if applicable).

G. The impact of resource recovery on financing

Resource recovery (e.g., recycling, composting), if properly conceived and implemented, can reduce the financial impact of waste collection and disposal services. For example, the separation of recyclable materials (such as paper, glass, metals, and plastics) at the source of generation leads to a reduction in the quantities of waste, which the local government would have to transport and dispose at a landfill. In economically developing countries, the mixed municipal waste stream typically contains on the order of 20% to 30% (by weight) of potentially recyclable inorganic materials. As the economic status of a particular country improves, consumption patterns change and an increase can be expected in the percentage of recyclable materials in the waste. Thus, savings in disposal costs may be available in the future if additional quantities of recyclable materials are recovered and marketed. In addition, the segregation and processing of the organic matter in the waste can make a sizeable contribution to the reduction of quantities requiring ultimate disposal, since organic matter typically constitutes 50% to 60% of the residential waste stream.

The recycling program must be properly planned and implemented; otherwise, the program may lead to substantial increases in the collection and processing costs (e.g., having to collect the source-separated materials by means of a vehicle other than a refuse collection truck). Perhaps one of the best approaches to encourage source separation is to provide some type of incentive to the community. One of the simplest and easiest methods of community-based recycling is the implementation of the buy-back centre. In this system, startup capital is provided to enable the centre to purchase ("buy back") recyclable materials from the generators. Generators are responsible for transporting the materials to the buy-back centre and the materials must meet certain minimum specifications. This approach works well if the generator does not have to travel long distances to sell the recyclable materials. The centre must be equipped with storage bins, scales, processing equipment to meet buyers' specifications and to reduce transport costs (e.g., baling equipment), and accounting offices.

Another approach to community recycling is to request and promote segregation of recyclables at the source of generation, followed by transport of the recyclable materials to a community-based facility for processing and marketing. To be cost effective, the collection and processing costs associated with the recycling program should be less than the revenue obtained through the sale of the materials, or the net cost of collection and processing should be less than the cost of collection and disposal if the materials were disposed instead of recycled. The criterion for cost effectiveness chosen by a community depends on a number of factors, including the environmental benefit of recycling, which is difficult to quantify economically. These and other approaches to resource recovery and recycling have been presented in other chapters.

Regardless of strategy or system, marketing of the recyclable materials is fundamental to the success of any type of recycling program. Recycling programs should not be instituted without having contracts or agreements signed for the purchase of the recyclable materials. The contracts should stipulate some key items, such as: specifications for the materials, minimum quantities accepted, physical form (baled, shredded, etc.), and floor prices. A municipality can also undertake and initiate market development programs in order to seek and establish new local and cost-efficient uses for the recyclable materials. On a regional scale, central governments can encourage the development of markets for recyclable materials from the waste by limiting subsidies for virgin materials that compete against recyclable materials for particular uses, such as any subsidies favouring forest products over wastepaper as a feedstock for pulp and paper manufacturers.

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CHAPTER XVII. POLICY ALTERNATIVES FOR IMPROVING SOLID WASTE MANAGEMENT

A. Introduction

Characteristically, in most developing nations, solid waste management and the provision of associated services are entrusted to a municipal agency. Associated services include all aspects of solid waste management, ranging from collection through final disposal. Another feature of solid waste management in developing countries has been the basing of important decisions upon findings made in a search for the least burdensome course of action. Not surprisingly, the almost inevitable outcome of such a limited course was the adoption of a solid waste management program that was unsatisfactory.

B. Decision-making

The proper approach to decision-making and program development is to take into account the combination of increasing demands and limited resources that usually prevail in developing nations. This combination necessitates the adoption of waste management systems that are based on practical and systematic methods. A further requirement is that program selection should essentially be a local activity, and should be a response to local needs. Consequently, no single formula is to be found that can provide a solution for every situation [1].

A serious problem that besets most developing countries is the high cost of solid waste management. Evidence of this difficulty is the fact that the expenses associated with providing solid waste services account for 10% to 50% of the revenue taken in by a typical municipality. Furthermore, deficiencies resulting from inadequate management cannot be remedied merely by resorting to increasing the already high expenditures. On the contrary, the attainment of high levels of efficiency in the overall system is one of the more effective means of expanding the coverage and improving the quality of the solid waste service.

Efficiency in solid waste management is a function of several fundamental factors. Factors of particular importance in a developing country setting may be classified as follows: 1): financial (e.g., budget, access to financing); 2) human resources (e.g., professional competence at the management and implementation levels, provisions for training personnel); and 3) pertinent political issues [2].

C. Financial aspects

C1. BUDGETARY issues

In comparison with those in industrialised countries, unit expenditures on solid waste management typically are larger in developing countries. The disparity arises in large part from the inefficiency and inadequacy characteristic of waste collection and transport in developing countries. The costs for collection services in a developing country generally range from US$2 to US$5/Mg. In a large metropolitan area, however, collection costs may be on the order of US$10/Mg. This cost is high despite the fact that expenditure on disposal in developing countries is very low because the usual method of disposal is the open dump, unencumbered by environmental constraints.

The budgetary problem is aggravated by the failure of the public to appreciate the significance of the disproportionately high cost of solid waste management. This failure originates in the absence of an understanding of the real costs associated with waste management, which is an outgrowth of a lack of awareness of the service charge, or of an erroneous belief that the charge only equals about 10% to 20% of the real cost.

A practice unfortunately typical of developing countries during periods of financial stress is the tendency to reduce funds allocated to maintenance of equipment and to the acquisition of supplies and replacement parts. This tendency has many unfavourable consequences, one of which is a sharp drop in the number of vehicles available for collection. Vehicle downtime may be as much as 40% to 60%. To maximise the number of functioning vehicles during times of financial stress, solid waste managers usually resort to cannibalising disabled vehicles to obtain parts for the repair of other vehicles. Another desperate measure is to keep vehicles in operation long past their useful lifespan [3].

C2. BUDGETARY reform

The objective of budgetary reform is the continuing assurance of an adequate solid waste management budget. A measure that would go far to the attainment of such an assurance is to give local governments the authority to defray solid waste management costs through the establishment of the necessary revenue base. Establishment of the revenue base can be facilitated through an updating of the cadastral. This can also be facilitated by amplifying the collection of taxes, fees, and licenses. Moreover, local governments should be empowered to levy and collect taxes from residents, including the imposition of user fees for solid waste services.

A serious problem arises from the three- to six-month delay that often intervenes between the drafting, approval, and appropriation of a budget for provision of solid waste management services and the actual receipt of the funds by the entity that provides the service. The problem is further aggravated by the fact that the amount eventually received almost inevitably is only a fraction of the original appropriation. Consequently, proper planning for the utilisation of the funds becomes extremely difficult. Another result is the unfavourable impact exerted upon the financial rating imposed by vendors and suppliers of equipment, replacement parts, and other items upon the solid waste service sector. The unfavourable rating has an inflationary effect upon charges for purchasing replacement parts and supplies. The inflation is an accommodation for the long delays in payment. Adding to the difficulties of the situation is the ineffectiveness of the budget cycle and an incorrect interpretation of the cycle.

A chronic shortage of funds in many municipalities intensifies the competition between the various departments within the municipalities for access to the limited funds that are available. This competition interferes with the proper balancing of the funds. Moreover, it encourages the absence of order and planning in the disbursement of available funds.

In summary, several measures can be taken whereby the required cash flow can be facilitated and maintained. Chief among them are the following two: 1) amplify and strengthen the self-sufficiency of local governments, endowing them with the authority to levy and collect taxes from constituents; and 2) empower solid waste service organisations to directly invoice and collect user fees from residents.

C3. DEVELOPMENT of a financial base

As is true in other governmental divisions, decision-making in the solid waste management sector is, or should be, strongly influenced by the magnitude of the available funding, i.e., the level of its monetary reservoir. The dependence originates in the obvious fact that the feasibility of implementing any given decision is a function of the existence and magnitude of the sector's financial resources. Unfortunately, all too frequently, decisions are made and their execution is attempted without regard to available financial resources. These unfounded decisions may rest upon erroneous assumptions regarding available financial resources, or the matter of financial resources simply may be ignored.

C4. EFFECTS of financial resources

The effect of financial resources upon the feasibility of implementing decisions has many ramifications, some of which are discussed in the paragraphs that follow.

One ramification is the fact that funding availability can act as a constraint upon process and facility improvement, or upon facility expansion.

A particularly significant effect of access to adequate financial resources is that it enables the inauguration of systems or processes that markedly improve the service. For example, the financial resource could serve as a source of funding for the construction of a needed transfer station. The acquisition of land depends upon access to funding, i.e., access to a financial reserve. In addition, access to such a reserve is needed to finance the construction of a transfer facility complex, and for the purchase of rolling stock.

Not all shortcomings in the solid waste management sector are entirely traceable to financial difficulties. Thus, a serious shortcoming can be the unawareness of the savings that accrue from the substitution of a more efficient system for a less efficient one. Unfortunately, funding for such substitutions usually fails to materialise. The customarily poor financial climate with respect to certain systems in the solid waste management sector can be explained by the modest political appeal of the systems. Moreover, the foreign funding component of the system may be too small to be of interest to international financing institutions.

Instead of adopting an appropriately simple (low) technology, many developing countries tend to select a technology that is more suited for an industrialised country. Obviously, adoption of an inappropriately high technology will generate an unfavourable financial climate in a developing country. Nevertheless, securing financial backing for appropriately low-cost, low technology is far more difficult than obtaining financial backing for high-cost, inappropriate, complex (high) technology. Thus, it is not unduly difficult to arrange for the loans and credits involved in financing expensive, and frequently ill-suited, processing options such as incineration and highly mechanised materials recovery schemes. On the other hand, arranging a local loan and financing for the acquisition of land for a low-cost sanitary landfill and for construction and operation of the facility is a far more difficult task.

C5. DATABASE needs

A failing that is common in developing countries (as well as in industrialised countries) is the virtual neglect of an attempt to precede a solid waste management undertaking with the implementation of a database. The database should include: 1) the raw data, 2) an analysis of the data (discussed in another chapter), and 3) the planning arising from the data analysis.

An adequate database is particularly essential in the design and implementation of the waste collection service. A satisfactory database makes it possible to improve the quality and coverage of the service at a lower cost, because the collection process usually is the most expensive of the management processes. Maximum lowering of collection costs involves the gathering of accurate current information on parameters such as: number of stops per route, amounts of waste collected per stop per route, time requirements, and productivities per worker and per vehicle in terms of crew size. These data should influence the design of collection routes and the rationale for assigning crew size and number of vehicles per given route.

In a developing country setting, reliance upon a management information system can bring about a 25% to 50% reduction of per unit cost of solid waste management service. Although the futility of not analysing amassed data should be readily apparent, neglect of the analysis is not infrequent. Often, the accuracy of data is unfavourably compromised because of failure to adhere to prescribed protocols. Ultimately, effectiveness of cost reduction measures is a function of quality of the professional skill with which they are formulated and applied.

C6. COST containment via design of collection service

The following is a list of steps and considerations that are conducive to the designing of a collection service that is commensurate with cost containment.

1. Adjust the number of loads per shift of work such that the practical loading potential per worker is maximised.

2. Select the type and size of vehicle that best befits the roads and loading conditions of the neighbourhoods to be served.

3. Adjust crew size per collection vehicle such that the utility of the vehicle is maximised. Crew size should be based upon time and motion studies of worker productivity under different sets of working conditions.

4. Keep collection vehicle "downtime" to a minimum. This can be done by scheduling adequate preventive maintenance. An essential element of preventive maintenance is the continued availability of spare parts and of the tools needed for repairs.

5. Ensure compliance by local residents with ordinances enacted in support of the solid waste service.

6. Secure the collaboration of the public in the waste collection activity. This can be accomplished by resorting to a suitable public education effort. For example, aspects of proper storage of waste at the site of generation constitute a useful subject for public education. Among the aspects would be durability and capacity.

7. Properly design the storage area, as well as the positioning of the receptacles on the day of collection.

C7. PROCUREMENT

The success or failure of a solid waste management activity largely depends upon the degree of access to required equipment. The reason for the dependence lies in the extensive technological orientation of the activity. Hence, equipment procurement becomes a critical feature. Because collection and processing constitute a major share of solid waste management, especially in a developing country setting, procurement of collection equipment assumes a significant importance.

Procurement involves the preparation of specifications and tender documents. In the procurement of collection vehicles or processing equipment, it is essential that recourse be had to the expertise needed to select the most appropriate types of equipment at the lowest cost. The extent of the spread between highest and lowest vehicle costs is exemplified by the spread between the current highest and lowest costs of a new, modern collection vehicle. The current lowest cost is US$50,000 and the highest is US$190,000. The foreign exchange component of the purchase price for a particular vehicle may vary between 60% and 95%. In most situations, the initial purchase price is not used as an indicator to determine whether or not the particular vehicle will result in a low total cost for ownership and operation.

Regarding the number of vehicles to be procured, obviously, number is a function of the capacity and degree of productive use of particular vehicles. Thus, one collection vehicle is required for every 1,500 to 10,000 residents. Practically speaking, the economic lifespans of waste collection vehicles range from 5 to 10 years.

C8. EQUIPMENT bid document: preparation and precautions

Ideally, responsibility for equipment acquisition is entrusted to a task force. Accordingly, members of the task force must work together to develop a detailed set of specification requirements.

The task of delineating the basic aspects of the bid documents should be assigned by the task force to a technically qualified individual. In making the delineation, the individual usually relies upon general specifications gleaned from brochures of one or two known equipment suppliers. Ideally, the decisive criterion for final acceptance of a bid is based upon the lowest qualified bid. Far less desirably, acceptance may rest upon political acceptability. An important, but often overlooked, criterion is lowest total ownership and operating cost. Comparative evaluations of vehicle ownership and operating costs should be made by knowledgeable mechanical engineers and by experienced supervisors from the fleet garage.

It is essential that decisions made by the task force concerning vehicle selection be based on actual vehicle operational experiences in the country, road conditions, driver skills, mechanic skills, available workshop equipment, local availability of spare parts, and opportunities for standardisation of components. In addition to the technical aspects, the specifications should include financial and legal conditions required for the particular acquisition.

In developing countries, the most likely sources of investment capital for the procurement of solid waste management equipment are entities such as the traditional international and bilateral development agencies (e.g., The World Bank). Certain funding agencies may insist upon international competitive bidding. On the other hand, a donor country may insist that the funds be used for the purchase of equipment manufactured within its domain. As far as developing countries are concerned, reliance upon funding sources currently available to them renders it very difficult to attain standardisation in the solid waste fleet. This in turn complicates the ability to stock the tools and replacement parts needed to keep the fleet in operation.

C9. COSTS apportionment

Information on actual costs is a precondition for the attainment of cost efficiency in a system. Although a manager may be given information on total costs of department salaries, fuel costs for the entire fleet, total costs for replacement parts, and debt service; he or she usually is not given detailed information. Moreover, the manager does not have the means of analysing existing data into meaningful information that could be used to improve the efficiency of the service. Information that could be used advantageously by the manager would be the unit cost of utilising a vehicle that has been used beyond its economic life, as compared to a new vehicle. Also useful would be a comparison of the cost of providing the service with a non-compactor collection vehicle and with a compactor, as well as an analysis of the cost advantages to be gained from the use of standardised containers. In addition, it would be useful to calculate the cost advantages of operating the fleet for two 6-hr shifts/day instead of one 8-hr shift.

Monitoring a solid waste management system demands access to data that are both reliable and applicable to the situation. The only fully satisfactory approach to the acquisition of such data is by way of an evaluation of the impact of the service upon the community's sanitary status.

In terms of percentage of average personal income, attainment of a comparable level of sanitation is more costly in developing countries than in industrialised countries. Although the cost of refuse collection in many developing countries is only about one-half that in industrialised nations; the magnitude of the average income is only a small fraction of the income of residents in industrialised countries. The consequence, therefore, is that a disproportionate amount of available revenues is spent on solid waste services in developing countries.

D. Human resources

D1. PERSONNEL requirements

The intricacies of solid waste management demand the services of highly qualified personnel that represent a broad array of professional disciplines. Illustrative of the breadth of the disciplinary array is the need for the input of professionals versed in mechanical engineering who would be responsible for the management and maintenance, repair, and deployment of the collection fleet. On the other hand, the input of professionals versed in civil engineering is essential to the design and operation of a sanitary landfill [5].

Regarding the design of optimal collection routes and the determination of appropriate collection methods and crew sizes, it is sufficient for the personnel assigned to this task to have had proper training and experience. However, a formal education in the principles of systems analysis would be helpful.

D2. FIELD supervision of collection service personnel

The importance of field supervision derives from the fact that the quality of the collection service is, to a great extent, a function of the quality of the performance exhibited by the staff, inasmuch as collection is a labour-intensive operation. Regarding the size of the supervisory staff, one field supervisor per five to eight collection vehicles is recommended. The difficulty in meeting this recommendation is intensified in many regions by a chronic shortage of competent professionals specifically trained in solid waste management. This deficiency is an outcome of the substantial dearth of formal education and of poor hiring practices. The unfortunate combination of circumstances compels numerous public and private sector institutions entrusted with solid waste management to employ untrained candidates, some of whom are unable to perform the tasks pertinent to routine operations.

The unfavourable consequences of the situation engendered by the shortage of qualified professionals are intensified by the practice of overburdening professionals with the responsibility of managing an overly large workforce. The lot of the professional in the solid waste management sector is rendered less attractive by the fact that the salary base in the solid waste sector usually is lower than that for comparable professional training and experience in other services in the public sector.

D3. ATTITUDE, morale, and motivation of personnel

The major significance of "attitude" arises from its effectiveness in minimising absenteeism. Absenteeism becomes a seriously deleterious factor in activities that require a given amount of human input. For example, an incomplete complement of workers almost invariably leads to an inadequate utilisation of equipment and/or overburdening of the remaining staff and crew.

Motivation is a factor because it is a positive force that impels an individual to participate in a given endeavour. One of the sources of motivation is a strong awareness of the utility of, and need for, the task being performed or to be performed. Judging from common experience, workers involved in a solid waste management activity generally have this awareness and, hence, possess the desired motivation. The community can foster and strengthen this motivation by initiating training programs and clarifying job descriptions. Monitoring and evaluating work performance, accompanied by assurance of job security, are excellent reinforcements of motivation. Finally, a program of motivation should be capped by the provision of basic benefits such as medical coverage and guarantee of a retirement pension.

Because motivation is a function of incentives and disincentives linked to performance evaluation, solid waste managers should be empowered to acknowledge superior performance by way of incentives such as formal recognition, further training, accelerated promotion, salary enhancement, and bonuses. Conversely, managers should be able to penalise inferior performance. This can be done through the imposition of disincentives such as fines, demotions, and dismissal.

D4. PUBLIC health inspectors

In accordance with the level of labour intensity, in developing countries, the size of the refuse collection workforce ranges from 5 to 50 labourers per 10,000 residents. Typically, the public health inspector assignment is one inspector per 100 to 300 collection workers. However, only from 5% to 40% of an inspector's time is devoted to solid waste related activities. Time over and above the 5% to 40% is reserved for the inspections of medical clinics, restaurants, food markets, public toilets, and other facilities and installations. In terms of time equivalents, this division of effort translates into approximately one full-time inspector for every 1,000 or more collection workers, or one inspector for every 200,000 residents. Generally, a public health inspector is entrusted with the enforcement of local health-related ordinances, definition of proper storage and disposal of waste, and the restricting of littering. Finally, the entire responsibility for providing public education on sanitation and improvement of the quality of the environment usually devolves upon the health inspector.

The preceding exposition of the labour situation demonstrates that the investments being made on public health inspection in developing countries are not sufficient to produce an educated and cooperative citizenry. Consequently, it is necessary to establish policies that will lead to a change in this situation.

E. Political issues

E1. AUTHORITY

Individuals charged with the management of an organisation must be authorised to make day-to-day operational decisions. In fact, the satisfactory functioning of an organisation depends upon the organisation being endowed with an authority commensurate with its responsibility. A serious difficulty in many developing countries arises from the fact that although the expenditure on solid waste management is relatively high, the position of the service in the municipal hierarchy is quite low. Frequently, the solid waste service has a divisional status within a public works or public health department. Another setup is as a section within a municipal semi-private authority established for water, wastewater, and solid waste.

Because of its comparatively low status, the authority is severely constricted. As a result, the manager of a solid waste group has little latitude in terms of hiring and appropriately paying the professional staff needed to plan and supervise the service. An additional and serious problem is the practice of burdening the manager's budget with the costs of low-level staff, some of whom may be on the payroll but not actually working.

The difficulties described in the preceding paragraphs can be avoided by broadening the autonomy of the solid waste sector and reorganising it either as a separate solid waste department within the municipal structure or as a semi-autonomous public enterprise. Establishing a separate municipal department enables greater accountability and also allows the employment of high-level professionals in the service. Setting up a completely separate entity would allow the authority to institute pay scales, which would be outside of the municipal salary scales and enable staff hiring and firing with limited interference from politicians. This type of organisation could enable the entity to generate financial resources so that it could be self-financing. There is the possibility that the establishment of such an independent entity might be interpreted as being a weakening of the municipality because it apparently would usurp one of its fundamental services. Consequently, the advantages and disadvantages of such a move must be carefully analysed and weighed before its implementation.

E2. PUBLIC education

Collaboration of the public is essential to the successful attainment of the objectives of the solid waste management service. Collaboration is best obtained by convincing the public that its cooperation is the key to the successful conduct of the service and, furthermore, that success of the service redounds in an improvement in the welfare of the public. One of the most effective means of securing such a conviction is through education [6].

Education can be accomplished formally and informally. A formal approach would involve the establishment of conventional educational programs in schools, as well as publicity campaigns. The program and campaigns would elaborate upon the benefits to be expected from proper waste management, and upon the baneful consequences of poor sanitation, while emphasising the high costs associated with inadequate public cooperation.

There are several informal modes of convincing the public that might loosely be termed "education". For example, one such approach is disciplinary in nature and, hence, may be burdened with some political odium. The approach would largely consist of the enactment and enforcement of relevant legislation (e.g., establishment of regulations and delineation of penalties). A much more effective (and far more politically palatable) approach is to initiate a "cleanup" campaign designed to motivate the citizenry and, thereby, elicit its participation. The subject of a cleanup campaign could be a neglected neighbourhood, a littered park or body of water, or any other locality in need of attention. Inasmuch as at least some of the active participants in the cleanup may have contributed to the littering, they will acquire an appreciation of the arduous and thankless nature of the management of solid waste - and in the future may refrain from littering.

E3. STATUS and resulting problems

The lowly status of solid waste management in the municipal officialdom in developing nations is responsible for many of the difficulties that afflict the service. Among the more serious of these obstacles is the prevailing failure of residents to cooperate with the agency that provides the service.

An example of lack of resident participation is the poor management of waste at the point of generation. The poor management consists of the practice of the waste generator of directly discarding waste into the environment; or, at most, of storing waste in randomly selected containers, such as cardboard boxes, rather than in properly designed receptacles. Unfortunately, the inadequate storage problem is compounded by failure to have filled storage containers readily available for servicing on designated collection days. The improper handling and storage and non-observance of collection day schedules render it exceedingly difficult to maintain cleanliness and order in delinquent neighbourhoods. Additionally, waste in unattended piles or wastes placed in inappropriate receptacles for collection are subject to being picked through by scavengers and dispersed by animals. The cost of emptying a properly designed waste container is only one-third that of collecting and disposing of dispersed refuse.

Few cities in developing countries enforce their littering and dumping laws. This relaxed attitude apparently is not influenced by the fact that littering and illegal dumping can make a well serviced city appear dirty even though residential refuse is properly stored and is collected on a daily basis. Moreover, the attitude apparently is not affected by the high cost of cleaning up after an untidy citizenry.

E4. POLITICAL factor

In developing and in industrialised countries, local and national public commitment is an essential element in the attainment of a solid waste management service that is both effective and efficient. Paradoxically, political commitment to the solid waste service demands that a protective barrier be set up and maintained between politics (political pressures) and the operation of the solid waste management service. In the absence of such a barrier, the work effort remains in danger of being concentrated on short-term, highly visible, publicity-oriented changes at the expense of accomplishing long-term, cost-effective improvements that happen to be less visible to the public.

The reality is that very frequently the ideal barrier either is not set up or is breached so often as to cease being effective. The result is that, in practice, the solid waste manager is a political appointee who often is devoid of experience or expertise in solid waste management. The outcome is that most of the appointee’s term in office is consumed in becoming acquainted with the service and in deciding upon a course of action. The appointee’s effectiveness is severely constrained by the reluctance or even refusal of staff to cooperate, which is not surprising because the staff is well aware of the appointee’s short tenure in office. This is particularly true where the collection workers unions are very strong (e.g., some Latin American countries).

E5. ROLES of the political leadership

E5.1. National level

Ranking high among the roles available to the political leadership regarding the improvement of the solid waste management service is one that consists of enacting and enforcing ordinances that prohibit littering and call for the public to collaborate with the service. Another role is to provide the solid waste service with a reliable and adequate budget. An exceedingly important role is to ensure that corrective measures be rigorously applied in situations in which the quality and effectiveness of the management service are being corroded by internal corruption and theft. The successful implementation of the corrective measures depends in large part upon the willingness of the leadership to make and enforce the difficult decisions that lead to the disciplining of transgressors.

E5.2. Local level

Conscious of the brevity of term of office characteristic of local official positions (e.g., municipality, district), and of the fact that a second term may not be permitted, politicians at the local level tend to concentrate on short-term, preferably potentially newsworthy projects.

Consequently, local office-holders may be vulnerable to promotional overtures made by purveyors of unneeded equipment. Unfortunately, proposals for the acquisition of a fleet of vehicles or for the construction of new facilities are more apt to gain and hold the attention of politicians than would proposals to improve the routine operating and maintenance needs of the solid waste service. In short, local solid waste services are very vulnerable to political pressures.

E6. CENTRALISED policy coordination

It has been found that problems generated by local circumstances and fostered by the local political leadership often can be rectified through the establishment of an interministerial coordinating body at the central government level. The coordinating body would be entrusted with: 1) the development of a national strategy, 2) the evaluation and coordination of major investments, 3) the development of projects, and 4) the making of budgetary allocations from the central government.

It would prove useful to augment the coordinating body with a group of solid waste professionals at the central government level. This group would be charged with: 1) analysing and making comparisons between the systems in the various localities, 2) keeping abreast of the state-of-the-art in other countries, and 3) serving as a clearinghouse of information available to support local solid waste managers.

Policy and program support proffered by the regional or central government serve as a strong platform for local action. Standards for service delivery and performance measures should be established at the national level. Additionally, monitoring, guidance, and regulation of local solid waste services are best accomplished when they are done at the central level. Other activities appropriately delegated to the central government include the acquisition and analysis of data on waste characteristics and quantities, operational norms, service costs, and appropriate technologies. The objective of laws, regulations, and policies promulgated at the central government level should be to provide support for compatible local ordinances and enforcement actions [4].

To avoid needless duplication of effort and expenditures, large-scale research and development work and pilot testing should mostly be confined to the central government level. The reason for the restriction is the fact that the necessarily high degree of expertise and the occasionally relatively expensive financing are not available at the local level.

In general, the implementation of measures designed to reduce the quantities of solid waste generated and to promote recycling is best left to the central government. This is especially true if the primary goal is to protect the quality of the environment. Any increase in the promulgation and stringency of such measures usually triggers an increase in the cost of waste management at the local level. However, the added cost is compensated by an improvement in environmental quality. In turn, the added cost and the improvement in environmental quality serve as incentives. The central government can make a considerable compensation for the costs by way of the establishment of procurement specifications and procedures, import trade policies, and business investment tax incentives such that the market demand for recyclables is markedly enhanced.

F. Conclusions

The burden associated with the management of solid wastes in developing countries is magnified by a chronic shortage of financial and technological resources and a dearth of qualified professionals sufficiently conversant and experienced in solid waste management. The dearth of solid waste management professionals renders the countries vulnerable to the promotional activities of purveyors of equipment that may or may not be needed, or may be ill suited to local or regional conditions, and that represent an unwise expenditure of funds. In many cases, the burden imposed by the aforementioned purveyors is compounded by pressures exerted by bilateral aid organisations and trade agencies to accept "gifts" of inappropriate equipment and technology. These organisations represent a variety of international agencies. The burden created by purveyors and by bilateral and international aid organisations has yet another facet -- namely, the many misconceptions concocted by the international media as to which techniques would be most effective in coping with the solid waste management problem in developing countries.

Yet another facet of the burden is the urging by certain international development agencies bent upon disbursing loan monies quickly. The catch is that the loan money be appropriated in investments that involve a large foreign exchange component. However, the reality is that such loans, in some cases, are of little use in the solid waste management sector in a developing country; inasmuch as improvements do not necessarily accompany increases in capital investments. The quality of solid waste management service is better served by establishing a program characterised by good management, close supervision, broadened knowledge, superior planning, and strict cost accountability. The successful implementation of such a program demands institutional strengthening, the development of appropriate regulations, and the implementation of a comprehensive and continuous public education program. A final and essential requirement is that the local professionals be trained and assisted regarding improving the efficiency of the present system without recourse to substantial monetary investments.

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CHAPTER XVIII. MANAGEMENT INFORMATION SYSTEMS

A. Introduction

Information management is the process whereby data are collected and analysed for the purpose of planning, evaluating, and monitoring systems. Management information systems (MIS) play a critical role in the planning and operation of solid waste management services. One of the primary reasons for this importance is that several activities in solid waste management are empirical and do not follow a set of theoretical principles. Another reason is the fact that the quantity and composition of the wastes vary substantially as a function of time, as well as among types of generators. These variations further complicate attempts to not only evaluate but also predict the performance of a solid waste management system. Therefore, data acquisition and analysis become the principal steps for describing the operation and performance of solid waste management systems.

As a general rule, those responsible for the management of solid wastes in economically developing countries do not pay adequate attention to the use and importance of information management. Typically, evaluations of performance and effectiveness of the solid waste management system are limited to visual observations of primarily streets and disposal sites. Inadequate coverage by the collection services, uncollected solid waste, and fires and unpleasant odour generation at the disposal site typically are blamed on a lack of equipment and human resources. Rarely is a more fundamental problem considered, i.e., inefficient utilisation of available resources. Invariably, one of the most serious problems that is identified by those involved in the management of solid wastes in developing countries is an insufficient level of funds.

Acquisition of vehicles and hiring of additional employees do not necessarily result in efficient and effective utilisation of available resources. In order to establish efficient solid waste management systems, the efficacy of existing systems and subsystems must be thoroughly assessed. The results of the assessment can be used to plan and implement improved, more efficient systems.

Each of the planning and operational phases of the process requires that accurate information be collected and processed. The emphasis here is on accurate information and proper processing of the information. Unfortunately, on the rare occasions where some type of MIS has been implemented, the accuracy of the data is seldom evaluated and a large amount of data are not analysed. Consequently, the entire effort simply is wasted. In order to facilitate the collection, processing, storage, and utilisation of the data, it is necessary to implement an MIS.

The basic data for the MIS should be obtained not only from the solid waste management system but also from a variety of other sources, such as land use and economic development. In order to be useful, the data collected should be catalogued and filed in a manner that allows easy retrieval and utilisation.

During the planning process, information is utilised to establish solid waste management goals for the planning period, to determine resource requirements; and to make decisions on investments for collection, processing, and disposal services. Information on current and future population, commercial and industrial development, quantity of solid waste generated, land use, and other topics is used to estimate the levels of demand for the solid waste system and to set goals. The information is then used to develop various options to meet the goals. Based on an analysis of the options, a particular alternative is selected using criteria such as level of recycling, waste diversion from landfill, or cost effectiveness. Using the selected option, resource requirements are determined and an investment schedule is developed.

With respect to the management of operations, information is used to evaluate the efficiency of the service and to improve the performance of the entire system. The types of data that are required include operation and maintenance history of vehicles and equipment, productivity of both equipment and workers, and expenditures.

If available, personal computers should be used to collect, process, store, disseminate, and utilise the information in planning and operational management. Information generated from actual operation of the services should be collected regularly (preferably on a daily basis) and stored on computer. Socioeconomic information relevant to solid waste management should also be collected and stored. These data are then processed to provide information in a useful form for subsequent utilisation. The processed information should be stored on magnetic media (computer disks) and printed on paper for use in planning and operational management. The use of personal computers also allows for online access to the processed information.

In addition to the operational data on solid waste management and socioeconomic statistics indicated in the preceding paragraph, information from technical publications; legal documents; and environmental data such as those required for environmental impact assessment of collection, processing, and disposal facilities should be obtained. This information should be used in planning, designing, and operating solid waste management systems. However, this type of information can be managed more effectively by a system similar to that used for the operation of a library. Therefore, it is advisable that the system for the management of literature should be developed separately from the basic MIS.

B. Evaluation of performance

The performance of a solid waste management system is a function of the amount and quality of resources allocated to carry out the services, as well as on the socioeconomic development and physical characteristics of the service area. The performance can be expressed mathematically as follows:

$$O = f(I, D)$$

where:

- O = the performance of the service,
- I = the resource inputs to the service, and
- D = the socioeconomic development and physical characteristics of the service area.

The variables related to the socioeconomic development and physical characteristics of the service area normally cannot be controlled by the authority. For instance, the width of a street could not be changed to allow passage of solid waste collection vehicles. Instead, the authority must modify its collection fleet to existing conditions in order to perform the required services.

On the other hand, the variables associated with resource inputs can and should be controlled by the authority. In fact, the success of a solid waste management system depends largely on how wisely available resources are utilised. Consequently, in order to improve the performance of its services, the waste authority should allocate available resources optimally. Resource allocation should take into consideration the nearly continuously changing service demands and constraints due to socioeconomic development and physical characteristics of the service area.

Decisions on operational management usually are made based on the level of socioeconomic development, physical characteristics of the service area, and a predetermined total resource input. In small municipalities in developing countries, the resource input generally is dictated by the central government. Under these conditions, the authority must operate the system such that maximum performance is achieved. Based on the information presented in the equation, this becomes an optimisation problem; that is, O is to be maximised, having I and D as constants. Therefore, the authority must select a set of collection, processing, and disposal methods, among various alternatives, such that O is optimised.

In waste management planning, the desired performance (O) generally is fixed as a future goal of the plan, with the estimated level of socioeconomic development and physical characteristics of the service area (D), and the level of resources required to achieve the goal (I) at a minimum cost. Thus, the problem becomes one of optimisation of I having O and D fixed at a certain time. The minimisation of I is, therefore, a decision criterion used in the planning process.

In addition to these criteria for evaluation, a ratio of the service performance to the resource input or vice versa (i.e., O/I or I/O) can also be used for evaluating the efficiency of solid waste management systems.

In order to make these evaluation processes possible and analytical, the variables in the equation must be determined and measured. These variables generally are called indicators. The indicators typically are divided into: service performance (used to describe O); resource input (used to describe I); efficiency (O/I or I/O); and socioeconomic and physical conditions (used to describe D) [1,3].

C. Indicators

In the previous section, information required for solid waste collection and disposal services was classified into the following major categories: socioeconomic and physical condition indicators, service performance indicators, resource input indicators, and efficiency indicators. The classification was based on evaluation and decision-making processes used in planning and operational management. Unfortunately, the information required for planning is not always the same as that required for operational management. For instance, day-to-day operational instructions require timely information with respect to specific location, personnel, and equipment involved. Additionally, the instructions do not necessarily coincide with the evaluation framework discussed in the previous section. The design of solid waste processing and disposal facilities requires site-specific information that does not fit into the evaluation framework. The general indicators described in this chapter are intended mainly for use in the planning and monitoring of solid waste management systems, as well as for operational management.

A discussion of the indicators, divided by the various key phases of a typical solid waste management system (i.e., generation, storage, collection, transfer and transport, processing and resource recovery, and final disposal), is provided below. A list of specific indicators is presented in Appendix C [2].

C1. GENERATION

The indicators in this phase of the solid waste management system primarily are focused on socioeconomic and physical conditions. These indicators represent the type and level of demand for solid waste management services.

In the list (Appendix B), the indicators (excepting those that describe the administrative area and its corresponding population) represent the generators that require the collection service. Some of these wastes can be disposed properly without utilising the formal public or private collection infrastructure. For instance, the waste generated by some commercial establishments can be privately collected and transported to the disposal facility. In industrialised countries, industrial waste (particularly hazardous industrial waste) is collected, transported, and disposed of separately from other sources of waste. Consequently, as was indicated in previous chapters, it is important to clearly define the types of waste that are collected and disposed of by the municipality, or by individual households, institutions, commercial establishments, or factories, before appropriate indicators are selected.

The quantity of waste generated by each one of these sources (waste generators) is an indicator of primary service demand. These indicators can be used to estimate the quantity of waste generated under different conditions, such as a different population size and increased levels of commercial or industrial activities. Therefore, the indicators are also useful for estimating the demand for collection, treatment, and final disposal.

In addition to the quantities of wastes generated, the characteristics of the wastes (i.e., physical and chemical) provide essential information for determining appropriate management methods.

C2. ONSITE storage

As previously discussed, onsite storage is the point at which the solid waste generated is stored for eventual collection by the municipal authority or by its contractor. Onsite storage can be classified under two general categories: 1) individual storage serving the occupiers of a single dwelling, shop, or office; and 2) communal storage serving the occupiers of multiple houses, apartments, shops, or offices.

Normally, the responsibility for the acquisition and maintenance of individual storage containers rests with the owner/occupier of each unit. On the other hand, the authority usually assumes responsibility for purchasing and maintaining communal storage containers. Indicators relating to individual storage can therefore be classified as socioeconomic and physical condition indicators, while those relating to communal storage are considered to be resource input indicators.

C3. COLLECTION and transport

Indicators for collection and transport can be classified either as service performance indicators or as resource input indicators. These two general types of indicators can be used to calculate efficiency indicators.

C4. PROCESSING and resource recovery

Indicators for describing processing and resource recovery can also be divided into performance, resource input, and efficiency indicators.

C5. FINAL disposal

Indicators that can be used for final disposal are very similar to those for evaluating processing and resource recovery activities. The indicators are also divided into service performance, resource input, and efficiency indicators.

C6. ADMINISTRATION

Administrative activities do not produce measurable outputs in the service and, therefore, the type of information generated in the administrative section is not classified as a service performance indicator. One possible exception is the information generated on the type and number of complaints. This type of information is considered a service performance indicator and normally is processed by the administrative section.

The administrative section generally is responsible for activities associated with enforcement, public education, and public relations. Although these activities do not fall directly under the category of service performance indicator, they indirectly have a profound effect on the performance of the service. The information on these activities is useful for planning and operational management of solid waste management services.

D. Establishment of the management information system

Once the type of information that would be useful for the evaluation of the solid waste management service has been identified, the next task at hand is to determine the procedure for collecting, storing, processing, and distributing the information. A system in which information is collected, stored, processed, utilised, and disseminated is called an MIS. Several approaches have been suggested for the establishment of an MIS. The final form of a particular system is largely a function of the quantity of information to be collected and the level of resources (human, physical, and financial) available for the development and maintenance of the system. It is safe to assume that, in most cases, a large municipality or metropolitan area will generate more data and will, therefore, require a relatively sophisticated computerised system for information management. On the other hand, a small municipality may only require a manual system. A variety of system configurations are possible, depending upon the size of the municipality and resources available. Therefore, this chapter will not suggest a single prototype MIS; instead it will provide special considerations required for designing such a system.

D1. ORGANISATION

The first step in developing an MIS is to identify and designate the personnel who will be involved in collecting, storing, processing, and disseminating the information. In most cases, personnel that are actually working in the field are requested to either generate or collect data that are obtained through some type of reporting system. The data are then stored, processed, and disseminated by staff in the administrative section. However, the personnel who will be participating in the process, and the manner by which the information is to be transmitted from one staff member to another, depend on how the solid waste management system is organised in the municipality.

Large municipalities generally are divided into districts. In turn, personnel assigned to the districts are responsible for providing waste collection services. Processing and final disposal facilities usually are sited throughout the municipality and are utilised by more than one district. Processing and disposal facilities, therefore, do not normally belong to a specific district, but are part of the entire system. In such a situation, the information generated in the field is collected, stored, processed, and utilised for action at the district offices and the information relevant to processing and disposal is assigned to the municipality’s headquarters.

Small municipalities normally have only one office responsible for the management and implementation of the waste management service; that office is responsible for collecting information from solid waste collection crews, as well as from personnel at processing centres and disposal facilities. The office also is responsible for storing, processing, and using the information in the decision-making process.

In some municipalities, solid waste management is carried out by more than one agency. For instance, equipment maintenance is performed by the operations maintenance department, while the collection system may be the responsibility of the health department. In such a case, equipment maintenance records and information on spare parts, downtime, human resources input, and others should be transmitted from the operations maintenance department to the health department for monitoring performance and for the scheduling and purchasing of collection vehicles. This information also is required to evaluate the overall efficiency of the collection service. In designing an MIS for this municipality, both departments should be required to have individual, but compatible, management information systems.

D2. DATA collection

There are various methods for collecting data. Data can be collected from existing sources, by conducting special surveys, by taking measurements, or through regular reporting mechanisms. Of the indicators given in Appendix C, the information on most socioeconomic and physical condition indicators (such as administrative area, population, the number of households, and commercial/business establishments) normally is available from the municipal departments responsible for urban planning and public works. Therefore, such information should be collected from those agencies and should be frequently updated.

Waste characterisation surveys, such as those described in Chapter III, should be carried out to collect information on generation rates, physical composition, bulk density, and storage indicators. Physical and chemical characteristics of the wastes, such as calorific value and chemical composition, are determined through laboratory analyses. If these types of data are required, it is important to determine the capabilities and experience of the laboratories such that reliable data are obtained.

Information on the indicators for collection, transport, processing, resource recovery, final disposal, and administration can be obtained from the respective services through a regular reporting system.

D3. STORAGE and processing

Storage and processing of the data can be performed either manually or electronically. A manual system consists of first labelling and cataloguing the information, followed by an accurate procedure of filing and analysing it.

The development of personal computers has been such that they have become accessible to many institutions and individuals in developing countries. The use of personal computers for information management has become practical and popular due to increases in memory and storage capacities, as well as increasingly affordable prices. In addition, there are various commercially available software packages for general-purpose data management, such as spreadsheet and database management. These packages can easily be applied to municipal solid waste services. Other advantages of using computers include the capability of producing graphs, tables, and maps, and the ease in transferring information (networking), e.g., between departments.

In a municipality where a computerised MIS has already been developed or is in the process of being developed for general accounting or other purposes, the MIS for solid waste management planning and operations should become part of the overall computerised system as a subsystem.

Once this linkage is established, information can be shared among various departments in the municipal government.

E. Conclusions

A large amount of data is used for planning, designing, and operating municipal solid waste collection, processing, and disposal services. Due to the diversity of situations throughout the world, and in many cases within a particular country, it would be difficult to design a single MIS that would be capable of satisfying the needs of all solid waste management functions. Instead of proposing a comprehensive prototype MIS that would be applicable to most situations, in this chapter we suggest that a simple system tailored to local conditions be established with available resources and information specific to the locality. The system should be flexible and capable of expanding, as more resources are made available.

Using this approach, a series of indicators that can be used to evaluate the performance of solid waste management services has been presented. In addition, a general methodology for establishing an MIS has been proposed. It must be emphasised that, due to space limitations, a number of indicators that are useful for certain decision-making processes in waste management have not been extensively covered. These indicators include literature information, environmental data, and various design parameters. As previously discussed, these indicators cannot easily be incorporated into the MIS proposed in this chapter.

Finally, this chapter presents an MIS that would be utilised by municipal government officials and does not describe the type of information that would be required by a national agency.

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Appendices

APPENDIX A. PUBLIC HEALTH ASPECTS

Rising urban population growth, limited municipal resources, and the complexity of municipal solid waste management (MSWM) in both industrialised and developing countries have complicated the relationship between environmental management and the health of urban inhabitants. The combined effects of casual disposal of wastes, insufficient waste collection service, and inadequate waste disposal facilities have always had serious, adverse implications for public health. Among these are the direct transmission of diseases and the spread of epidemics, degradation of the quality of the urban and natural environments and, most importantly, the social reinforcement of poor hygienic habits and practices, all of which compose a vicious cycle.

The inclusion of hazardous waste, health care waste, and excreta (although in small quantities) in the urban waste stream complicates the search for practical responses to the problem of maintaining the health of the public. For example, the potential spread of AIDS, SARS, and other infectious diseases through the discharge of health care wastes into the general urban waste stream is a continuous and growing threat. The implications of inadequate municipal waste management upon the health of the public are serious and they cannot be ignored.

This appendix focuses on the public health implications of generating, collecting, processing and disposing solid waste in developing counties, and on methods of managing the risks to the health and safety of the general public and of the personnel involved in collection and disposal of solid waste. The approach adopted for this discussion is to follow the various key stages, from generation through final disposal of municipal solid waste (MSW), and in the process to discuss common public health impacts on both the public and on the workers who directly handle the wastes. The impacts on the environment in general are mentioned where relevant. Some attention is also given to the topic of special and hazardous wastes.

A. The nature of municipal solid waste

From the public health point of view, MSW can be divided into three categories, with subcategories that are based largely on their sources and/or processes of generation: 1) domestic wastes; 2) special and hazardous wastes; and 3) other wastes, as shown in Table A-1. While most of these wastes could be isolated at the source of generation and managed in a rational way, in practice, the municipal waste stream is usually a mixture of two or more of the categories. This is the reality of most developing countries and some of the emerging or transition economies of Central Asia and Eastern Europe, where waste management systems have generally broken down.

Table A-1. Waste categories with potential public health impacts

Category	Description
Domestic wastes	General household wastes with used batteries and drugs containers, street sweepings with small quantities of excreta
Special and hazardous wastes	Health care waste (sharp and infectious components), toxic chemical, pharmaceutical, and other industrial wastes, as well as radioactive wastes
Other wastes	Untreated abattoir waste, construction wastes with asbestos components, and sludges from wastewater treatment plants

B. Potential health impacts in the waste cycle

Public health impacts of MSW can occur along all stages of the waste cycle. Mismanagement of waste at each point along the cycle has the potential of introducing both short- and long-term adverse health impacts; these call for serious attention. Groups at risk from adverse public health impacts associated with MSW are listed in Table A-2. Some types of potential health impacts associated with solid waste are discussed below.

Table A-2. Groups at risk from adverse public health impacts associated with MSW

- The population of unserved areas, especially pre-school children and the elderly
- Waste operators and scavengers
- Workers in facilities that produce infectious, toxic, and cancer-causing materials
- People living close to waste facilities
- The population supplied with water polluted by waste dumping or by inadequately protected landfill sites

B1. GENERAL

The first type of health impact is accidental injuries, such as cuts and punctures from sharp objects in the waste. Workers and other persons who manually collect and process solid waste regularly are especially at risk. Fires in collected and disposed waste also represent potential health and safety hazards to workers as well as the public. Another hazard is that which manifests itself when large volumes of disposed waste become unstable and, in the process, collapse and bury workers, scavengers, or shacks on or near the site containing their inhabitants. Small amounts of hazardous chemical waste in garbage may result in accidental injuries, but may also lead, in some extreme cases, to poisoning. Also, some cases are on record of children playing with radioactive waste illegally collected from health care facilities and land disposed, with the eventual result that the children contract cancer.

The second type of health impact is infections caused by exposure of humans to solid waste or its products of decomposition. Blood borne infections such as tetanus, resulting from injuries caused by infected sharp items in the waste, are common. Ophthalmologic and dermatological infections from exposure to contaminated dust are also possible. Enteric infections may result from accidental ingestion of waste, but more often such infections occur from drinking water from unconfined aquifers or nearby streams polluted by leachate from waste, from consumption of raw vegetables produced on fields irrigated with contaminated leachate from waste piles, and from eating food in garbage. Worm infestation among children results mainly from direct contact with human excreta. Infections may also be transmitted through rodents and insects feeding on waste and acting as passive carriers of disease germs. Many tropical diseases transmitted by vectors such as mosquitoes have their origins in breeding ponds created by indiscriminate waste disposal. Zoonosis, a disease carried by stray, wild, and scavenging animals feeding on waste, is also reported in many parts of the world.

B2. GENERATION and storage

The production and storage of waste represents the first points of physical contact and other routes of exposure between the waste and humans or the environment. The exposure and potential for adverse human health risks are particular concerns in the case of special or hazardous waste, especially during the production of industrial products with toxic byproducts. While the risk is generally less in the case of generation and storage of domestic solid waste, the inclusion of relatively small quantities of infectious and toxic waste, such as bottles containing hazardous types of pharmaceutical products, photographic material, batteries, infectious health care wastes and sharps (e.g., syringe needles and scalpels), excreta, and other such substances, can turn seemingly benign domestic waste into potentially dangerous waste, with attendant serious public health impacts.

Storage of waste can also lead to adverse public health effects by: 1) creating fertile grounds for the breeding of household pests; 2) animals feeding on the waste; and 3) obstructing natural drainage channels, leading to the formation of ponds that then serve as breeding grounds for insects and other carriers of human pathogens. Backyard dumping or storage of waste often creates noxious odours that results from decomposition of biodegradable materials, and breeding grounds for insects and rodents that are potential carriers of infectious diseases.

B3. WASTE recovery, recycling, and reuse

In developing countries, scavenging is widely practiced and socioeconomic conditions do not allow its abolition or prohibition. Scavengers are extremely vulnerable because they belong to one of the most underprivileged groups of the population and are most often illiterate. They are exposed to serious health hazards from waste and are also exposed to social and economic abuses from waste recycling traders. In some cities, scavengers live in shacks built on the disposal sites. Some may be born, live, work, die, and be buried in the dump. Street children very often survive by scavenging materials from waste set out for collection. Health surveys have shown that the health status of scavengers is very low, and that they suffer from infections, including persistent skin infections. Their life expectancy is far below the average in their respective countries.

Scavengers may be protected in the same way as regular solid waste crews, but in low-income countries, occupational health and safety services are most often deficient for such crews, and scavengers can expect none of those services. However, the scavenger’s situation may be improved if they are organised and receive assistance to improve both working conditions and their housing and sanitation, as the Zabbaleen communities in Cairo, Egypt have demonstrated.

B4. COLLECTION and transfer

One important hygienic requirement in public health is that all MSW produced, even in low-income areas, be collected and removed from the point of generation. These sanitation activities minimise or eliminate the potential of humans coming into direct contact with putrefying waste. If uncollected garbage piles up in human settlements, inhabitants will be exposed to direct health impacts. Domestic solid waste properly handled at home but inadequately stored prior to collection will also expose people to negative health impacts.

In cities of low-income developing countries, local governments are often unable to collect most of the MSW produced in their cities. Collection coverage below 50% is common for several cities, which means that there is practically no collection in low-income neighbourhoods. This situation results in waste piling up in those neighbourhoods. All inhabitants of unserved settlements are exposed to direct contact with waste, but pre-school children are the most exposed, as they seldom move out of their neighbourhood and are more likely to play around the uncollected waste heaps.

The organic fraction of uncollected waste undergoes uncontrolled fermentation, which creates conditions favourable to the survival and growth of microbiological pathogens, especially if wastes are mixed with human excreta due to lack of proper and adequate sanitary facilities. If the waste undergoes anaerobic fermentation, methane gas, which is combustible, is generated, which with a source of ignition can expose humans to fire, smoke, or even an explosion. Organic waste is also the feeding stock and natural environment for insects and rodents, which are potential carriers of enteric pathogens. Such waste is also ideal for feeding and harbouring stray and scavenging animals -- potential carriers of zoonosis. Uncollected waste might also contain sharp objects, which are potential sources of infective wounds, and also small amounts of hazardous chemical waste.

Finally, inadequate collection of waste means open and indiscriminate dumping. One public health consequence of open dumping can be obstruction of stormwater runoff. This results in flooding and creation of ponds during the rainy season, which become habitats and breeding places for waterborne vectors of tropical diseases. Helminths, such as hookworm, survive on soil polluted by waste and will infect barefooted people. Waste collection or disposal operators are exposed to direct impacts from waste. Solid waste workers are particularly vulnerable because of their low educational status, and are therefore difficult to reach by health education and preventive actions. As shown in Table A-3, waste workers are exposed to a multitude of health hazards that result from direct handling of and contact with waste.

The most practical public health problems arising from transfer and transportation of waste are related to improper safeguards in the transfer or transportation process. Uncovered transportation vehicles or containers cause littering of the waste and the possible spread of airborne contaminants; leachates from trucks used for transportation are another source of pollution. Worst-case scenarios are en route accidents that result in ground and surface water contamination. The choice of low-risk transportation routes is very important.

Table A-3. Occupational hazards associated with waste handling

Accidents

- Muscular-skeletal disorders resulting from the handling of heavy containers
- Wounds, most often infected wounds, resulting from contact with sharp waste
- Intoxication and injuries resulting from contact with small amounts of hazardous chemical waste collected with garbage
- Trauma, burns, and other injuries resulting from occupational accidents at waste disposal sites, or from methane gas fires or explosions at landfill sites

Infections

- Dermal and blood infection resulting from direct contact with waste and from infected wounds
- Ophthalmologic and respiratory infections resulting from exposure to infected dust, especially during landfilling operations
- Zoonosis resulting from bites by wild or stray animals feeding on wastes
- Enteric infections transmitted by insects feeding on wastes

Chronic diseases

- Incineration operators are especially exposed to chronic respiratory diseases resulting from exposure to dust, to toxic and carcinogenic risks resulting from exposure to hazardous compounds, to cardiovascular disorders and heat stress resulting from exposure to excessive temperature, and to loss of hearing function due to exposure to excessive noise

B5. TREATMENT and disposal

Waste treatment and disposal facilities have the potential to create health hazards for waste workers; they also create health hazards and nuisances to populations living in their vicinity. For this reason, the location of such facilities reasonably far away from human habitat is desirable. Waste disposal facilities also create wide-ranging environmental impacts. The most significant of these indirect impacts are groundwater pollution by leachate generated as a result of uncontrolled land disposal of waste, and air pollution caused by uncontrolled incineration of waste.

Waste disposal operators, scavengers, and occasional visitors to solid waste facilities are exposed to infectious wounds, inhalation of infected dust, skin contact with infected material, bites from disease-transmitting insects or animals, and burns or injuries from many kinds of accidents (see Table A-3).

These accidents may result from the movement of trucks and bulldozers on the site, from spontaneous fires started inside the waste, from methane gas explosions inside or adjacent to land disposal sites, or from the slides of unstable slopes. Nearby populations are exposed to high noise levels from disposal operations, to air pollution from dust and smoke produced at the dump, to strong odours, and to infective bites from animals and insects that live and breed on the dump. Human habitation should thus not be permitted close to treatment and land disposal sites. Unfortunately, scavengers and their families tend to build their domiciles very close to if not on waste disposal sites; their removal may be a very sensitive issue. An example is the lengthy negotiation over the closure of the "Smoky Mountain" dump in Manila, Philippines.

The above-listed hazards may be mitigated by the practice of modern sanitary landfilling, discussed in the main body of this publication. Due to modern landfill design and operation, odours, dust emissions, fires, the proliferation of insects, rodents, and stray animals, and other impacts are controlled.

B5.1. Composting and reuse

Composting and reuse are largely environmentally friendly operations; however, if improperly carried out, they may generate some health hazards. Workers at composting facilities, when poorly protected, are exposed to infection from dust inhalation and to infective wounds from sharps. They are also exposed to occupational accidents during waste shredding operations. In developing countries, farmers working barefoot are exposed to infective wounds from small sharps included in poorly processed compost.

Separate collection of even small quantities of hazardous waste can expose poorly protected or poorly trained workers to health and safety hazards. These hazards may be infectious or toxic. Recycling of non-disinfected infectious waste represents serious health and safety risks to both operating personnel and the public. Discarded medical equipment such as syringes and scalpels should not be reused. Precautions should be taken such that these items are prevented from entering the waste stream where there is potential for contact by scavengers plying their trade.

The indiscriminate reuse of contaminated containers, particularly for the storage of drinking water, beverages, and food items, can lead to health and safety issues.

B5.2. Incineration

Proper siting and proper emission control facilities are very important in limiting exposure of humans to air pollution produced as a result of incineration of solid waste, particularly in densely inhabited, large cities.

Besides air pollution, environmental impacts of incinerators result from the need to dispose of bottom ash, fly ash, and wastewater produced by exhaust gas cleaning processes. Fly ash and acidic wastewater from gas cleaning systems are hazardous chemical wastes. Incinerator operators are exposed to occupational and industrial accidents. They are also exposed to high levels of noise, temperature, and air pollution.

Nearby populations will not only be exposed to the consequences of any industrial accidents, but also to significant levels of noise and air pollution. The best way to protect the public from incinerator air emissions is to limit settlements to beyond the boundary of minimally acceptable air quality. The determination of this boundary requires qualified and experienced professionals to analyse many issues, including types and levels of emissions emitted at the facility and dispersed downwind, meteorological conditions, applicable routes of human exposure, and types of health risks. The public may also be affected by water pollution if ash and wastewater from the incinerator are not properly treated and disposed. Many industrialised countries, as well as the European Union and the Nordic Council, are enforcing standards limiting incinerator emissions; those standards cover HCI, HF, particulates, NO_x, CO_x, SO_x, Pb, Cd, Hg, As, Zn, dioxins, furans, and other compounds.

Ash from incinerators has been reused in civil engineering works. However, in industrialised countries, the most prevalent method of management is disposal of the ash in lined landfills to control the risk of underground pollution by soluble toxic chemicals leached out of the ash. Both fly ash and bottom ash contain chemical constituents that pose potential serious risks to operating personnel and the public. The chemical constituents of concern include heavy metals, dioxins, and furans. Fly ash in particular tends to be very hazardous because of its fine particulate size distribution and the fact that heavy metals and other non-combustible toxic chemicals in the waste are concentrated in the mass remaining after combustion of the waste. Proper methods of transporting, treating, and disposing of bottom and fly ash are required to minimise health and safety risks to both operating personnel and the general public.

Untreated wastewater produced by incinerator gas cleaning systems is highly acidic. To protect both the public and the environment, this acidity must be neutralised with alkali before discharging such wastewater into any sewer system for treatment. Under no circumstances should the effluent be discharged into the environment without prior treatment.

B5.3. Open dumps and landfills

Dumps and landfill sites can have a substantial impact on both surface and groundwater quality, with subsequent potential health hazards for people who depend on such resources for subsistence. Rainwater runoff from poorly designed and operated landfills or from open dumps can reach nearby streams after having been heavily polluted through contact with waste. However, the most serious threat usually is that associated with leachate generated within the waste and its subsequent infiltration into unconfined aquifers below or adjacent to disposal sites. This results in chemical and viral pollution of groundwater. The health hazard from polluted groundwater is far greater than from polluted surface water, because rural populations around the landfill may drink from shallow wells without treating the water. Even if the well water or surface water source is subjected to treatment, the treatment may not be effective against some of the chemical pollutants contained in leachate produced from solid waste.

To protect surface water quality, it is necessary to prevent water flowing over or infiltrating through waste before reaching the surface source. Proper location and design and operation of land disposal facilities is required in order to minimise the risk of pollution of ground and surface waters by solid waste leachate.

Communities near the disposal sites also are impacted by the traffic in and out of the facility.

C. Special and hazardous wastes

In most communities in the developing world, small amounts of infectious material, sludge, sharps, chemical waste, and waste with high heavy metals content are regularly collected together with normal municipal waste. These categories of wastes create special health hazards for waste management operators, scavengers, and eventually the general population. While exposure to solid waste is frequent in poor neighbourhoods, the quantities of hazardous waste that are present in the waste are usually low. On the other hand, people in wealthy neighbourhoods tend to use more chemical consumer products and store medical products at home. The likelihood, therefore, of the presence of small amounts of hazardous waste in their garbage is high.

C1. INFECTIOUS waste

Infectious waste generated from health care activities performed in hospitals, veterinarian offices, and small clinics are most often disposed together with regular garbage. This situation can create particularly serious health hazards, of which the transmission of viral blood infections (such as AIDS and hepatitis B and C, through wounds caused by discarded syringe needles) is but one example.

C2. HAZARDOUS chemicals

Chemical consumer products used at home are often hazardous; they may be flammable, reactive, or corrosive, or they may be toxic and carcinogenic. At home, these products should be stored in a safe place, out of reach of children. If stores of domestic chemicals are adequately managed, the resulting waste will be only the packaging, with residues of chemicals, and it will be acceptable to dispose those small amounts of hazardous waste in the garbage container. Unfortunately, oftentimes a large quantity (e.g., a half-full bottle) of hazardous chemicals, whether solvents, pesticides, or varnish, finishes in the garbage container. The collection, handling, and improper disposal of even small amounts of dangerous chemicals represent substantial hazards to the health and safety of both the waste generators and the waste collectors.

D. Suggested public health and occupational safeguards

D1. OVERVIEW

From the information presented in the preceding sections, it is clear that adverse health impacts can and do result along the whole cycle of the MSWM process. A proper understanding by municipal waste managers and workers of the health and safety impacts associated with solid waste and the methods of exposure is the basis for confronting these problems. Three generic types of waste-linked health impacts have been identified, as summarised in Table A-4: 1) injuries and exposure to chronic diseases; 2) bacterial, viral, or parasitic infections; and 3) indirect creation of endemic conditions for specific tropical waterborne diseases.

From the lists of impacts, the conclusion can be drawn that safe handling and appropriate disposal of all municipal waste streams are paramount in ensuring a healthy living environment. Given the poor state of the economies of most developing countries and the sheer magnitude of their waste management problems, only strategies based on incremental improvements to the existing situation are practical in most cases.

E. Hygienic requirements at home

Any solid waste produced at home must be collected and stored in a safe container. Organic waste must not be kept indoors for more than 48 hours in a warm climate, or 5 days in a cool climate. Containers for storing waste are best placed outdoors or in a space dedicated only to waste storage. Any infectious waste, sharps, or chemical waste must be properly packed before being put in storage containers. Large quantities of highly hazardous chemical waste, such as solvents, should not be put in domestic waste containers, but should be labelled, packaged properly, and stored separately for collection and disposal.

Garbage chutes must be avoided or bypassed in low-cost, high-rise apartments when regular maintenance is uncertain, because waste will accumulate. Existing chutes and indoor waste storage rooms of apartment houses must be kept clean and periodically disinfected. Visual evidence of insects and rodents in the building is an indicator of mismanagement of waste.

Urban populations must be educated in hygienic waste management at home and in the neighbourhood. Community leaders in low-income settlements must be motivated to contribute to hygienic waste management in their neighbourhood. Selection of safe and appropriate garbage containers in developing countries is not always easy. Uncollected waste from suburban areas may be temporarily managed by either recycling on the plot or buried onsite, but every effort must be made to put in place an appropriate collection system for all sections of the population.

Table A-4. Summary of waste-linked diseases and conditions, with their causes or pathways of transmission

Injuries and chronic diseases

- Cuts and infective wounds from sharp waste
- Burns and respiratory trauma from burning waste
- Trauma from collapses of large volumes of disposed waste
- Burns or wounds from hazardous chemicals in waste
- Toxication and cancers from exposure to hazardous waste
- Chronic respiratory diseases from exposure to dust

Bacterial, viral, or parasitic infections

- Bacterial (tetanus, staphyloco ccus, streptoco I ccus) or viral (hepatitis B, AIDS) blood infections resulting from injuries caused by infectious sharp waste
- Eye (trachoma, conjunctivitis) and skin (mycosis, anthrax) infections from waste-generated infected dust
- Respiratory infections (bacterial or viral pneumonia) from exposure to waste-generated infectious dust
- Vector-borne diseases, viral (dengue, yellow fever) or parasitic, (malaria, filariasis, schistosomiasis), transmitted by vectors living or breeding in waste-generated ponds; and worm infestation, transmitted by contact with polluted soil (hookworm)
- Bacterial (cholera, diarrhea), viral (dysentery), or parasitic (helminthiasis, amoebiasis, giardiasis) enteric diseases, transmitted:
  - by insects and rodents feeding on wastes
  - by accidental ingestion of waste food
  - through drinking water contaminated by leachate from waste
  - through eating food contaminated by leachate from waste
- Zoonosis carried by stray animals and rodents feeding on waste (rabies, plague, leishmaniasis, hydiatasis, tick-borne fevers)

Tropical diseases transmitted by waterborne vectors in urban areas

- Malaria transmitted by anopheles mosquitoes
- Dengue and yellow fever transmitted by aedes mosquitoes
- Filariasis (Bancroftian) transmitted by culex mosquitoes
- Schistosomiasis harbored by bulinus and other snails

F. Hygienic requirements in the neighbourhood

As a primary goal, all municipal waste generated in any neighbourhood should be collected and removed promptly for proper disposal. Garbage and organic municipal waste must be collected prior to reaching an advanced stage of fermentation; this stage is indicated by strong odours.

Suggested collection frequencies that are consistent with good sanitation practice are listed in Table A-5. These collection frequencies should be goals. It is recognised that limitations of human and financial resources in developing countries may limit the ability to achieve the goals. A range of values is given in the table for each type of climate because waste stored in tightly closed containers can be collected less often than waste stored in open containers, exposing them to the elements and vectors.

Table A-5. Collection frequencies commensurate with good sanitation practice

Area	Collection Frequency
Tropical countries	Daily or every other day collection
Warm-temperate countries	Every two or three days in summer, every three or four days in winter
Cool-temperate countries	Once or twice a week in summer, once a week or biweekly in winter

If waste containers are handled manually, their size and weight should be limited to avoid muscular-skeletal disorders among waste collectors. The use of 200-L drums should be avoided. Waste containers with tight fitting lids should be used to store waste for collection, thus serving as a deterrent to human or animal intrusions, and minimising exposure of the waste to precipitation. The highest safety level is reached through the use of closed and puncture-resistant garbage containers. The use of plastic bags for storage of waste is risky to the solid waste personnel, who may be exposed to protruding sharps, etc. during the collection activity, and is problematic because the bags can be punctured or opened when handled by the collector or by rodents and stray animals. Populations of domestic stray or wild animals must be controlled in urban areas to prevent zoonosis and to avoid damage to waste containers such as plastic bags, with subsequent spreading of garbage on the roadway. Any waste spread on roadways must be removed by street cleaning operations.

G. Occupational health and safety requirements

To reduce the risks listed above, waste workers must wear protective clothes, boots, and gloves. At waste disposal sites, facemasks or simple scarves wrapped around the face should be used. Incinerator operators must also be protected against excessive noise and temperature. Waste workers should receive health education and be trained in accident prevention and emergency measures. They should have access to showers and cleaning facilities after their work shift and be immunised against tetanus and hepatitis B. Periodic medical examinations or screening should also be carried out on waste workers.

Where affordable, there should be separate collection of domestic chemical waste and waste with high heavy metal content, such as batteries, broken thermometers, and infectious and other toxic health care wastes. Used syringes should be packed in tamper-proof, puncture-resistant plastic containers or metal containers before being placed into a trash container. In countries and health care facilities that can afford it, segregation and separate collection of infectious waste should be employed to reduce to a minimum the quantities of infectious waste that require management and to render the waste more suitable for disinfection or sterilisation at a designated infectious waste disposal facility.

Waste managers in developing countries may also wish to use chemical encapsulation to encapsulate and immobilise discarded sharps, and to serve as a form of protection against the risk of injury and infection to humans. In this process, sharps are placed into a metallic barrel or a tough plastic drum. When this container is approximately 70% full, fluid cement mortar is poured into the container until all of the sharps are engulfed. After the mortar has solidified, the sharps are immobilised and the container may be disposed in a landfill. After a few weeks, due to natural mortality of microbiological pathogens, the sharps so treated will have lost their infective nature.

In case hazardous waste or health care wastes are intended for composting, it is necessary to collect the biodegradable materials separately or to carefully monitor for and segregate any hazardous chemical waste or infectious waste that could adversely affect the bacteriological processes during composting and/or the characteristics, quality, and use of the compost. These admonitions limit the exposure of the compost facility operators, the public, and the environment to dangerous and toxic waste. The segregated hazardous waste and infectious waste must then be properly collected, treated, and disposed.

H. Management framework for the minimisation of health impacts

Since many serious public health problems are directly or indirectly related to poor management of solid waste, good solid waste management practice serves to protect the public health and, therefore, the overall well being of communities. Consequently, the first two priorities should be to ensure: 1) complete coverage of the population by an appropriate and efficient municipal waste collection service, and 2) proper disposal of the collected waste in a suitable processing or disposal facility.

During the planning and implementation of the first two priorities, those in charge of waste management should also develop occupational health and safety procedures and services for solid waste workers, including not only waste collection and disposal operators but also scavengers.

The only rational way of dealing with the public health aspects in a comprehensive way is to put the health impacts into a strategic planning context for the overall MSWM system. In this way, planning can take due cognisance of causalities and mitigation measures required to prevent the adverse impacts from occurring in the first place. A comprehensive public health impact assessment should be made at the project design stage, either separately or as part of the environmental impact assessment. The process should be repeated every five years to keep track of unforeseen developments and to establish the information base for rational decision-making in the future. In the final analysis, public education and consciousness raising should be the cornerstone of any mitigation effort.

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APPENDIX B. CHARACTERISTICS OF COMPOSTED YARD WASTE

Table B-1. Concentration of soluble metals in yard waste compost (saturated media in mg/kg)

Metal	Site 1[a]	Site 2[b]
Calcium	50	59
Magnesium	16	23
Iron	3.70	3.70
Manganese	0.80	2
Zinc	0.14	0.17
Copper	0.08	0.07
Boron	0.20	0.20
Sulphur	12	6
Sodium	21	31
Aluminium	4.80	3.30

Source: *Portland Area Compost Market Study*, Final Report, prepared by CalRecovery, Inc. for the Metropolitan Service District, Portland, Oregon, October 1988.

[a] One sample.

[b] Average of seven samples.

Table B-2. Concentrations of pathogens found in yard waste compost

Pathogen	Site 1	Site 2
Salmonella	negative	negative
E. coli	$> 1.0 \times 10^3$	$< 1.0 \times 10^4$
Faecal coliform	2.3×10^3	9.3×10^4
Total coliform	1.4×10^3	3.0×10^5
Pseudomonas spp.	positive	positive

Source: *Portland Area Compost Market Study*, Final Report, prepared by CalRecovery, Inc. for the Metropolitan Service District, Portland, Oregon, October 1988.

Note:

1. *Aspergillus fumigatus* (rhizopus and geotrichum found), human parasitic ova, dog parasitic ova, *Entamoeba coli*, *Entamoeba histolytica*, *Ascaris lumbriocoides* (roundworm), *Taenia* spp. (tapeworm), and *Trichuris trichuria* (hookworm) not found in either site.

Table B-3. Nutrient content and other parameters of yard waste compost

Parameter	Units	Site 1	Site 2
Total (Acid Digestion) CEC[a]	meq/100g	26.8	28.2
Nitrogen	%	0.90	0.63
Sulphur	%	0.26	0.20
Phosphorus	%	0.16	0.14
Potassium	%	0.72	0.62
Water Soluble			
Nitrogen	ppm	2.0	< 1.0
Sulphur	ppm	12.0	6.0
Phosphorus	ppm	143[b]	121[c]
Potassium	ppm	3,132[b]	2,604[c]
NH_4-N	ppm	21[b]	20[c]
NO_3-N	ppm	6[b]	4[c]
Bulk Density	kg/m^3	353[b]	431[c]
Moisture Content	%	48.5[b]	48.9[c]
Organic Matter	%	67.3[b]	64.5[c]
pH		7.1[b]	6.7[c]
Specific Conductance	mmho/cm[d]	1.4[b]	1.4[c]
Particle Size			
9.5 mm	% passing	94.2[b]	95.0[c]

Source: *Portland Area Compost Market Study*, Final Report, prepared by CalRecovery, Inc. for the Metropolitan Service District, Portland, Oregon, October 1988.

[a] CEC = cationic exchange capacity, expressed in miliequivalents (meq) exchangeable cations per 100 grams of dry soil.

[b] Average of eight samples.

[c] Average of five samples.

[d] mmho/cm = millimho per centimetre.

APPENDIX C. PERFORMANCE INDICATORS FOR SOLID WASTE SERVICES

A. Generation

A1. DEMOGRAPHIC information

- administrative or political area (area bounded by the administrative boundaries of the municipality in km^2)
- service area (area requiring solid waste management services in km^2)
- total population in the administrative area
- population in the service area
- number of households, commercial establishments, and institutions (e.g., schools, public libraries, religious buildings, hospitals) in the service area
- number of parks and other public places in the service area
- number of markets in the service area
- number of factories in the service area
- length of roads and streets requiring sweeping (km)
- length of drains requiring cleaning (km)

A2. QUANTITIES of waste generated

- household
- commercial/business
- institutional
- park/public
- market
- street sweeping
- drain cleaning
- industrial
- total waste

Generally, waste generation (by source) is expressed in terms of daily wt/unit. Therefore, the indicators presented in the previous paragraph can be expressed as:

- household waste (kg/cap/day)
- commercial waste (kg/x/day, where x can be m^2 of floor area of commercial establishment, unit volume or dollar value in sales, number of employees, etc.)

- institutional waste (kg/x/day, where x can be number of students, m^2 of the area of park or public place, number of visitors, etc.)

- market waste (kg/x/day, where x can be the number of market spaces, m^2 of floor area, dollar in sales, etc.)

- industrial waste (kg/x/day, where x can be unit volume or dollar of production output, m^2 of floor area, number of employees, etc.)

- street sweeping waste (kg/km/day)

- drain cleaning waste (kg/km/day)

- total waste (kg/cap/day)

B. Waste characterisation

B1. PHYSICAL composition (% wet or dry wt basis)

- putrescible matter
- bones
- paper
- plastics
- yard/garden
- wood
- glass
- metals
- rubber and leather
- miscellaneous inert material

B2. CHARACTERISTICS

- moisture content (%)
- bulk density (kg/m^3)
- higher and lower calorific values (kcal/kg)
- chemical composition (N, C, P, Ca, K, etc.)

C. Storage

C1. INDIVIDUAL containers

- type (e.g., bin, bag, basket)
- size or capacity (L)
- material (e.g., plastic, metal, bamboo)
- maintenance condition

- number and location of storage units (on a map)
- cover or lid
- use of standardised containers (%)

C2. COMMUNAL receptacles

- type (e.g., bin, bag, basket)
- size or capacity (L or m^3)
- material (e.g., plastic, metal, wood, bamboo)
- number and location (on a map)
- maintenance condition
- cover or lid
- maximum distance from house (m)
- average lifespan of container

C3. COST

- purchase cost of individual container (cost/ container)
- purchase cost of communal container (cost/ container)
- repair cost of communal container (cost/ container/yr)

D. Collection and transport

D1. SERVICE performance indicators

D1.1. Coverage

Indicators are shown in the following list for household waste only. Similar indicators could apply to the other categories of waste.

- household waste collected (area in km^2 or % of the service area; population or % of the population; number of houses or % of the number of houses; quantity or % of household waste generated in the service area)
- commercial/business waste collected
- institutional waste collected
- park/public place waste collected
- market waste collected
- street sweeping waste collected
- drain cleaning waste collected
- total waste collected

In localities where solid waste is collected and transported by contractors and/or by private individuals or institutions, the following indicators can be used:

- number of contractors
- population or number of houses or establishments served by contractors or by private haulers for each category of waste
- percentage of population or number of houses or establishments served by contractors or by private haulers for each category of waste
- the quantity of waste collected by contractors or private haulers for each category of waste

D1.2. Frequency

Collection frequency varies from more than once a day to once a week, or even less frequently. Indicators relating to collection frequency can be actual collection frequency or the percentage of the actual to the required collection frequency. This information can be arranged according to generators of solid waste as well as types of on-site storage.

D1.3. Complaints

Type and number of complaints made to the solid waste management authority are good indicators of the quality of the service. Some of the types of complaints that can be used are: uncollected waste, odour, flies and insects, spillage during transportation, or complaints about the attitudes of collection workers. The number and type of complaints should be recorded by collection zone.

D2. RESOURCE input indicators

D2.1. Human resources

For each category of staff, the number of workers; the average and total wages (daily, monthly, and annually); and the fringe benefits (e.g., health insurance, pension, paid leave), if any, are the resource input indicators.

- supervisors
- drivers
- collection workers
- street sweepers
- vehicle maintenance workers
- others (e.g., drain cleaners)

D2.2. Physical resources

Examples of the types of equipment are as follows:

- compactor trucks
- dump trucks
- fixed-bed trucks

- tractors
- trailers
- others (e.g., tilt frame vehicles, mechanical sweepers)
- pushcarts
- collection bins/baskets
- brooms

The following information should be collected for each category of equipment:

- number
- type or make
- capacity
- year of purchase
- purchase cost
- amount and cost of fuel consumed
- cost of regular service/maintenance
- cost of repair and spare parts
- average downtime

In situations where private contractors are employed for the collection service, the contractor's human and physical resource inputs and the contractual fees must be recorded.

D3. EFFICIENCY indicators

- weight or volume of solid waste collected daily per dollar of collection cost
- weight or volume of solid waste collected directly by the municipal authority daily per dollar of collection
- weight or volume of solid waste collected daily by contractors per dollar of contractual fees
- population served per collection worker
- population served per vehicle
- households served per collection worker
- length of street swept per sweeper

E. Processing and resource recovery

E1. SERVICE performance indicators

Processing plants can be categorised as follows:

- size reduction
- compaction

- transfer station
- composting
- materials recovery
- incineration

It is suggested that the following indicators be recorded for each facility:

- design capacity (Mg/day)
- amount of waste processed (Mg/day)
- amount of product generated (Mg/day)
- amount of residue generated (Mg/day)
- revenue from sales of products (cost/yr)
- savings due to reduced disposal cost (cost/yr)
- number of complaints by type (e.g., odour, flies and insects, unsightliness)

E2. RESOURCE input indicators

E2.1. Human resources

- plant manager
- engineers
- technicians
- labourers

For each category of human resource, the following indicators should be recorded:

- number
- average and total salaries
- fringe benefits (e.g., health insurance, pension, paid leave)

E2.2. Physical resources

- land
- facilities and equipment
- utilities consumed (electricity, gas, water, etc.)
- spare parts and other materials

Capital, as well as operation and maintenance, costs of these resources should also be recorded as resource input indicators.

In situations where contractors are employed, the contractor's human and physical resources and the contractual fees should be recorded as resource input indicators.

E3. EFFICIENCY indicators

There are a number of efficiency indicators that can be calculated based on the data collected; the following list provides some of the most common ones.

- annual revenue from sales of products per annual total cost
- annual revenue from sales of products, plus annual savings due to reduced disposal cost per annual total cost
- quantity of waste processed per total cost
- quantity of materials recovered per sorter

F. Final disposal

F1. SERVICE performance indicators

The following list provides representative service performance indicators for final disposal facilities:

- total capacity (m^3)
- amount of waste disposed (Mg or m^3/day or /yr)
- remaining capacity (m^3)
- number of complaints by type (e.g., odour, flies, etc.)

F2. RESOURCE input indicators

Human resource inputs can be categorised as:

- plant managers
- engineers
- technicians
- labourers

For each category of human resource, the following indicators should be recorded:

- number
- average and total salaries
- fringe benefits

Physical resources include:

- land
- support facilities (e.g., office, fencing, weigh bridge, garage, surface water diversion system, liners, leachate collection and treatment facilities, landfill gas extraction system, groundwater monitoring wells)
- equipment (e.g., bulldozers, backhoes, compactors)

- electrical power and water supplies

Capital, as well as operation and maintenance, costs for the human and physical resources are also resource input indicators.

In the event that private contractors are employed, their human and physical resources and the contractual fees should be recorded.

F3. EFFICIENCY indicators

The most useful and commonly used efficiency indicator is the unit cost of waste disposed (cost/Mg).

F4. ADMINISTRATIVE indicators

Some of the most common administrative indicators include:

- number of violations (e.g., littering, illegal dumping, requirement for provision of storage containers)

- number of organised public communication activities (e.g., mass-media campaign, exhibitions, community cleanup contests, community meetings, recycling bazaars)

- number of public education activities

- number of participants in each of these activities

APPENDIX D. COSTS OF SOLID WASTE MANAGEMENT TECHNOLOGIES

Before making an investment in an MSW treatment technology, decision-makers must know what costs are entailed. Predicting such costs is possible to some extent, but it is necessary to specify the exact technology under consideration and the circumstances in which it will be used.

Making general comparisons between technologies, to be used as guides across a wide variety of situations, is very difficult. When specifying costs for an MSWM technology, one has to take into account a large range of factors that may vary considerably from one country to another and even within one country.

Definitions can be problematic. For example, in estimating the cost of a municipally sponsored materials recovery program, the specification of what is to be collected, and the method of including (or not including) avoided landfill costs, can have large effects on the estimates of costs. For example, the cost of landfilling depends significantly on conditions at the site chosen and on the methods that will be employed for monitoring and controlling leachate and landfill gas production. As another example, there are many types of vehicles and methods that can be used for waste collection and, consequently, the costs of collection can vary substantially among the alternatives.

When making comparisons among countries, fluctuating (and sometimes overvalued) exchange rates complicate the process of estimating costs. High rates of inflation in many countries make it difficult to consistently translate dollar costs into local costs. Subsidisation or taxation of local or imported inputs into MSWM activities can lead to a significant difference between the simple financial cost of implementing a technology and the real economic cost of doing so.

With the above discussion in mind, it is possible to make some very broad generalisations about MSWM costs. Table D-1 presents estimated costs of some MSWM technologies as a function of income level, i.e., low, middle, and high. High-income levels are associated with highly industrialised regions or countries. Both waste generation rates and costs of solid waste management systems reflect the level of industrial development. The technologies listed in the table are collection, transfer, and sanitary landfill. Also shown in the table are estimates of the cost of solid waste management as a percentage of income. As indicated by the data in the table, the proportion of income spent on MSWM in high-income regions is generally lower than that in low-income regions.

Table D-2 compares the disposal costs of some alternative technologies for large cities, listed approximately in order of increasing cost of disposal.

Table D-1. Costs of solid waste management as a function of income

	Low Income	Middle Income	High Income
Avg. Waste Generation (Mg/cap/yr)	0.1	0.2	0.7
Income (US$/cap/yr)	500	3,000	25,000
Collection cost (US$/Mg)	15 to 40	25 to 75	75 to 150
Transfer cost (US$/Mg)	4 to 10	6 to 20	20 to 25
Sanitary landfill (US$/Mg) (US$/Mg)	5 to 25	15 to 20	30 to 100
Total Cost without Transfer	20 to 65	40 to 95	105 to 250
Total Cost with Transfer	24 to 75	46 to 115	125 to 275
Cost as % of Income	0.4 to 1.6%	0.2 to 0.7%	0.3 to 0.8%

1. Average income values based on selected world development indicators from the World Development Report 2000/2001, published for The World Bank by Oxford University Press.
2. Costs are for owning, operation, maintenance, and debt service in 2002, and assuming no equipment provision through grants.

Table D-2. Disposal costs of alternative technologies for large cities

	Low Income	Middle Income	High Income
Open dumping (US$/Mg)	0.5 to 2	1 to 3	Not applicable
Sanitary landfill (US$/Mg)	5 to 25	15 to 30	30 to 100
Composting (US$/Mg)	5 to 25	15 to 40	30 to 80
Incineration (US$/Mg)	30 to 60 (Note 5)	30 to 80 (Note 4)	70 to 100 (Note 4)

1. The above sanitary landfill costs are for cities of over 500,000 people, or over 250 tonnes/day, in order to capture economies-of-scale. For smaller cities, costs could be higher.
2. The higher range of costs for sanitary landfill is for systems with plastic membrane bottom liners and leachate collection and treatment systems; while the lower range of costs is for natural attenuation landfills, where site conditions do not require leachate management.
3. The higher range of costs for composting is for systems with mechanised classification, pulverisation, and forced aeration, while the lower range of costs is for systems with hand sorting, trommel screening, and simple turned windrows.
4. The higher range of costs for incineration is for systems with modern air pollution control and ash handling systems, while the lower range of costs is for systems with limited air pollution control equipment and no specialised ash handling equipment.
5. Limited air pollution control equipment and no specialised ash handling.

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GLOSSARY

Aerobic composting - a method of composting organic wastes using bacteria that need oxygen. This requires that the waste be exposed to air, either via turning or by forcing air through perforated pipes that pass through the material.

Anaerobic digestion - a method of composting that does not require oxygen. This composting method produces methane. Also known as anaerobic composting.

Ash - the non-combustible, solid byproducts of incineration or other combustion process.

Autoclaving - sterilisation via a pressurised, high-temperature steam process.

Baghouse - a combustion plant emission control device that consists of an array of fabric filters through which flue gases pass in an incinerator flue. Particles are trapped and thus prevented from passing into the atmosphere.

Basel Convention - an international agreement on the control of transboundary movements of hazardous wastes and their disposal, drawn up in March 1989 in Basel, Switzerland, with over 100 countries as signatories.

Biodegradable material - any organic material that can be broken down by microorganisms into simpler, more stable compounds. Most organic wastes (e.g., food, paper) are biodegradable.

Bottom ash - relatively coarse, non-combustible, generally toxic residue of incineration that accumulates on the grate of a furnace.

Bulky waste - large wastes, such as appliances, furniture, and trees and branches, that cannot be handled by normal MSW processing methods.

Cell - the basic unit by which a landfill is developed. It is the general area where incoming waste is tipped, spread, compacted, and covered.

Cleaner production - processes designed to reduce the wastes generated by production.

Co-disposal - the disposal of different types of waste in one area of a landfill or dump. For instance, sewage sludges may be disposed of with regular solid wastes.

Cogeneration - production of both electricity and steam from one facility, from the same fuel source.

Collection - the process of picking up wastes from residences, businesses, or a collection point, loading them into a vehicle, and transporting them to a processing, transfer, or disposal site.

Combustibles - burnable materials in the waste stream, including paper, plastics, wood, and food and garden wastes.

Combustion - in MSWM, the burning of materials in an incinerator.

Commingled - mixed recyclables that are collected together after having been separated from mixed MSW.

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Communal collection - a system of collection in which individuals bring their waste directly to a central point, from which it is collected.

Compactor vehicle - a collection vehicle using high-power mechanical or hydraulic equipment to reduce the volume of solid waste.

Composite liner - a liner system for a landfill consisting of an engineered soil layer and a synthetic sheet of material.

Compost - the material resulting from composting. Compost, also called humus, is a soil conditioner.

Composting - biological decomposition of solid organic materials by bacteria, fungi, and other organisms into a soil-like product.

Construction and demolition debris -waste generated by construction and demolition of buildings, such as bricks, concrete, drywall, lumber, miscellaneous metal parts and sheets, packaging materials, etc.

Controlled dump - a planned landfill that incorporates to some extent some of tile features of a sanitary landfill: siting with respect to hydrogeological suitability, grading, compaction in some cases, leachate control, partial gas management, regular (not usually daily) cover, access control, basic recordkeeping, and controlled scavenging.

Curing - allowing partially composted materials to reside in a pile for a specified period of time as part of the maturing process in composting.

Disposal - the final handling of solid waste, following collection, processing, or incineration. Disposal most often means placement of wastes in a dump or a landfill.

Diversion rate - the proportion of waste material diverted for recycling, composting, or reuse and away from landfilling.

Drop-off centre - an area or facility for receiving compostables or recyclables that are dropped off by waste generators.

Dump - see *Controlled dump* and *Open dump.*

Emissions - gases released into the atmosphere.

Energy recovery - the process of extracting useful energy from waste, typically from the heat produced by incineration or via methane gas from landfills.

Environmental impact assessment (EIA) -an evaluation designed to identify and predict the impact of an action or a project on the environment and human health and well being. Can include risk assessment: as a component, along with economic and land use assessment.

Environmental risk assessment (EnRA) - an evaluation of the interactions of agents, humans, and ecological resources. Comprised of human health risk assessment and ecological risk assessment, typically evaluating the probabilities and magnitudes of harm that could come from environmental contaminants.

Fabric filter - see *Baghouse.*

Flaring - the burning of landfill gas/methane captured and emitted from collection pipes at a landfill.

Fluidised-bed incinerator - a type of incinerator in which the stoker grate is replaced by a bed of limestone or sand that can withstand high temperatures. The heating of the bed and the high air velocities used cause the bed to bubble, which gives rise to the term "fluidised".

Fly ash - the highly toxic particulate matter captured from the flue gas of an incinerator by the air pollution control system.

Garbage - in everyday usage, refuse in general. Some MSWM manuals use garbage to mean "food wastes", although this usage is not common.

Groundwater - water beneath the earth's surface that fills underground pockets (known as aquifers), supplying wells and springs.

Hazardous waste - waste that is reactive, toxic, corrosive, or otherwise dangerous to living things and/or the environment. Many industrial byproducts are hazardous.

Heavy metals - metals of high atomic weight and density, such as mercury, lead, and cadmium, that are toxic to living organisms.

Household hazardous waste - products used in residences, such as paints and some cleaning compounds, that are toxic to living organisms and/or the environment.

Humus - the end product of composting, also called compost.

Incineration - the process of combusting solid waste under controlled, approximately stoichiometric conditions to reduce its weight and volume, and often to produce energy.

Informal sector - the part of an economy that is characterised by private, usually small-scale, labour-intensive, largely unregulated, and unregistered manufacturing or provision of services.

Inorganic waste - waste composed of material other than plant or animal matter, such as sand, dust, glass, and many synthetics.

Integrated solid waste management - coordinated use of a set of waste management methods, each of which can play a role in an overall MSWM plan.

International NGO - an organisation that has an international headquarters and branches in major world regions, often with the purpose of undertaking development assistance.

In-vessel composting - composting in an enclosed vessel or drum with a controlled internal environment, mechanical mixing, and aeration.

Itinerant waste buyer - a person who moves around the streets buying (or bartering for) reusable and recyclable materials.

Kerbside collection - collection of compostables, recyclables, or trash at the edge of a sidewalk in front of a residence or shop.

Landfill gases - gases arising from the decomposition of organic wastes; principally methane, carbon dioxide, and hydrogen sulphide. Such gases may cause explosions at landfills.

Landfilling - the final disposal of solid waste by placing it in a controlled fashion in a place intended to be permanent. The term is applied to both controlled dumps and sanitary landfills.

Leachate - liquid (which may be partly produced by decomposition of organic matter) that has seeped through a landfill or a compost pile and has accumulated bacteria and other possibly harmful dissolved or suspended materials. If uncontrolled, leachate can contaminate both groundwater and surface water.

Leachate pond - a pond or tank constructed at a landfill to receive the leachate from the area. Usually the pond is designed to provide some treatment of the leachate, by allowing settlement of solids or by aeration to promote biological processes.

Lift - the completed layer of compacted waste in a cell at a landfill.

Liner - a protective layer, made of soil and/or synthetic materials, installed along the bottom and sides of a landfill to prevent or reduce the flow of leachate into the environment.

Manual landfill - a landfill in which most operations are carried out without the use of mechanised equipment.

Market waste - primarily organic waste, such as leaves, skins, and unsold food, discarded at or near food markets.

Massburn incinerator - a type of incinerator in which solid waste is burned without prior sorting or processing.

Materials recovery - obtaining materials that can be reused or recycled.

Materials recovery facility (MRF) - a facility for separating commingled recyclables by manual or mechanical means. Some MRFs are designed to separate recyclables from mixed MSW. MRFs then bale and market the recovered materials.

Methane - an odourless, colourless, flammable, explosive gas, CH_4, produced by anaerobically decomposing MSW at landfills.

Microenterprise - a synonym for small-scale enterprise: a business, often family-based or a cooperative, that usually employs fewer than ten people and may operate “informally”.

Mixed waste - unsorted materials that have been discarded into the waste stream.

Modular incinerator - a relatively small type of prefabricated solid waste combustion unit.

Monofill - a landfill intended for one type of waste only.

MSW - municipal solid waste.

MSWM - municipal solid waste management.

Municipal solid waste - all solid waste generated in an area except industrial and agricultural wastes. Sometimes includes construction and demolition debris and other special wastes that may enter the municipal waste stream. Generally excludes hazardous wastes, except to the extent that they enter the municipal waste stream. Sometimes defined to mean all solid wastes that a city authority accepts responsibility for managing in some way.

Municipal solid waste management - planning and implementation of systems to handle MSW.

NGO – Non-governmental organisation. May be used to refer to a range of organisations, from small community groups, through national and international organisations. Frequently these are not-for-profit organisations.

Nightsoil - human excreta.

NIMBY - "Not In My Back Yard". An expression of resident opposition to the siting of a solid waste facility based on the particular location proposed.

Open dump - an unplanned "landfill" that incorporates few if any of the characteristics of a controlled landfill. There is typically no leachate control, no access control, no cover, no management, and many scavengers.

Organic waste - technically, waste containing carbon, including paper, plastics, wood, food wastes, and yard wastes. In practice in MSWM, the term is often used in a more restricted sense to mean material that is more directly derived from plant or animal sources, and which can generally be decomposed by microorganisms.

Pathogen - an organism capable of causing disease.

Pollution - the contamination of soil, water, or the atmosphere by the discharge of waste or other offensive materials.

Post-consumer materials - materials that a consumer has finished using, which the consumer may sell, give away, or discard as wastes.

Primary material - a commercial material produced from virgin materials used for the manufacture of basic products. Examples include wood pulp, iron ore, and silica sand.

Privatisation - a general term referring to a range of contracts and other agreements that transfer the provision of some services or production from the public sector to private firms or organisations.

Processing - preparing MSW materials for subsequent use or management, using processes such as baling, magnetic separation, crushing, and shredding. The term is also sometimes used to mean separation of recyclables from mixed MSW.

Producer responsibility - a system in which a producer of products or services takes responsibility for the waste that results from the products or services marketed, by reducing materials used in production, making repairable or recyclable goods, and/or reducing packaging.

Putrescible - subject to decomposition or decay. Usually used in reference to food wastes and other organic wastes that decay quickly.

Pyrolysis - chemical decomposition of a substance by heat in the absence of oxygen, resulting in the production of various hydrocarbon gases and carbon-like residue.

Recyclables - items that can be reprocessed into feedstock for new products. Common examples are paper, glass, aluminium, corrugated cardboard, and plastic containers.

Recycling - the process of transforming materials into raw materials for manufacturing new products, which may or may not be similar to the original product.

Refuse - a term often used interchangeably with solid waste.

Refuse-derived fuel (RDF) – solid fuel produced from MSW that has undergone processing. Processing can include separation of recyclables and non-combustible materials, shredding, size reduction, and pelletizing.

Resource recovery - the extraction and utilisation of materials and energy from wastes.

Reuse - the use of a product more than once in its original form, for the same or a new purpose.

Rubbish - a -general term for solid waste. Sometimes used to exclude food wastes and ashes.

Sanitary landfill - an engineered method of disposing of solid waste on land, in a manner that meets most of the standard specifications, including sound siting, extensive site preparation, proper leachate and gas management and monitoring, compaction, daily and final cover, complete access control, and recordkeeping.

Scavenger - a person who picks out recyclables from mixed waste wherever it may be temporarily accessible or disposed of.

Scrubber - emission control device in an incinerator, used primarily to control acid gases, but also to remove some heavy metals.

Secondary material- a material recovered from post-consumer wastes for use in place of a primary material in manufacturing a product.

Secure landfill - a disposal facility designed to permanently isolate wastes from the environment. This entails burial of the wastes in a landfill that includes clay and/or synthetic liners, leachate collection, gas collection (in cases where gas is generated), and an impermeable cover.

Septage - sludge removed from a septic tank (a chamber that holds human excreta).

Setout container - a box or bucket used for residential waste that is placed outside for collection.

Sewage sludge - a semi-liquid residue that settles to the bottom of canals and pipes carrying sewage or industrial wastewaters, or in the bottom of tanks used in treating wastewaters.

Site remediation - treatment of a contaminated site by removing contaminated solids or liquids or treating them onsite.

Source reduction - the design, manufacture, acquisition, and reuse of materials so as to minimise the quantity and/or toxicity of' waste produced.

Source separation - setting aside of compostable and recyclable materials from the waste stream before they are collected with other MSW, to facilitate reuse, recycling, and composting.

Special wastes - wastes that are ideally considered to be outside of the MSW stream, but which sometimes enter it and must often be dealt with by municipal authorities. These include household hazardous waste, medical waste, construction and demolition debris, war and earthquake debris, tires, oils, wet batteries, sewage sludge, human excreta, stoichiometric-condition slaughterhouse waste, and industrial waste. In combustion chemistry, the condition whereupon the quantity of oxygen provided to the combustion process is exactly that needed to completely oxidise all carbon in the fuel to carbon dioxide.

Subsidy - direct or indirect payment from government to businesses, citizens, or institutions to encourage a desired activity.

Tipping fee - a fee for unloading or dumping waste at a landfill, transfer station, incinerator, or recycling facility.

Tipping floor - unloading area for vehicles that are delivering MSW to a transfer station, processing facility, or incinerator.

Transfer - the act of moving waste from a collection vehicle to a larger transport vehicle.

Transfer point - a designated point, often at the edge of a neighbourhood, where small collection vehicles transfer waste to larger vehicles for transport to disposal sites.

Transfer station - a major facility at which MSW from collection vehicles is consolidated into loads that are transported by larger trucks or other means to more distant final disposal facilities, typically landfills.

Transition countries - the countries of Eastern Europe and the former Soviet Union that are in various stages of restructuring their economies. The changes involve a move away from being substantially state-run toward a variety of new configurations, ranging from moderate economic liberalisation to a significant dismantling of the state's role in the economy.

Vectors - organisms that carry disease-causing pathogens. At landfills, rodents, flies, and birds are the main vectors that spread pathogens beyond the landfill site.

Vermiculture - see *Worm culture*.

Virgin materials - any basic material for industrial processes that has not previously been used, for example, wood pulp trees, iron ore, crude oil, bauxite.

Waste characterisation study - an analysis of samples from a waste stream to determine its composition.

Waste collector - a person employed by a local authority or a private firm to collect waste from residences, businesses, and community bins.

Waste dealer - an intermediary who buys recyclable materials from waste generators and itinerant buyers and sells them, after sorting and some processing, to wholesale brokers or recycling industries.

Waste management hierarchy - a ranking of waste management operations according to their environmental or energy benefits. The purpose of the waste management hierarchy is to make waste management practices as environmentally sound as possible.

Waste picker – see *Scavenger*.

Waste reduction - all means of reducing the amount of waste that is produced initially and that must be collected by solid waste authorities. This ranges from legislation and product design to local programs designed to keep recyclables and compostables out of the final waste stream.

Waste stream - the total flow of waste from a community, region, or facility.

Waste-to-energy (WTE) plant - a facility that uses solid waste materials (processed or raw) to produce energy. WTE plants include incinerators that produce steam for district heating or industrial use, or that generate electricity; they also include facilities that convert landfill gas to electricity.

Water table - level below the earth's surface at which the ground becomes saturated with water.

Wetland - an area that is regularly wet or flooded and has a water table that stands at or above the land surface for at least part of the year.

Windrow - an elongated pile of aerobically composting materials that are turned periodically to expose the materials to oxygen and to control the temperature to promote biodegradation.

Working face - the length and width of the area in which waste is being deposited at a landfill. Also known as the tipping face.

Worm castings - the material produced from the digestive tracts of worms as they live in earth or compost piles. The castings are rich in nitrates, potassium, phosphorus, calcium, and magnesium.

Worm culture - a relatively cool, aerobic composting process that uses worms and microorganisms. Also known as vermiculture.

Yard waste - leaves, grass clippings, prunings, and other natural organic matter discarded from yards and gardens.

About CalRecovery, Inc.

CalRecovery, Inc. was established in California, USA in 1975 to provide services in waste management and the production and use of non-conventional sources of energy to public and private entities. The range of services includes: project management, field test evaluations, technical assistance, research and development, conduct of feasibility studies, preparation of master plans, and system design and implementation with emphasis on resource recovery and waste diversion from landfills. CalRecovery has an international clientele, having performed work in more than 40 countries in most regions of the world. Additionally, the company is proud to have been amongst the first few entities to have worked with NASA on the management of solid waste in space.

In addition to the sound experience in developing countries, CalRecovery has a multi-disciplinary staff capable of working on a variety of tasks, from training to financial analyses and public participation. Members of CalRecovery devote a considerable amount of their time to providing formal and informal education and training at various universities and other institutions throughout the world.

Over the years, the firm has been involved in projects involving the technologies of waste minimization, source separation, composting, recycling, energy recovery, and landfill disposal. Based on the extensive experience from working in many industrialized and developing countries, members of CalRecovery typically combine methods and solutions that are practical and cost-effective, under a wide range of social, political, and economic conditions.

The firm is a leader in integrating solid waste management systems with other key community services such wastewater treatment and power production aimed at maximum waste minimization and the optimization resource recovery. CalRecovery is well-versed in waste characterization. The company has an extensive database on the characteristics of solid wastes from many countries around the world, as well as basic design data on many solid waste treatment facilities in a variety of countries.

Other pertinent titles by members of CalRecovery include:

- *Organic Wastes for Fuel and Fertilizer in Developing Countries* (1980)
- *Resource Recovery from Municipal Solid Wastes,* Volumes I and II (1982)
- *Unit Operations Models for Solid Waste Processing* (1986)
- *Handbook of Solid Waste Properties* (1993)
- *Material Recovery Facility Design Manual* (1993)
- *Recycling Equipment and Technology for Municipal Solid Waste: Material Recovery Facilities* (1993)
- *Composting and Recycling Municipal Solid Waste* (1993)
- *Material Recovery Facility Design Manual* (1993)
- *Guidance for Landfilling Waste in Economically Developing Countries* (1998)
- *Modern Composting Technologies* (2005)

For additional information, please refer to www.calrecovery.com

About the UNEP Division of Technology, Industry and Economics

The UNEP Division of Technology, Industry and Economics (DTIE) helps governments, local authorities and decision-makers in business and industry to develop and implement policies and practices focusing on sustainable development.

The Division works to promote:

> sustainable consumption and production,
> the efficient use of renewable energy,
> adequate management of chemicals,
> the integration of environmental costs in development policies.

The Office of the Director, located in Paris, coordinates activities through:

> The International Environmental Technology Centre - IETC (Osaka, Shiga), which implements integrated waste, water and disaster management programmes, focusing in particular on Asia.

> Production and Consumption (Paris), which promotes sustainable consumption and production patterns as a contribution to human development through global markets.

> Chemicals (Geneva), which catalyzes global actions to bring about the sound management of chemicals and the improvement of chemical safety worldwide.

> Energy (Paris), which fosters energy and transport policies for sustainable development and encourages investment in renewable energy and energy efficiency.

> OzonAction (Paris), which supports the phase-out of ozone depleting substances in developing countries and countries with economies in transition to ensure implementation of the Montreal Protocol.

> Economics and Trade (Geneva), which helps countries to integrate environmental considerations into economic and trade policies, and works with the finance sector to incorporate sustainable development policies.

UNEP DTIE activities focus on raising awareness, improving the transfer of knowledge and information, fostering technological cooperation and partnerships, and implementing international conventions and agreements.

For more informtaion,
see **www.unep.fr**

This publication looks at the use of technologies that are environmentally sound for managing municipal solid wastes in developing countries.
It is designed as a sourcebook on solid waste management, covering a multitude of topics including the principles of solid waste management, processing and treatment, and final disposal. It also covers key non-technical aspects, and offers regional overviews on SWM.

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