CHAPTER 2

LITERATURE REVIEW

2.1 Source of Solid Waste

Major source of solid waste in different cities of Asia Pacific region may be classified as follows (Baldisimo and Lohani ,1988) :

1) **Domestic Source**

Domestic sources in a city includes single family dwellings, duplex, multifamily dwelling, low, medium, and high-rise apartments. Household waste are the chief constituents of municipal solid wastes (MSW).

2) **Commercial Area**

Among the sources are stores, restaurants, markets, office complexes and others. Solid waste generated from commercial sources in different parts of a city therefore consist of many varieties of refuse.

3) **Institutional Sources**

This refers to universities, schools, hospitals, government offices, and others. Generally institutional solid wastes contain a large proportion of paper and other light materials, that could easily be separated for recycling or combusting to recover heat energy.

4) **Street Sweeping Source**

This refers to streets, alleys, parks, highways and others. The type of solid waste include rubbish and special wastes.

2.2 Type of Solid Waste

Type of solid waste may be classified as follows (Tchobanoglous, Theisen and Vigil , 1993) :

1) Residential and Commercial Solid Wastes

Residential and commercial solid wastes consist of the organic (combustible) and inorganic (non-combustible) solid wastes. Typically, the organic fraction consists materials such as food waste or garbage, paper of all types, card board, plastic of all types, textiles, rubber, leather wood and yard wastes. The inorganic fraction consists of items such as glass, crockery, tin cans, aluminum, ferrous metals, and dirt. If the waste components are not separated when discarded, then the mixture of these wastes is also know as commingle residential and commercial MSW.

2) Institutional Solid Wastes

Institutional source of solid waste include government centers, schools, prisons, and hospitals. Excluding manufacturing waste from prisons and medical wastes from hospital, the solid waste generated at these facilities are quite similar to commingled MSW.

3) Construction and Demolition Wastes

Construction waste are wastes from the construction, remodeling, and repairing of individual residences, commercial buildings, and other structures. The quantities produced are difficult to estimate. The composition is variable but may include dirt; stones; concrete; bricks; plaster; lumber; shingles and plumbing, heating and electrical parts. Demolition wastes are wastes from razed building, broken-out streets, sidewalks, bridges and other structures. The composition of demolition wastes is similar to construction wastes, but may include broken glass, plastics, and reinforcing steel.

4) Municipal Services Wastes

Municipal services wastes, resulting from the operation and maintenance of municipal facilities and the provision of other municipal services, include street sweeping, road side litter, waste from municipal

litter containers, landscape and tree trimmings, catch-basin debris, dead animals and abandoned vehicles.

5) Treatment Plant Waste and Other Residues

Treatment plant wastes are solid and semisolid wastes from water, wastewater, and industrial waste treatment facilities. The specific characteristics of these materials vary, depending on the nature of the treatment process. Wastewater treatment plant sludge are commonly co-disposed with MSW in municipal landfills. Ashes and residues are materials remaining from the combustion of wood, coal, coke, and other combustible wastes. (Residues from power plants normally are not included in this category because they are handled and processed separately.) These residues are normally composed of fine, powdery materials. Glass, crockery, and various metals are also found in the residues from municipal incinerators.

6) Industrial Solid Wastes Excluding Process Wastes

These are all solid wastes which are generated at industrial sites except industrial process wastes and any hazardous wastes.The specific components of these waste vary, depending on the group of industrial or industrial process.

7) Agricultural Wastes

Agricultural wastes are waste and residues resulting from diverse agricultural activities such as the planting and harvesting of row, field, tree and vine crops ; the production of milk ; the production of animals for slaughter, and the operation of feedlots. At present, the disposal of these wastes is not the responsibility of most municipal and county solid waste management agencies.

8) Special Wastes

Special waste from residential and commercial sources include bulky items, consumer electronics, white goods, yard waste that are collected separately, batteries, oil and tires. These waste are usually handled separately from other residential and commercial wastes.

Bulky items are large worn-out or broken household, commercial and Industrial items such as furniture, lamps, bookcases, filing cabinets, and other similar items. Consumer electronics includes worn out, broken, and other no-longer-wanted items such as radios, stereos, and television sets. White goods are large worn-out or broken household, commercial and industrial appliances such as stoves, refrigerators, dishwashers, and clothes washers and dryers.

9) **Hazardous Wastes**

Hazardous wastes are wastes or combinations of wastes that pose a substantial present or potential hazard to human health or living organisms.

2.3 Composition of Solid Waste (Tchobanogious et al., 1977, 1993)

Composition is the term used to describe the individual components that make up a solid waste stream and their relative distribution, usually based on percent by weight. Information on the composition of solid waste is important in evaluating equipment needs, systems, and management programs and plans.

2.3.1 Composition of MSW in Thailand

The composition of MSW in Thailand varies in the different part of country depending on density and size of communities and their socio-economic condition. Previous study estimated that about 55 percent of municipal solid waste in regional cities in Thailand are composed of garbage and putrescible fraction and the rests are paper, plastic, textiles glass, metals, etc.

The data on the distribution of MSW are present in Table 2.1. The moisture content of solid waste is about 55 percent. The nationwide density of solid waste varies in range of 250 to 360 kg/cu.m. depending upon local conditions. (Environmental Health Division, 1989)

Table 2.1 Composition of solid waste in Thailand

Description	% By Weight	
	Bangkok [(a)]	Regional Cities [(b)]
1. Combustible Part		
- Vegetable	30.00	54.21
- Paper	19.00	15.48
- Plastic	7.60	12.02
- Leather, Rubber	1.00	0.67
- Textiles	3.30	3.75
- Wood	21.70	2.14
2. Non-combustible Part		
- Glass, Ceramic	2.60	3.31
- Metal	2.50	2.86
- Stone, Bone	6.40	1.46
3. Miscellaneous	5.90	4.10

Source : (a) The Bangkok Solid Waste Management Study in 1982 by JICA
(b) Project on Environmental Quality Development for Regional Cities in 1984 by ONEB

2.4 Solid Waste Quantities

The quantities of solid waste generated and collected are of critical importance in determining compliance with municipality or government waste diversion programs : in selecting specific equipment; and in designing of waste collection routes, materials recovery facilities (MRF_S), and disposal facilities.

2.4.1 Estimation of Solid Waste Quantities

Waste quantities are usually estimated on the basis of data gathered by conducting a waste characterization study, using previous waste generation data, or some combination of the two approaches.

Tchobanoglous, et al., (1977, 1993) categorized methods commonly used to assess solid wastes quantities as follows :

1) Load-Count Analysis. In this method, the number of individual loads and the corresponding waste characteristics (type of waste, estimate volume) are noted over a specified time period. If scales are

available, weight data are also recorded. Unit generation rates are determined by using the field data and, where necessary, published data.

2) Weight-Volume Analysis. In this method, data (weight-volume) obtained by weighing and measuring each load so it will certainly provide better information on the specific weight of the various forms of solid wastes at a given location.

3) Material Mass Balance Analysis. This method is the way to determine the generation and movement of solid wastes with any degree of reliability for each generation source, such as an individual home or a commercial or industrial activity (see Fig 2.1). In some case the material balance method of analysis will be required to obtain the data need to verify compliance with state-mandated recycling program.

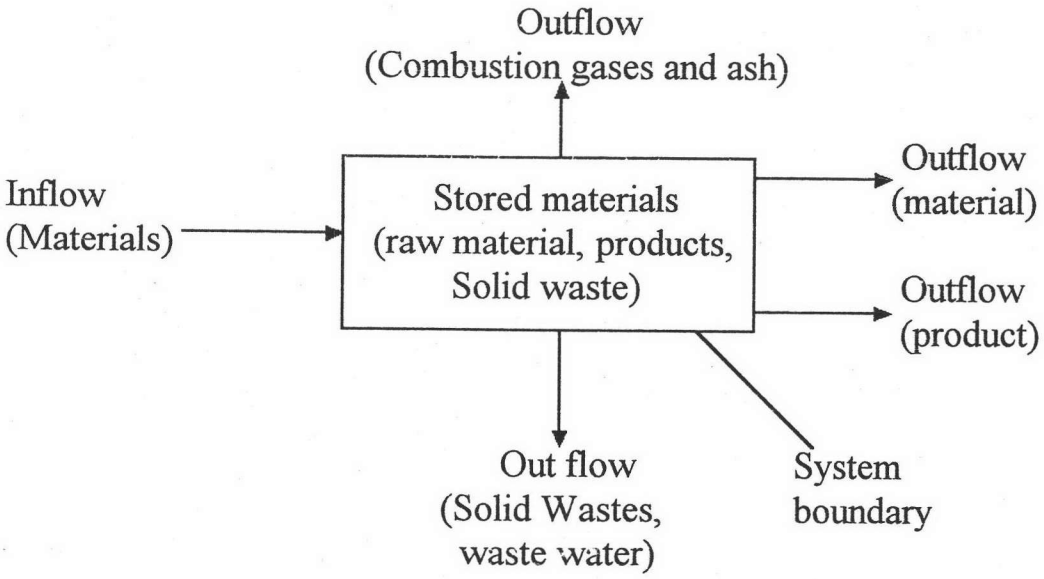

Fig 2.1 Definition sketched for materials balance analyses used to determine solid waste generation rate.

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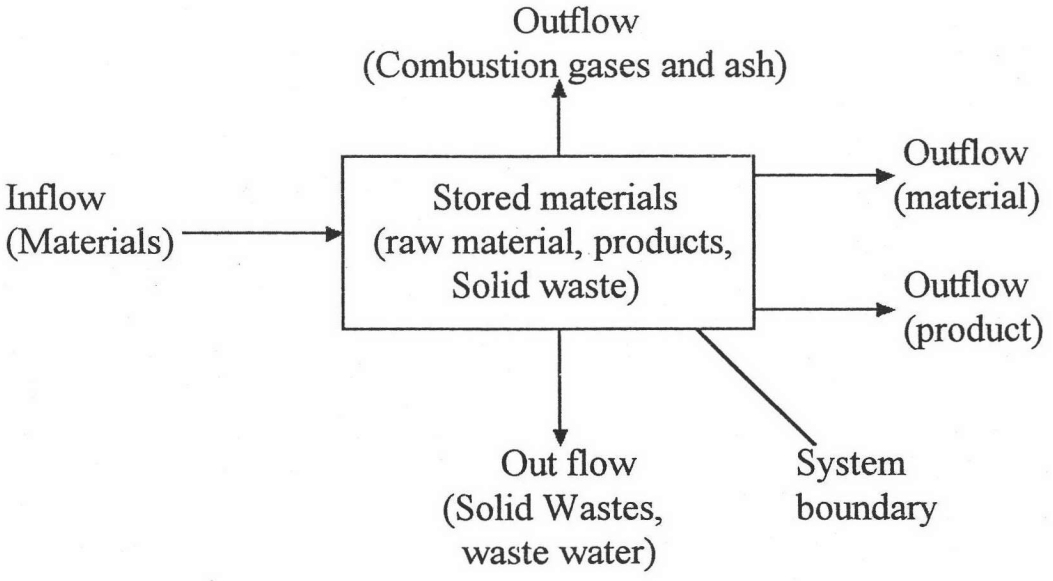

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To calculate the mass of waste generated or collected in all Port Hartcourt Nigeria containers per day, the following equation was applied

$$W_l = \Sigma (nvD/y)$$

Where W_l = mass of generated or collected in all field size container per day, kg
n = total number of containers
v = volume of each container
D = density of waste, kg/m^3
y = average number of days required to fill a container

2.5 Solid Waste Generation Rate

A difficult problem in estimating the generation rate for municipal solid waste is the fact that most reported data describe the *collected* rather than the *generated* quantity. The difference between the amount of waste generated and the amount of waste collected can be accounted by the amount of material 1) composted, 2) burned in fireplace, 3) discharged to sewers, 4) given to charitable agencies, 5) sold at garage sales 6) delivered to drop-off and recycling centers, and 7) recycled directly

2.5.1 Solid Waste Generation Rate in Thailand

a) Municipality

Results of the solid waste generation rates of the municipalities can be summarized according to the region as shown in Table 2.2

The existing and projected quantities of MSW produced in the municipalities of each regional area as calculated from the generation rate and the population are depicted in Figure 2.2. It can be seen that in 1992 the central region represented the highest solid waste source with the total amount of 1,280 tons/day. The municipalities in the north-eastern, southern

Table 2.2 Solid waste generation rates of the municipalities of Thailand (1992)

Region	Generation Rate (kg/cap/day)	
	Range	Average
Central	0.56-1.04	0.726
Northern	0.46-0.98	0.685
North-Eastern	0.66-0.78	0.695
Southern	0.64-0.93	0.797
Average		0.721

source : Comparative study on appropriate methods for solid waste disposal in 1993 by Macro Consultant Co.,Ltd.and Fichtnes (Asia) PTE Ltd.

and northern regions accounted for the total amounts of 820, 740 and 580 tons/day respectively, Whereas the gross amount generated in the country was about 3,420 tons/day. However, the result of the field survey also indicated that the uncollected refuse in the municipal areas averaged 22% of the total waste stream or represented 753 tons/day for the year 1992. It is anticipated that in the next 15 years (2007) the total amount of MSW generated in the country would reach a daily rate of 7,370 tons and the uncollected amount would be 1,620 tons if the collection efficiency is unimproved.

b) Sanitary District

The solid waste generation rates of the sanitary districts categorized by regions as shown in Table 2.3

Table 2.3 Solid waste generation rates of sanitary districts of Thailand (1992)

Region	Generation Rate (kg/cap/day)	
	Range	Average
Central	0.42-0.80	0.624
Northern	0.42-0.73	0.568
North-Eastern	0.46-0.57	0.535
Southern	0.55-0.65	0.599
Average		0.622

source : Comparative study on appropriate methods for solid waste disposal in 1993 by Macro Consultant Co.,Ltd.and Fichtnes (Asia) PTE Ltd.

Figure 2.2 Projected Refuse Quantities of Municipality in 1992-2007

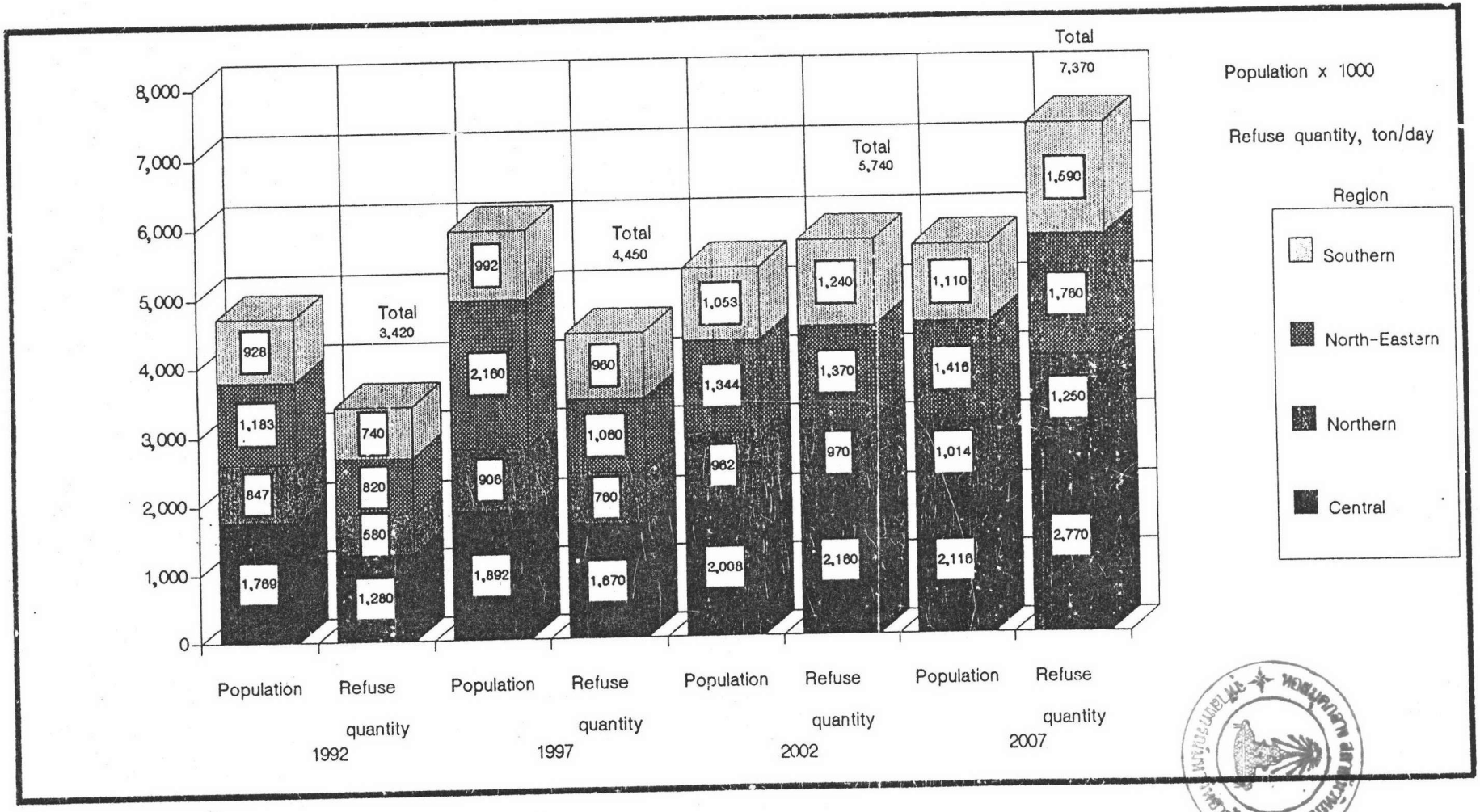

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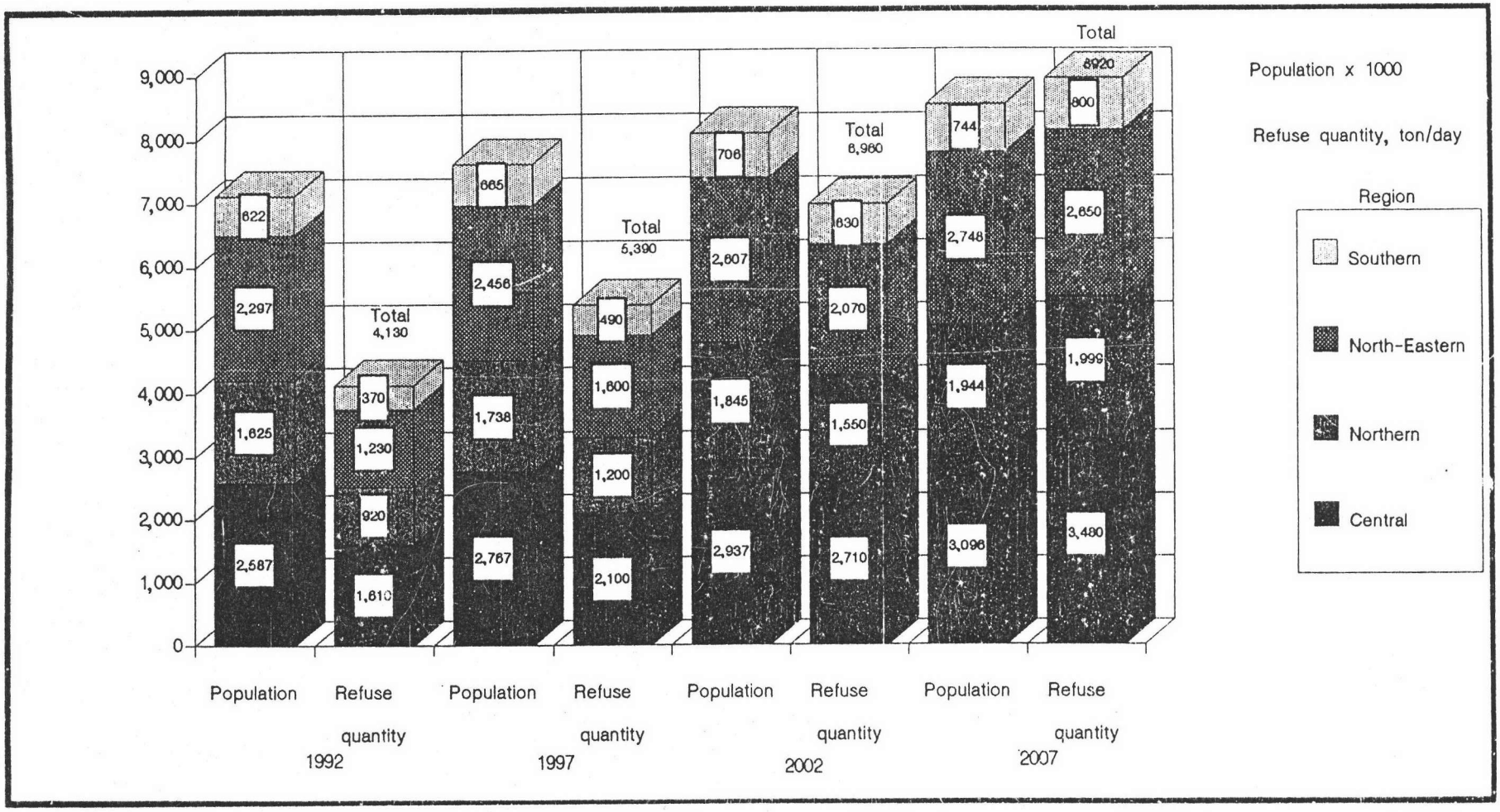
Figure 2.3 Projected Refuse Quantities of Sanitary Districts in 1992-2007



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The projected refuse quantity generated in the sanitary districts throughout the country in the next 15 years(2007) is illustrated in Figure 2.3. It can be seen that the current waste quantity (1992) produced within the central region was the highest figure of 1,610 tons/day, while the generated quantities within the communities of the north-eastern, northern and southern regions were 1,230,920 and 370 tons/day respectively. The total amount of refuse generated in the sanitary districts throughout the country was about 4,130 tons/day. Based on the obtained data, the uncollected refuse left over in the S.D. was as high as 39% Which was equivalent to 1,615 tons/day. It is estimated that in 2007 the amount of refuse generated in the S.D. communities would increase to 8,920 tons/day with 3,480 tons/day of the uncollected refuse in case the collection efficiency is unimproved.

2.6 Affecting Factors for Solid Waste Generation

The generation rates and characters of municipal solid waste are varied in different countries and cities because of different influenced factors. The most important factors are listed as followed.

1) Geographic location

This factor includes geographical characteristics of the land, climate and rainfall season. A significant situation of variation in the amount of garden waste generated, weight of refuse, moisture contents etc. are affected by the changes in seasons or climate. In some countries, the waste amount and characters are varied from spring to winter within a year. Furthermore, the raining and typhoon seasons in some tropic countries may have affected both quantity and quality of waste too.

2) Population

Municipal wastes are mainly produced by human, thus variation in population has influenced the amount of waste generated within a city of country.

3) Economic conditions and standard of living

The economic status or condition have affected the amount and types of goods that have been purchased. Usually, wealthier group with

higher purchase ability, their goods tend to be higher quantity and more exquisite, thus produce higher amount of wastes and packaging materials.

4) Industrial, commercial and housing development planning

The rapid development of these planning within a city has main effects on the quantity of municipal wastes. Such urbanization activity may encourage the migrants and thus increase the population and amount of waste generated.

5) Increase in the use of new products

This trend has effects on the character of waste such as density moisture content and chemical compositions. The increase of packaging materials, pre-cooked or frozen foods and disposable diapers etc. would have changed the waste stream within a community.

6) Frequency of collection and service coverage

It is common that higher frequency of collection and thus more wastes are collected.

7) The habits and customs of living

These factors have greatly affected both the waste generation and composition from many aspects such as festivals, habits or life style. The waste characteristics are varying from city to city and also within the same city itself too. For example, generation rates during festival seasons are usually higher than normal because of the preparation and celebration. Also, different life style would perform its specific waste stream characteristic.

8) Fruit seasons

During these seasons, the portion of fruit wastes has usually increased the amount of garbage components and the moisture contents of the refuse.

9) Individual household waste reduction methods

This factor only reduce the waste collected while the generation rates from each household are remained a same level. The reduction methods are different among developed and developing countries. Home grinders are commonly applied in the former. Open burning or dumping into rivers are existed in the latter which might cause air and water pollution.

10) The extent of recycling and sorting systems

Under this system, some reusable materials are sorted from the waste before sending to processing or treatment plants. Quantities of waste collected are reduced and the reusable materials such as papers and bottles may not exist in the waste stream.

11) Waste collection cost from waste producer

Increasing of collection cost would cause each household to reduce the waste generation rates. However, this may only effective for some bulky wastes which are collected by special services. In some commercial and industrial areas, the payment by waste generators is due to the number of collection trips, therefore the payees always tend to limit the amount of waste generated.

12) Legislation and regulation

The existence of local, state and federal regulations concerning the use and disposal of specific materials may have affected the generation of certain types of wastes.

13) Public attitude

Significant reductions in the quantities of solid wastes will occur when and if the public are willing to change their habits, life styles and with awareness in maintaining an aesthetic environment and national resources.

The factors that affect municipal solid waste are important in planning the solid waste management system and can be considered into the development of national environment policies as well as policies. Therefore, the impact of these factors in a city should be evaluated separately in each situation.

2.7 The Affecting Factors in Previous Study

A study by U.S. Environmental Protection Agency (EPA) (1969) derived the equation for estimating the quantity of solid waste generation rate (W) within a residential area. The equation was in the form as :

$$W = 35.8S - 7.25F - 6.44D + 0.82P - 0.4I + 89400 \quad ...(2\text{-}1)$$

In the study from Shell and Shupe (1972), the tons of municipal solid waste in a route (W) could be estimated as :

$$W = 0.0179S-0.00376F-0.00322D+0.0071P-0.0002I+44.7 \quad ...(2\text{-}2)$$

Where S = Number of stops
F = Number of families
D = Number of single-family dwelling units
P = Population
I = Adjusted gross income per dwelling unit

Grossman ,Hudson and Marks, (1974) developed a model for a town in New England and yielded the following results :

$$Y = 619X_1 + 655X_2 - 35X_3 + 37X_4 + 8.5X_5 + 626 \quad ...(2\text{-}3)$$

Where Y = gallons of uncompacted solid waste produced per week

The affecting factors were :

X_1 = blockfaces with low income
X_2 = blockfaces with middle income
X_3 = single-unit dwellings
X_4 = dwellings containing two to four living units
X_5 = dwellings with five or more living units

Hartono (1984) estimated the amount of solid waste of each sources in Bandung city, Indonesia, by the following equations :

(1) residential area,

$$Y_{11} = 1.75+2.26X_{11}-(6.9x10^{-1})X_{14}+(6.7 \times 10^{-3})X_{17} \quad ...(2\text{-}4)$$

Where Y_{11} = generation rate, l/day

The affecting factors were :

X_{11} = number of people in the house
X_{14} = income level
X_{17} = population density of the area, number/km^2

(2) solid waste from streets,

$$Y_{31} = 18.23+(6x10^{-2})X_{31} + 6.38X_{32} + (17x10^{-3})X_{33} \quad ...(2\text{-}5)$$

Where the affecting factors were :

X_{31} = length of street, m
X_{32} = width of street, m
X_{33} = population density of the area, number/km^2

(3) solid waste from offices

$$Y_{51} = 573.63+(35x10^{-3})X_{51} - 37.63X_{53} - 13.03X_{54} \quad ...(2\text{-}6)$$

Where the affecting factors were :

X_{51} = number of officers
X_{53} = number of storeys
X_{54} = number of work hours

Japan International Cooperation Agency (JICA) (1982) derived the relationship between solid waste generation volume and land-used pattern. It was formulated as :

$$g = 0.474\ X_1 + 0.611\ X_2 + 1.23\ X_3 + 0.486\ X_4 \qquad ...(2\text{-}7)$$

Where g = generation unit by area, $m^3/km^2.d$

The affecting factors were :

X_1 = land use, residential, %
X_2 = land use, mixed use, high density, %
X_3 = land use, mixed use, low density, %
X_4 = land use, institutional, %

In the study carried by Sridhar et al. (1985) to investigate the characteristics of refuse in Ibadan of Nigeria, it showed that the waste generation in this city is affected by the development of economic after the country independence and the improvement of economic condition after the discovery of oil. The used of plastic and polythene were increased since that period. Also, the traditional lifestyle caused to the significant amount of garbage (59.3 %) and leaves (7.9 %) which were mainly used for preparing food while generation rates were varied with different socio-economic group.

Chan (1993) estimated solid waste generation rate in each sources in Kuala Lumpur, Malaysia and reported that the generation rates of residential areas were : 0.67, 0.65 and 0.45 kg/capita/day in high, medium, and low socio-economic strata. In commercial area, 17.3 kg/stall/day (4.61 kg./m^2/day) for wet market, 8.7 to 13.1 kg/shop/day (0.10 to 0.15 kg/m^3/day) for shopping complex, 0.8 kg/bed/day for hospital and 0.6 kg/student/day for school. And solid waste generation rate in Kuala Lumpur City was 1.55 kg/capita/day.