Part I

Principles of Municipal Solid Waste Management

CHAPTER I. INTRODUCTION

A. Definition of developmental status

The status of development of a country may be categorised in several ways. With respect to its impact on solid waste management, in this publication status of development is categorised on the basis of availability of economic resources and on degree of industrialisation. Status of economic development is more a measure of the permanent economic framework than of the existing condition of the economy (recession vs. prosperity). In this document, the emphasis is on solid waste management in a setting that is primarily non-industrial. Such management is adapted to the nature and quantities of waste generated and to the availability of technology for handling and processing characteristic of non-industrial settings. Degree of industrialisation is measured in terms of extent of mechanisation and availability of technological resources. Justifiably or not, the terms "developed" and "industrialised" occasionally are used synonymously.

Because of localised changes in degree of development within each country, it is difficult to apply a single developmental category as far as solid waste management is concerned. For example, a large urban community (typically the capital city and surrounding area) in a developing nation may be in a stage of development that is well above that of the rest of the nation. On the other hand, these communities are not entirely immune to the limitations imposed by the status of the nation.

In this document, the authors have made an effort to incorporate in each section a range of coverage that encompasses the range of development that is typically found in economically developing nations without resorting to repetitive descriptions of technologies that do not vary substantially with scale of operation or degree of sophistication.

It is important to note that although the information presented in this document is applicable primarily to developing countries, some of it may also be applicable to a nation in transition or even to a developed or industrialised nation.

B. Characteristics of solid waste in developing countries

"Municipal solid waste" (MSW) is a term usually applied to a heterogeneous collection of wastes produced in urban areas, the nature of which varies from region to region. The characteristics and quantity of the solid waste generated in a region is not only a function of the living standard and lifestyle of the region's inhabitants, but also of the abundance and type of the region's natural resources. Urban wastes can be subdivided into two major components -- organic and inorganic. In general, the organic components of urban solid waste can be classified into three broad categories: putrescible, fermentable, and non-fermentable. Putrescible wastes tend to decompose rapidly and unless carefully controlled, decompose with the production of objectionable odours and visual unpleasantness. Fermentable wastes tend to decompose rapidly, but without the unpleasant accompaniments of putrefaction. Non-fermentable wastes tend to resist decomposition and, therefore, break down very slowly. A major source of putrescible waste is food preparation and consumption. As such, its nature varies with lifestyle, standard of living, and seasonality of foods. Fermentable wastes are typified by crop and market debris.

The primary difference between wastes generated in developing nations and those generated in industrialised countries is the higher organic content characteristic of the former. The extent of the difference is indicated by the data in Table I-1, in which is presented information relative to the quantity and composition of municipal solid wastes generated in several countries.

Table I-1. Comparison of solid waste characterisation worldwide (% wet wt)

Location	Putres -cibles	Paper	Metals	Glass	Plastics, Rubber, Leather	Tex-tiles	Ceramics, Dust, Stones	Wt (g)/ cap/ day
Bangalore, India [1]	75.2	1.5	0.1	0.2	0.9	3.1	19.0	400
Manila, Philippines [2]	45.5	14.5	4.9	2.7	8.6	1.3	27.5	400
Asunción, Paraguay [2]	60.8	12.2	2.3	4.6	4.4	2.5	13.2	460
Seoul, Korea [3]	22.3	16.2	4.1	10.6	9.6	3.8	33.4[a]	2,000[a]
Vienna, Austria [4]	23.3	33.6	3.7	10.4	7.0	3.1	18.9[b]	1,180
Mexico City, Mexico [5]	59.8[c]	11.9	1.1	3.3	3.5	0.4	20.0	680
Paris, France [4]	16.3	40.9	3.2	9.4	8.4	4.4	17.4	1,430
Australia [7]	23.6	39.1	6.6	10.2	9.9		9.0	1,870
Sunnyvale, California, USA [6]	39.4[d]	40.8	3.5	4.4	9.6	1.0	1.3	2,000
Bexar County, Texas, USA [6]	43.8[d]	34.0	4.3	5.5	7.5	2.0	2.9	1,816

[a] Includes briquette ash (average).
[b] Includes "all others".
[c] Includes small amounts of wood, hay, and straw.
[d] Includes garden waste.

Wastes generated in countries located in humid, tropical, and semitropical areas usually are characterised by a high concentration of plant debris; whereas those generated in areas subject to seasonal changes in temperature or those in which coal or wood are used for cooking and heating may contain an abundance of ash. The concentration of ash may be substantially higher during winter. Regardless of climatic differences, the wastes usually are more or less contaminated with nightsoil. These differences prevail even in wastes generated in large metropolitan areas of a developing country.

Ideally, solid waste should not contain faecal matter or urine, and the mixing of these materials with household waste should be prohibited by law. However, enforcement difficulties, combined with variations in way of life, necessitate some tolerance in this matter. Solid waste collection in a manner satisfactory with respect to environmental health is made difficult when human excretory wastes are mixed with household wastes. Handling of pathological wastes, abattoir wastes, industrial wastes, and similar materials, in association with household wastes, also should not be permitted. Nevertheless, it is important to keep in mind that despite all precautions, some pathogens and chemical residues inevitably will be present in the waste.

C. Importance of a sound solid waste management program

In an attempt to accelerate the pace of its industrial development, an economically developing nation may fail to pay adequate attention to solid waste management. Such a failure incurs a severe penalty at a later time in the form of resources needlessly lost and a staggering adverse impact on the environment and on public health and safety. The penalty is neither avoided nor lessened by a resolve to do something about the waste at a later time, when the country may be in a better position to take appropriate measures. This is true because, as is indicated by the data in Table I-1, the rate of waste generation generally increases in direct proportion to that of a nation's advance in development. Nor is the penalty lessened by the faulty rationalisation that advances in developmental status have higher priority than maintenance of a liveable environment. The greater the degradation of the environment, the greater is the effort required to restore its good quality. In summary, the effort to preserve or enhance environmental quality should at least be commensurate with that afforded to the attainment of advance in development.

C1. ENVIRONMENTAL and health impacts

The organic fraction of MSW is an important component, not only because it constitutes a sizable fraction of the solid waste stream in a developing country, but also because of its potentially adverse impact upon public health and environmental quality. A major adverse impact is its attraction of rodents and vector insects for which it provides food and shelter. Impact on environmental quality takes the form of foul odours and unsightliness. These impacts are not confined merely to the disposal site. On the contrary, they pervade the area surrounding the site and wherever the wastes are generated, spread, or accumulated.

Unless an organic waste is appropriately managed, its adverse impact will continue until it has fully decomposed or otherwise stabilised. Uncontrolled or poorly managed intermediate decomposition products can contaminate air, water, and soil resources.

C2. EPIDEMIOLOGICAL studies

Studies have shown that a high percentage of workers who handle refuse, and of individuals who live near or on disposal sites, are infected with gastrointestinal parasites, worms, and related organisms [8]. Contamination of this kind is likely at all points where waste is handled.

Although it is certain that vector insects and rodents can transmit various pathogenic agents (amoebic and bacillary dysenteries, typhoid fever, salmonellosis, various parasitoses, cholera, yellow fever, plague, and others), it often is difficult to trace the effects of such transmission to a specific population.

Due to the implementation of modern solid waste management practices, both the public health and the quality of the environment are benefited directly and substantially.

A modern solid waste management program can be implemented for a reasonable cost. This is an important fact because there are ample known situations where solid waste management costs in developing countries are high and the level of service low. But, if the underlying reasons for these situations are analysed, then one can see in many cases that cost-effective waste management systems would result if the identified deficiencies in the systems were remedied.

For example, in some developing countries, municipalities spend a disproportionate amount of financial resources on certain solid waste services, in particular waste collection and sweeping. In the past, a common approach to curing poor service provision was to simply expend more capital (e.g., the acquisition of additional equipment, design and construction of facilities, etc.) without also addressing and remedying inefficiencies inherent in the system. Unfortunately, high capital investment in the solid waste management sector in many developing countries does not necessarily lead to improvements in the quality of service. On the other hand, substantial improvements can be achieved in many cases by making low-cost, or sometimes no-cost, modifications in the existing system, with the focus being on increasing system efficiencies. Examples of such improvements are the efficient design of collection routes, modifications in the collection vehicles, reductions in equipment downtime, and public education, (e.g., education and communication leading to the production of less waste and the reduction of litter).

D. Recovery and utilisation of resources

For several reasons, resource recovery is a major element in solid waste management in developing nations. Reclaimable inorganic components (metals, glass, plastic, textiles, and others) traditionally have been recovered mostly by way of unregulated manual scavenging by private individuals (typically known as the "informal" sector). In recent years, the trend is to formalise and mechanise scavenging through the establishment of material recovery facilities (MRFs) [6]. Reuse and recovery of the inorganic components of the waste stream is an important aspect of waste management.

Special attention is given to organic (biodegradable) residues since, in the majority of developing countries, these residues constitute at least 50% of the waste (by weight). The resource recovery aspect regarding the organic component is threefold:

1. The component can be used in agriculture as a soil amendment through composting.

2. Its energy content can be recovered either biologically or thermally. Biological energy recovery is by way of methane production through anaerobic digestion. Thermal recovery is by way of combustion to produce heat.

3. The organic content can be hydrolysed either chemically or enzymatically to produce a sugar. The sugar can be used as a substrate for ethanol fermentation or for single-cell protein production.

Of the three applications, use in agriculture is the most practical. Although dating back many years, methane production ("biogasification") has only recently begun to receive serious attention as a potential alternative source of energy. Many hurdles, primarily economic in nature, must be surmounted before either single-celled protein production or ethanol fermentation become a practical reality.

An accurate knowledge of the quantity and composition of the waste input is essential to the success of a resource recovery undertaking. The composition and constancy of the amount of the input must be assured. Obviously, it would be sheer foolishness to attempt an operation of any practical size without having an assured supply of raw material. Not only must the constancy of the supply be assured, it must always be available at a reasonable cost. Additional requirements are adequate economic and qualified human resources.

As far as economically developing nations are concerned, with rare exception, adequate economic resources would preclude processes such as hydrolysis and perhaps large-scale anaerobic digestion in a reactor. These processes depend upon relatively expensive sophisticated equipment. On the other hand, composting can range from the composting carried out by individual homeowners to that undertaken by municipalities. Equipment for composting need not be sophisticated.

Last but not least, the availability, size, and continuity of a market or some form of demand for the reclaimed resource must be determined, lest recycling become merely a prelude to landfilling.

E. Scope and organisation of the book

The book is organised into two volumes. In Volume I, it is further divided into four parts, four appendices, and a bibliography and glossary. The contents of each of the four parts are summarised below:

- Part I deals with the principles of solid waste management. Including the Introduction, it consists of five chapters that collectively cover framework for management of solid waste, waste quantity and characteristics, storage and collection, and street cleaning.

- Part II deals with processing and treatment. The eight chapters include recycling, agricultural utilisation of the organic components, and biological and thermal recovery of energy. Composting is explored in detail.

- Part III is concerned with final disposal. Its single chapter covers sanitary landfilling.

- Part IV consists of four chapters and deals with non-technological matters: regulatory and economic instruments, financial aspects, policy alternatives, and management information systems (MIS).

The appendices of the publication include supporting and additional information related to public health, compost characteristics, performance indicators, and costs of solid waste management technologies.

Volume II describes solid waste management in several geographical regions around the world, and provides contact information for each region. *Volume II is included on a CD in the inside cover of Volume I.*

Thus, the publication covers the principal elements of solid waste management planning and implementation that would be appropriate for developing nations. Both non-technical and technical issues are discussed in detail since the planning and implementation of solid waste management systems necessarily involves an understanding of both sets of issues. Since the waste stream in developing countries is largely organic in nature, use of organic waste in agriculture and composting receive considerable attention.

The primary emphasis of this book is on the management of solid waste in an urban setting. The urban setting may be a small municipality, any intermediate size community, or a large metropolitan area. In some cases, technological aspects could be extrapolated to rural settings.

The publication is directed toward individuals who are responsible for solid waste management or have a significant role in it. The intent is to acquaint such individuals with available options and to supply background information needed to arrive at decisions that are in keeping with the country's cultural, economic, and technological conditions. Consequently, the information is geared more toward decision-making than to detailed engineering design of specific facilities at particular places. Detailed engineering design demands input by competent professionals specifically well versed in solid waste management and in sympathy with the special needs of the community seeking their professional aid. This is particularly true when the scale of a project exceeds a few tons of waste per day. Although detailed engineering design is not the focus of this publication, for many of the technical subjects covered in the publication, fundamental scientific and engineering principles are described. Consequently, the reader is exposed to the basic relationships between performance and operating conditions and can use the basic principles to analyse solid waste management systems based on a particular set of circumstances.

As the Introduction comes to a close, the authors would like to emphasise that the management of solid wastes is a difficult problem that need not be made more difficult by unnecessarily using complex (high)-technology. The avoidance of unnecessary high technology is critical to successful solid waste management in the low technology economies of developing nations. Importation of complex equipment and technology should be kept to a minimum. Too frequently, a technology that may be considered low technology and readily applicable in one country may be too sophisticated and otherwise unacceptable in the country doing the importing. This statement applies not only to methods of disposal but also to the collection of wastes and even to the devices for storing them.

F. References

1. Nath, K.J., "Solid Waste Management in the Present Indian Perspective", proceedings of ISWA 1993 Annual Conference, Jönköping, Sweden, September 1993.

2. Diaz, L.F. and C.G. Golueke, "Solid Waste Management in Developing Countries", *BioCycle*, 26:46-52, September 1985.

3. Japan International Cooperation Agency, *Master Plan and Feasibility Study on Seoul Municipal Solid Waste Management System in the Republic of Korea*, Draft Final Report, Tokyo, Japan, 1985.

4. Scharff, C. and G. Vogel, "A Comparison of Collection Systems in European Cities", *Waste Management & Research*, 12(5), October 1994.

5. CalRecovery, Inc., *Criterio de Diseño - Planta de Selección y Recuperación de Subproductos de los Residuos Sólidos Municipales*, prepared for Mexico City, Mexico, December 1992.

6. CalRecovery, Inc., *Handbook of Solid Waste Properties*, Governmental Advisory Associates, Inc., New York, New York, USA, 1993.

7. Morwood, R., "Australian Waste Management - Towards 2000", *Proceedings of 32nd Annual International Solid Waste Exposition*, SWANA, San Antonio, Texas, USA, August 1994.

8. Cal Recovery Systems, Inc., Norconsult A.S., and Engineering-Science, *Metro Manila Solid Waste Management Study - Review of Existing Conditions*, May 1982.