AMOUNTS AND COMPOSITION OF MUNICIPAL SOLID WASTES

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Keywords: solid wastes, hazardous wastes, pollution, quantity, composition, management, generation, classification, collection, transportation, transfer, recovery, recycle, reuse, treatment, disposal, reduction.

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Summary

Municipal solid waste (MSW) includes solid or semi-solid materials that a possessor, in residential, institutional or commercial establishment, no longer considers of sufficient value to retain. Improper management of MSW by a community can have a significant impact on human health and the environment. For this reason, all the information on solid wastes, especially the sources, quantity and composition, are vital to the design and operation of the functional elements associated with the management of solid wastes. These elements include waste generation, storage, collection, processing, recycling and reuse, treatment, and final disposal.

This chapter introduces the reader to the measures and methods used to quantify solid waste amounts; the materials balance approach for estimating solid waste quantities; and some factors affecting waste generation rates. In addition, a detailed discussion of the composition of solid wastes is also provided along with some MSW activities in the world. With this information on hand a community should be in a position to prepare for the next level of challenges, including:

- Planning MSW minimization/reduction;
- Evaluating current recycling programs if applicable;
- Setting new recycling programs;
- Designing future solid waste facilities; and
- Moving toward sustainable development.

1. Introduction

One of the most important activities in solid waste management is to determine the quantity and characteristics of the MSW. A community needs to know how much solid waste is generated and how fast it generates in the area so that they can assess their current and future needs in budgeting, operation and processing and disposal facilities. They can use the characteristic data to design processing equipment. In the case of composting, information on the biodegradable fraction of the solid waste becomes important. In the U.S.A, many cities have been conducting waste characterization studies for a number of years. However, such study can be resource intensive because it can involve large numbers of waste sources and waste samples. To facilitate the study, a review of the existing information would definitely be needed; this includes solid wastes management planning documents, waste management records, and other pertinent information from local governments/communities. If there are no existing documents, an extensive fieldwork and effort may be required to establish a baseline.

2. Sources of MSW

A basic knowledge of the sources and types of solid wastes is needed in the evaluation of composition and generation rates of MSW Sources of MSW in a community are related to many aspects of residential units. The categories are listed in Table 1.

Source	typical facilities, activities, or locations where wastes are generated	types of solid wastes
Residential	single family and multifamily detached dwellings low-, medium- and high-rice apartments, etc	food waste, paper, cardboard, plastics, textiles, leather, yard wastes, wood glass, tin cans, aluminum, other metals ashes, street leaves, special wastes, household hazardous wastes
Commercial	stores, restaurants markets, office building, hotels, motel, print shops service, stations auto repair shops, etc.	paper, cardboard, plastics, wood, food, waste, glass, metals, special wastes, hazardous wastes, etc
Institutional	Schools, hospitals, prisons,	as above in commercial

	govern-mental centers	
Municipal Services	street cleaning, landscaping, catch basin cleaning, parks and beaches, other recreational areas	special wastes, rubbish, street sweepings, landscape and tree trimmings, catch basin debris, general wastes from parks, beaches, and recreational areas

Table1. Sources of MSW within a community

As a basis for subsequent discussions, it will be helpful to define various types of solid waste generated. However, the definitions and classifications of solid waste vary greatly in the literature and in business. Consequently, the use of published data requires good judgment. The following definitions are intended to serve as a guide for practical operations and are not meant to be precise in a scientific sense.

2.1. Residential and Commercial

Residential and commercial solid wastes consist of organic and inorganic solid wastes from residential areas and commercial establishments. Typically, the organic fraction consists of materials such as food waste, paper of all types, cardboard, plastics of all types, textiles, rubber, leather, wood, and yard wastes. In some developed countries with modern "high tech" classifying equipment, all recyclable and non-degradable materials such as paper, fibers and plastics would not be included in the organic fraction. The inorganic fraction consists of items such as glass, crockery, tin cans, aluminum, ferrous metals, and dirt. If the waste components are not separated before discarding, then the mixture of these wastes is also known as co-mingled residential and commercial MSW.

Special wastes from residential and commercial sources include bulky items, consumer electronics, white goods, yard wastes, batteries, paints, waste oils, and tires. These wastes are usually handled separately from other residential and commercial wastes. Most developed and some developing countries treat those wastes within MSW that pose a substantial presence of potential hazard to human health or living organisms as hazardous wastes. Hazardous wastes are required to be handled, treated and disposed in accordance with stringent local or national environmental regulations.

2.2. Institutional

Institutional sources of solid wastes include government-ascribed organizations, centers, universities and schools, prisons, and hospitals and so on. The solid wastes generated at these facilities are quite similar to commingled MSW. In most developed countries hospital medical wastes are handled and processed separately from other solid wastes.

2.3. Municipal services

Other community wastes, resulting from the operation and maintenance of municipal facilities and the provision of other municipal services, include street sweepings, roadside litter, wastes from municipal litter containers, landscape and tree trimmings, dead animals, and abandoned vehicles. It is not possible to predict where and when these wastes can be

found. These wastes are often handled as originating from non-stationary sources in contrast to residential sources, which generate waste at constant rate and composition in a specific area and time. These sources could be called repetitive generation sources.

3. Amounts of Municipal Wastes

In municipal environmental management, it is very important to be able to forecast the amount of solid wastes generated. This information is needed not only to formulate environmental standards and assess environmental impacts of the wastes, but also to evaluate the potential quantity of re-useable energy and material resource in wastes. Accurate records of quantities of solid waste generated and collected are of critical importance in selecting specific equipment and in designing waste collection routes, materials recovery facilities, and disposal facilities. Also they can be used for budget preparation and operation optimization.

The data on solid waste quantity are also an essential foundation for environmental economy programs and can greatly influence final environmental management target and strategy. Furthermore, corresponding disposal can be executed so that environment management can be more rational. As different category and objects are involved, diverse statistical methods and data accuracy considerations are used in investigations.

Since the definition for "Municipal Solid Waste" varies from place to place and different common names have been used, (i.e. rubbish, refuse, junk, or trash), it could cause confusion and consequently lead to reporting errors on the quantity and composition of solid wastes. To avoid this problem, a detailed waste classification system can be recommended for reporting. Examples of the divergence are presented as follows:

- The wastes found in public areas are also attributable to the municipal wastes, especially yard wastes including leaves, grass clippings, trees, and construction and demolition debris. The total quantity of the wastes in this category is considerable. In addition, over-sized wastes like abandoned cars, refrigerators, furniture are specially collected and disposed in most cities generally. These wastes are identified here but are excluded from further discussion in this chapter.
- Some publications considered that a part of non-hazardous industrial wastes produced in cities should be classified under municipal wastes. To a certain extent, this point of view is reasonable because it is hard to determine which type of wastes (for example, some wastes from cottage industries) belongs to municipal wastes. Since conceptual confusion would be induced by this definition, these wastes are omitted in this chapter.
- A small amount of hazardous wastes are mixed in household wastes, such as combustible solvents, discarded lighters, paint, batteries and fluorescent lamps, and these have not been classified effectively in some developing countries. On the basis of modern environmental regulations, they should all be defined as hazardous wastes.

4. Estimation and Calculation of Quantity of MSW

Investigation on amount of municipal wastes means a series of data to be collected

simultaneously, including quantities of solid waste generated, separated for recycling, and collected for further processing or disposal. The principal reason for measuring these is to obtain data that can be used to develop and implement effective solid waste management program. Different methods and units are used to quantify solid waste quantities.

4.1. Measuring unit

It is necessary to estimate the quantities of solid waste that will be generated, by waste category, within a community. Estimates of MSW quantities are usually based on the amount of waste generated per person per day, kg/person · d (this chapter excludes industrial wastes). However, because the waste composition varies significantly in different areas, the use of kg/person/d may be misleading, especially when quantities are being compared. For commercial wastes, a more meaningful approach would be to relate the quantities generated to the number of customers, the dollar value of sales, or some similar unit.

In general, weight is used for measurement of solid waste quantities. It is because the use of volume as a measure of quantity can be misleading. A cubic meter of loose wastes is a different quantity from a cubic meter of compacted wastes as regards both collection vehicle and landfill. When a volume unit is used, the quantity must be related to either the degree of compaction or the specific weight of the waste under specific conditions. Weight is the only accurate basis for records because tonnage can be measured directly, regardless of the degree of compaction. Weight records are also necessary in the transport of solid wastes because the quantity that can be hauled usually is restricted by highway weight limits rather than by volume. In the design and operation of landfills, volume and weight are equally important.

4.2. Relation between Quantity of MSW and Economic Growth

Economic growth, improvement of living conditions, change of energy structure, and increase of city population, all these bring fast accelerating increase in amounts of MSW. The following statistics show average daily MSW generation (per person) in countries of different economic levels.

- highly developed countries: 1.2~1.8 kg/person / d
- industrial countries: 0.7~1.2 kg/ person / d
- countries of medium income: 0.5~0.75 kg/ person / d
- countries of low income 0.3~0.6 kg/ person / d

The major factors affecting amounts of MSW are population, standard of living, social energy resources structure, people's diet habits, etc. Modeling of these factors is a challenging task. As a conventional duty of local government in most countries, population surveys are readily available. All other factors, which are difficult to transfer to numerous parameters, are synthesized in an MSW Generation Coefficient G_R. So the generation of MSW in a city can be formulated by following equation:

$$G_T = G_R M \times 10^{-3} \times 365 \quad (1)$$

where: G_T: Generation of MSW of the city (ton/a)
G_R: MSW Generation Coefficient (kg/person / d)
M: population in the city.

Providing accurate G_R is the basic prerequisite for exact calculation of MSW Generation.

Many scholars evaluated the value of G_R in 1970s. On the basis of a large number of statistical data, researchers found that a rigorous direct proportion can express the relationship between G_R and Gross National Product (GNP). The ratio $\triangle G_R / \triangle GNP$ is usually called Elasticity Coefficient and denoted as "*S*". Elasticity Coefficient *S* is an invariant parameter generally for different economy step in a country or for countries with different economic levels. Similar relationship has been found between GNP and consumption of water, energy, electricity, etc. In fact, the Elasticity Coefficient *S* could be used for evaluation of the manifold influence imposed to generation and/or consumption by GNP in designing and planning progress.

Based on the GDP and G_R data collected from some large cities in the world during the late 1960s to the early 1970s, a linear relationship was determined with a correlation coefficient of 0.869[*]:

$$\log G_R = 0.35 \times \log GDP + 1.393 \quad (2)$$

It was noted that the contribution of each factor varies depending on the time period, economic and technological conditions, economic and population policies. Take Japan for example. Before the 1960s, municipal waste generation increased slowly due to the slow population growth. After the 1960s, during which the Japanese economy reached a fast rate of development, municipal waste generation increased rapidly due to strong GNP growth, and the impact of population increase became less and less significant. In the early 1970s, as a result of the international petroleum crisis, the municipal waste generation suffered a sharp decrease. In developed countries, municipal waste generation is intensively controlled by the level of environmental education offered by the government and citizen's awareness on the significance of environmental quality and resources. Life style and dietary habit of residents create diversity.

4.3. Collection Efficiency of MSW

The amount of MSW generated and the amount of waste collected for processing and/or disposal are different. In regional statistics, the generation of MSW is computed based on actual data—the amount of wastes transferred out of the area divided by the size of population. Since the amount generated depends on season, month and holidays, this method does not work well in forecasting. In order to design adequate systems of transportation and collection, long-term records and data-extrapolation is needed. Despite that, weighing can only provide the quantity of wastes collected. When computing the generating amount of MSW, a coefficient Collection Efficiency, which is defined as the ratio of waste quantity generated and collected, should be used. For residential and

commercial wastes the difference ranges from 5% to 15% depending on localities. The existence of recycling programs within a community definitely affects the quantities of wastes collected for further processing or disposal. Whether such operations affect the quantities of waste generated is not understood.

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