UNIT 5 ESTIMATION METHODS OF SOLID WASTES QUANTITIES

Structure

5.1 Introduction

Poor solid waste management practices have a serious threat to health and environment because it may lead to air, soil and water pollution. Unfortunately, only 60% of the waste generated in developing countries is collected and disposed. The collection and treatment of solid waste are usually insufficient due to a lack of complete information on the amount of municipal solid waste discards. A reliable estimation of the solid waste quantity is very important for proper solid waste planning and management. Waste quantification is importancein the designing of waste collection routes, material recovery facilities, and disposalfacilities, selecting specific equipment and vehicles, cost estimates of solid waste management.

Objectives:

After studying this unit, you should be ableto

- UnderstandEstimation of the quantity of solid waste
- LearnForecasting of the solid waste
- To understand the factor influencing solid waste Estimation rate

5.2 Estimation of Solid Waste

There is a various method to quantify the waste generation amount or rates. There are two methods, hard measures and soft measures used to investigate waste generation rates. The hard measure method such as material flow analysis (MFA) and sorted & weighed while the soft measure method is interviewed and questionnaire and estimation based on statistical data. Both volume and weight are used for the measurement of solid waste quantities. But the use of volume as a measure can be misleading. For example, a cubic metre of loose waste is a different quantity from a cubic metre of waste that has been compacted in a collection vehicle, and each of these is differentfrom a cubic metre of waste that has been compacted further in a landfill. Therefore, measured volumes of waste must be either related to degree of compaction or specific weight of the wastes under the conditions of storage Representation of solid waste quantities in terms of weight is more convenient because tonnages can be measured directly regardless of degree of compaction.

5.2.1 Load Count Analysis

The number of individual loads and the corresponding waste characteristics (type of waste, estimated volume)are noted over a specified time period and Unit generation rates are determined by using the field data and where necessary, published data.

Generation rate = Total waste produced/ (Sampling duration in days × total number of people)

5.2.2 Weight Volume Analysis

Collection vehicles are weighed at entrance to transfer station using platform scales and the volume of eachtruck is estimated.

Figure 5.1: Weighing of collection vehicle (truck)

Waste generation rates are quantified by measuringthe load of waste in collection vehicles either at a municipal or privateweighbridge in the city.Alternately, the volumes of different vehicleused for transportation of waste are considered. A summation of the quantities of waste transportedby each vehicle typemultiplied by the total number of trips to the landfill by similar vehiclesdetermines the total quantity of waste transported.

Total waste collected = Quantity of waste transported by each vehicle x no. of trips

Various expressions for unit waste generation rates

- Residential waste: kg/capita/day
- Commercial waste: kg/capita/day
- Industrial waste: kg/product
- Agricultural waste: kg/ raw product

5.3 Material Flow Analysis

The only way to determine the generation and movement of solid wastes with any degree of reliability is to perform a detailed material flow analysis(MFA) for each generation source, such as an individual home or a commercial or industrial activity. Material flow analysis is a process through which the complete flow of material is analyzed in a particular system. It considers life-cycle approach and is often called “cradle-to-grave” analysis. Through balancing inputs and outputs for the individual processes and for the system, using the basic principles of conservation of mass, any deficiencies in our understanding of the system will be revealed and can be remediated (Figure 5.1). A consistent, documented and transparent MFA is the basis for efficient management of resources and proper control of residual waste streams and discharges to the environment.

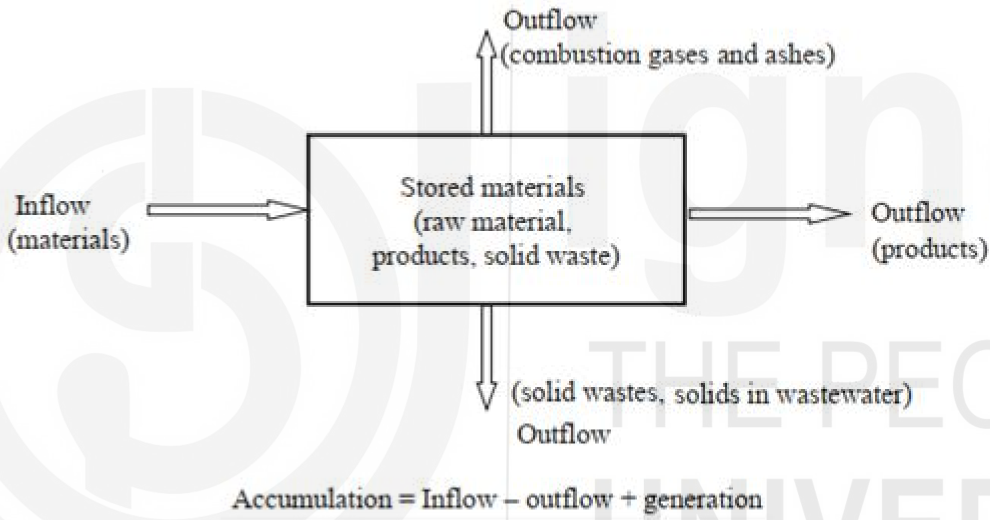


Figure 5.2: Block diagram of Materials Mass Balance analysis

In the MFA context, waste generation in terms of the waste streamsto be handled by the waste management system are imports to the system and waste collection, waste treatment andlandfilling are processes within the system. The landfill differs from the other process since a stock of landfilled wasteaccumulates in the landfill over time. Recycled and utilized materials are exports from the system. Losses of mass dueto degradation or combustion of organic matter are exports to the air compartment. Figure 5.2 given below sketches a mass balancefor a fictitious waste management system. Figure 5.3 is n example of mass balance of methane gas from landfills

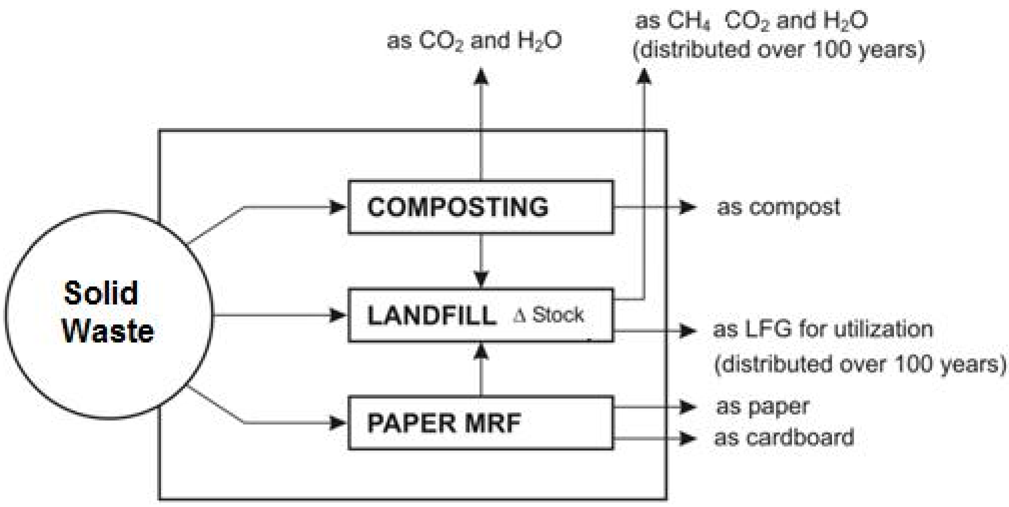


Figure5.3: Sketches a mass balance for a fictitious waste management system

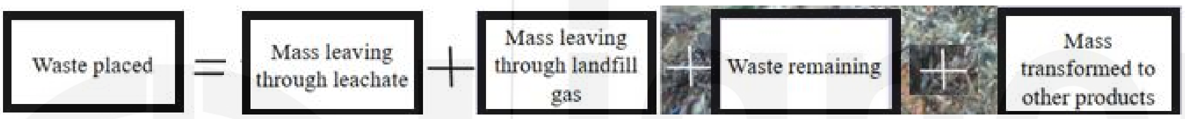


Figure 5.4: An example of mass balance of methane gas from landfills

Unlike the conventional waste, E-waste has different end points for the same good and also the varied discarding patterns. For instance, a personal computer (PC) bought would have an average life span of 5 years. However, user of PCs would show varying patterns of discarding it after its life span is over. Some may continue to use it beyond its life time; others may donate it where it is used further for some years. Some may keep in store and others may pass it on to informal recyclers where they would use the useful part forrefurbished PCs and other may be subjected to material recovery and final disposal. An accurate material flow analysis along with certain assumptions can give precise E-waste estimate.

SAQ 1

1. Write short notes on (a) load-count Analysis (b)Mass volume analysis
2. Write mass balance equation and explain each term. Write the Steps involved in mass balance analysis.

5.4 Estimation Based on Statistical Data

This estimation method is based on the statistical data that available from the database in the related country. The data normally related to the building activity and numbers of construction licenses for selected years is available. The calculation and extrapolation made is based on the available data. They are different amount of waste generated depending on their factor of contribution. The amount of generation may vary because of construction waste depend on the types of technology used in certain areas. The study calculates for the housing and commercial building by taking the average useful area of commercial building and the overall area of intervention multiplied by the amount of waste each activity.

The E-wastesare estimated by taking into account the data statistics for sales of electronic equipments and their average life period. It takes into account two critical assumptions. The first assumption is that particular equipment is discarded as waste once its life span gets over. And second assumption is the method doesn't take into account the variation in the average life period of the electronic equipment.

5.5 Consumption Use Method

Consumption based method consider the data on the stock of the electronic equipment at the household sector. Then, in order to estimate the amount of electronic waste, one need to divide the stock levels by the life span (average) of the equipment. While estimating stock levels, both penetration level as well as the number of households is taken into account. One can do the similar exercise for industrial sector as well. Government of India, in its census (2011), collected information on various electronic equipments such as TV, Radio Transistor, Refrigerator, Air Conditioner etc. at household level. This data set would make it easier and feasible to conduct this type of analysis for E-waste estimation.

5.6 Econometric Analysis

Econometric analysis takes into consideration various factors which affects the estimation of E-waste like GDP of an economy, growth rate of an economy, population of a country, etc. and then tries to estimate e-waste by employing regression tools. This method would fail to consider the heterogeneous character of consumer behaviour and also the life cycle aspects of the analysis which is a key for estimating E-Waste.

5.7 Interview and Questionnaire

Another technique applies in waste quantification is a questionnaire and expert interview. It is considered as a soft measurement technique. Using this method, Begum et al. conductedan interview using questionnaire with 2-3 years of monitoring throughout the project uration in combination with the developer, contractor, subcontractor, project manager, quantity surveyor and site supervisor. The study is focusing on the comparison between the non residential building and the residential building. The amount of waste in tones for $100m^2$ floor spaces is 56.642. Experts emphasized that the quantitative data obtained from questionnaire survey are not the real figures of specific contracts but were estimates based on the experience of the respondents.

To estimate E-waste the survey could be conducted on a household basis, commercial establishment basis or even on an industrial basis. The questions are framed in such a way to collect information about the options of disposing off the electrical appliances, the average year of using an electrical product after re-using, obsolescence rate of different electrical appliances etc.

Variation in generation and collection rates:

- The quantities of solid waste generated and collected vary daily, weekly, monthly, and seasonally.
- Largest variation occurs with individual residence and small commercial establishments.
- Residential waste generation rates usually peak during festive seasons.
- In general, as the size of the waste source increases, the variation in the peak day, week and month decreases.

5.8 Relation between quantity of MSW and economic growth

Economic growth, improvement of living conditions, change of energy structure, and an 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. Modelling 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.

$$G_T = G_R M \times 10^{-3} \times 365$$

Where: G_T = Generation of MSW of the city (ton/d)

G_R = MSW Generation Coefficient(Kg/person/d)

M = Population in the cityG_R

Providing accurate G_R is the basic prerequisite for exact calculation of MSW Generation. On the basis of a large number of statistical data, researchers found that a rigorous direct proportion can express the relationship between GR and Gross National Product (GNP). The ratio $\Delta G_R/\Delta GNP$ 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 stated as below.

$\log G_R = 0.35 \times \log GDP + 1.393$

It was noted that the contribution of each factor varies depending on the time period, economic and technological conditions, economic and population policies.

SAQ 2

1. Explain the factors affecting solid waste estimation.
2. **Problem 1:** the present population of a city is estimated at 50,000 and the waste generation rate is estimated at 0.322 kg/cap/day. Calculate waste generated in a year.

3. **Problem 2**: A landfill area of (150 m x 100 m) is available for handling 25 years' municipal solid waste (MSW) for a town of 5,00,000 people. Out of the total landfill area only 80% is actually available for land fill and other is used for auxiliary services.

Assuming that average per capita MSW discard per year in town is 0.05 tonne, landfill density is 500 kg/m^3, and that the 15 percent of the actual landfill cell volume is used for soil cover, estimate (a) the landfill lift in one year. (b) Number of years for which the landfill can be used if the landfill cannot be increased beyond 25 m.

4. Please provide a mass balance of the composting process receiving 3 Tons waste per day.

5. Explain the relation between quantity of MSW and economic growth.

5.9 Method for Estimation of E-Waste Generation

E-waste generated by producer for a specific EEE (i.e. Electrical& electronics equipments) category code is to be estimated on the basis of quantity (number or weight) of EEE placed in the market in the previous years and taking into consideration the average life of the equipment. Such estimate should be carried out using the following method;

The generation of e-waste from end of life products:

E-waste generation (weight or number) in the financial year 'x – y' = Sales in the financial year '(x-z) - (y-z)'

where, 'x – y' = financial year in which generation is estimated, and

z= average life span of EEE

Average life of the EEE to be used in the above formula is given below:

Table No. 1: Average life of EEE

Sr. No.	Categories of electrical and electronics equipment	EEE Code	Average Life
i.	**Information technology and telecommunication equipment**		
	Centralized data processing	ITEW 1	
	Mainframe		10 Years
	Minicomputer		5 Years
	Personal Computing: Personal Computers (Central Processing Unit with input and Output Devices)	ITEW 2	6 Years
	Personal Computing: Laptop Computers (Central Processing Unit with input and Output Devices)	ITEW 3	5 Years
	Personal computing: Notebook Computers	ITEW 4	5 Years
	Personal Computing: Notepad Computers	ITEW 5	5 Years
	Printers including Cartridges	ITEW 6	10 Years

	Copying Equipment	ITEW 7	8 Years
	Electrical and Electronic typewriters	ITEW 8	5 Years
	User terminals and systems	ITEW 9	6 Years
	Facsimile	ITEW 10	10 Years
	Telex	ITEW 11	5 Years
	Telephones	ITEW 12	9 Years
	Pay Telephones	ITEW 13	9 Years
	Cordless telephones	ITEW 14	9 Years
	Cellular telephones	ITEW 15	
	Feature Phones		7 Years
	Smartphones		5 Years
	Answering systems	ITEW 16	5 Years
ii.	**Consumer electrical and electronics:**		
	Television sets (including sets based on (Liquid crystal and Light emitting Diode technology)	CEEW1	9 Years
	Refrigerator	CEEW2	10 Years
	Washing Machine	CCEW3	9 Years
	Air-conditioners excluding centralized air conditioning plants	CCEW4	10 Years
	Fluorescent and other mercury containing lamps	CEEW5	2 Years

Example for Calculation of E-waste Generation

E-waste generation (weight or number) in the financial year 'x – y' = Sales in the financial year '(x-z) - (y-z)'

'x – y' = financial year in which generation estimated,

z = average life span of EEE

For example, for financial year 2016 -17,

x - y = 2016 -17 (April 2016 to March 2017)

If EEE, for which generation is to be estimated, is ITEW 15

means cellular phones that is either smart phone or feature phones then

z=5 years or z = 7 years as from the table.

1. The estimated generation of end of life **ITEW 15** – smart phone in the **FY 2016-17**

= Sales in the (FY year 2016-5 – 2017-5) either in terms of weight or number

= Sales in the financial year 2011-12 in terms of weight or number

2. The estimated generation of end of life ITEW 15 – feature phone in the FY 2016- 17

3. = Sales in the (FY year 2016-7 – 2017-7) either in terms of weight or number

4. = Sales in the financial year 2009-10 in terms of weight or number

- Therefore, generation of end of life of smart phone in the FY 2016-17 = Sales in the financial year 2011 – 12 either in terms of weight or number
- Similarly, generation of end of life of feature phone = Sales in the financial year 2009-2010 either in terms of weight or number

5.10 Forecasting of solid waste generation

Municipal Waste

The mathematical calculation is an ultra-.process beginning with the estimation of future population based on the present trend and then calculates the future amount of municipal solid waste generation (Weber, 2004) of studied countries

Future Population = Initial Population$(1 + \frac{\%\,\text{growthrate}}{100})^{\text{years}}$

Future amount of municipal solid waste generation = (Predicted population) x (Waste generation rate) x (Number of day) ÷ (1000 kg per metric ton)

Medical Waste

Total medical waste generation using the equation:

M=B.R/1000 (ton/day)

Where-

M-Total medical waste generated (ton/day)

B-Number of sickbed (bed)

R-Generation rate of medical waste (kg/ bed/ day). It depends on a number of factors such as the increasing rate of population, socialeconomic condition, types and scales of hospitals, etc.

SAQ 3

1. What is E-waste?
2. Using following data evaluate the quantity of solid waste generated rate per week for a city residential area consists of 5000 homes. Given data are collected from local

transfer station and observation period was one week. Assume approximately 2 adults and 1 child per home (2.5 people per home).

No.of. vehicle	No. ofStrip	Volume(m^3)	Specificweight (kg/m^3)
I	15	10	280
II	20	8	210
III	25	12	320

5.11 Summary

The most important aspect of solid waste management is the quantity of waste to be managed. The quantity determines the size and number of functional units and equipment required for managing the waste. Thequantities are measured in terms of weight and volume. The weight is fairly constant for a given set of discarded objects whereas volume is highly variable. Waste quantities are usually estimated based on past records of waste generation. The methods commonly used to assess the quantities are (i) load count analysis; (ii) weight volume analysis; and (iii) material balance analysis.

The prediction of municipal solid waste (MSW) generation plays an important role in a solid waste management system. Population growth and migration, underlying economic development, household size, employment changes, and the impact of waste recycling would influence the solid waste generation.

5.12 Keywords

MFA	Material flow analysis is an analytical method to quantify flow materials or substances in a well-defined system.
Transfer station	A transfer station, or resource recovery centre, is a building or processing site for the temporary deposition, consolidation and aggregation of waste
Landfill	A landfill site, also known as a tip, dump, rubbish dump, garbage dump, or dumping ground, is a site for the disposal of waste materials.
E-waste	Electronic waste or e-waste describes discarded electrical or electronic devices.
GDP	It stands for "gross domestic product" and represents the total monetary

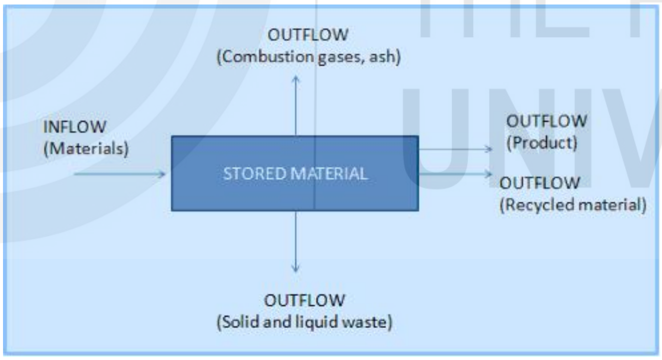
	value of all final goods and services produced (and sold on the market) within a country during a period of time (typically 1 year).
Medical waste	Medical waste is any waste that is generated as a by-product of healthcare work at doctor's surgeries, dentists, hospitals and laboratories

5.13 Answers to SAQs

SAQ 1

1. **Refer Section 5.2**
2. **Refer Section 5.3**
   Steps involved in mass balance analysis are given below.
   1) Identify boundary of the system or source for which mass balance is to be performed
   2) Identify all activities within the system or across it that affects waste generation
   3) Identify rate of waste generation associated with each of these activities
   4) Use following mathematical relationship between quantity of waste generated, collected, stored and moved from the system for performing mass balance

Material Stored = Inflow – Outflow - Waste Generation



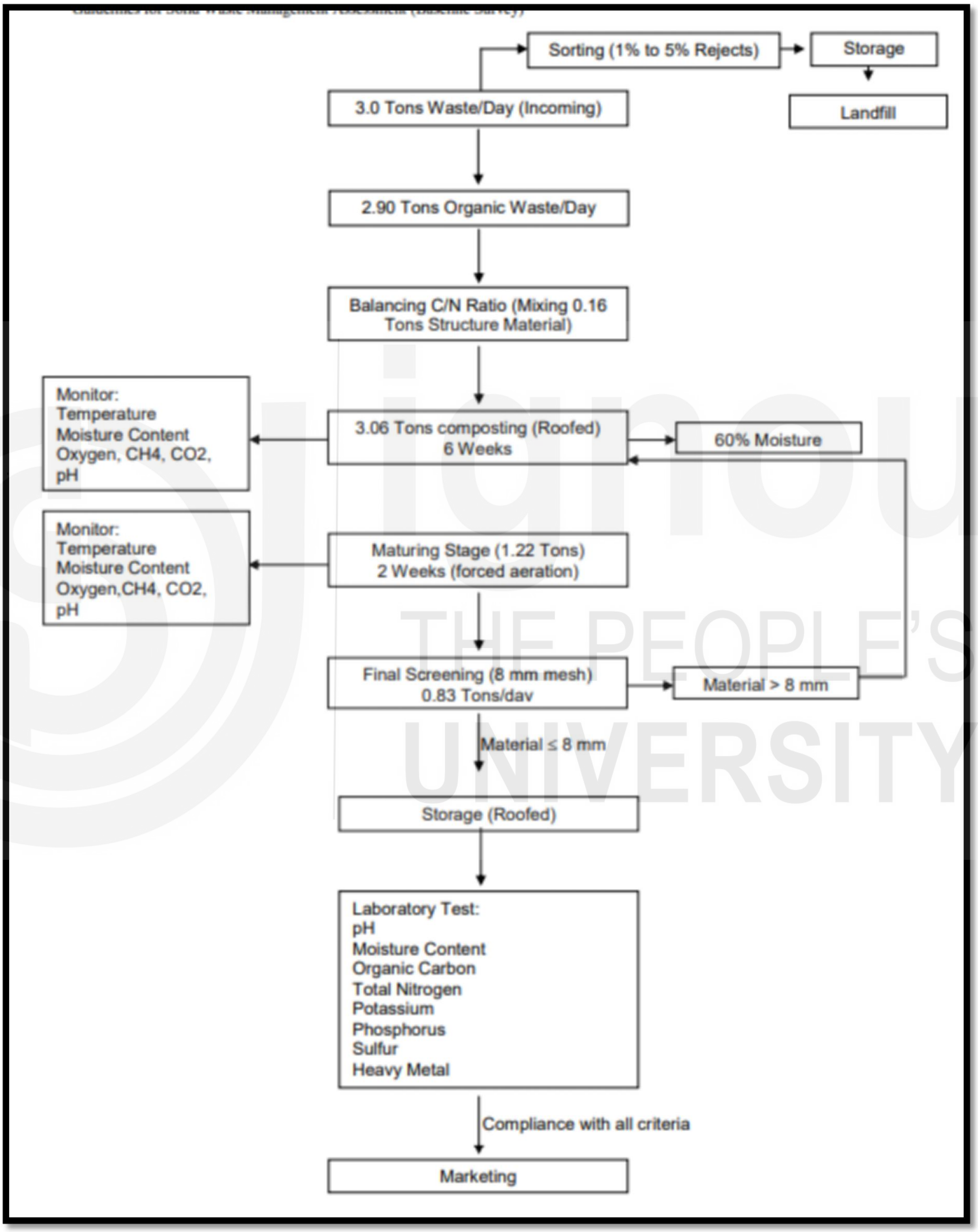
SAQ 2

1. **Refer Section 5.7, 5.8**

2. the total present population of a city is estimated at 50,000 and the waste generation rate is estimated at 0.322 kg/cap/day, the total waste generated per day would be 50,000 * 0.322 = 16,100 kg/day, or 16.1 metric tons/day. Therefore, waste generated in a year = 16.1*365= 5876.5 Tons.

3. (a) Volume of MSW generated by town per year = (0.05x1000) x500000/500 = 50000 m3, Land fill lift per year = [50000/(0.85)]/(0.8x150x100)= 4.902 m
(b) No. of years for which the land fill can be used=25/4.902=5.1 year

4. An example of a mass balance is shown below.



5. Refer Section 5.8

SAQ 3

1. **Refer Section 5.9**
2. **Step 1: Determine the total quantity of waste**
3. Total quantity of waste (kg) = No. of Strip * Volume (m3)* Specific weight (kg/m3)

No.of. vehicle	No. ofStrip	Volume(m^3)	Specificweight (kg/m^3)	Total Quantity(kg)
I	15	10	280	42000
II	20	8	210	33600
III	25	12	320	96000
				171600

Step2:Determinethequantityofsolidwastegeneratedrateperweekforacityresidentialarea consists of5000 homes.

$$\text{Quantity of solid waste generated} = \frac{\text{Total Quantity in kg}}{\text{no. of . homes} * \text{ no. of. person per home} * \text{ no. of day}}$$

Given: 2 adults and 1 child per home (2.5 people per home)

$$\text{Quantity of solid waste generated} = \frac{171600}{5000 * 2.5 * 7}$$

$$\textbf{Quantityofsolidwastegenerated} = \mathbf{1.9611 kg/capita/day}$$

5.14 Further Reading

References:

1.Tchobanoglous George, Hilary Theisen, and Samuel Vigil. Integrated Solid Waste Management.Engineering Principles and Management Issues. New York: McGraw-Hill, 1993.

2.Kreith, Frank, ed. Handbook of Solid Waste Management. New York: McGraw-Hill, 1994

3. Action Plan on Management of Municipal Solid Waste by CPCB on 5th Feb 2015