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Design of Municipal Solid Waste Landfill for Baghdad City

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ABSTRACT

Accumulation of municipal solid waste in residential areas is one of the public health problems in Iraq. In the other hand, accurate and reliable information on solid waste generation rate are very important elements to plan and implement solid waste management system. The volume and surface area required for a landfill to dispose the municipal solid wastes generated in Baghdad city is evaluated in this study. The per capita solid wastes generation rates are measured for a family consists of 10 individuals by using portable balance (Salter, 0 to 130 kg). Probability sampling is used to determine the minimum number of measurements needed to evaluate the mean of per capita solid wastes generation rate with a certain level of precision (a specified error level of 5% is selected corresponds to 95% confidence that the mean value is in accurate estimate of the true value). The results indicate that an area of approximately 1603 m on a side is required for the next 20 years as a sanitary landfill for disposing the municipal solid wastes generated in Baghdad city.

***Keywords*:** Municipal solid waste generation rate, landfill

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1. INTRODUCTION

The growing volume of solid waste generated by communities is a concern for public health officials. Some of the concerns include aesthetics (e.g., the visual appearance of many collection sites and odors associated with solid waste), the potential for groundwater contamination, an increase in vectors (rodents, insects, etc.) that may spread diseases, and other issues regarding sanitation. To handle these matters, boards of health and local health agencies must determine the appropriate means of collecting, storing, and transferring wastes; the location of landfills; and the practice of recycling, when possible, to reduce costs and improve environmental conditions. In addition, boards of health may be responsible for overseeing the regulation and licensure of the conditions and facilities of solid waste disposal. Solid waste results from various sources, such as animal wastes, hazardous wastes, industrial and medical wastes, food wastes, mineral waste, and nonhazardous wastes.

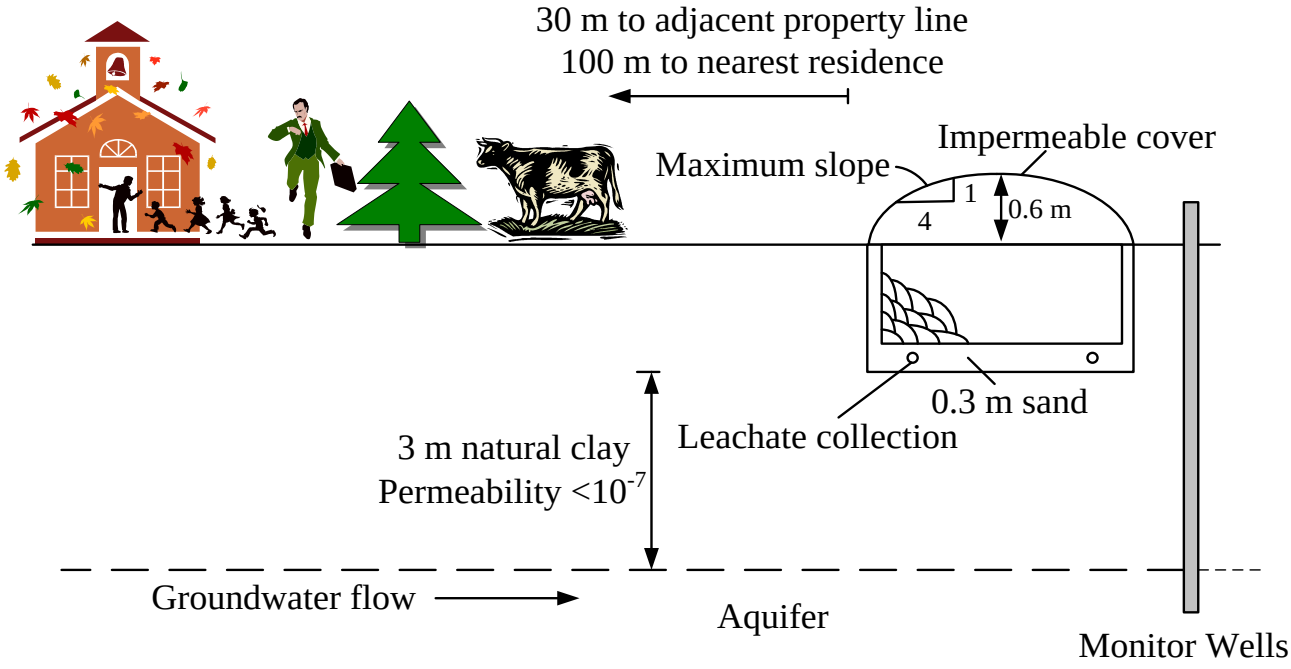

Figure 1. Municipal solid waste landfill [4]

Land application of solid wastes can be an effective way to recycle materials and avoid the undesirable environmental impacts often associated with traditional methods of waste disposal. The main advantage of a sanitary landfill (Fig. 1) is that handling and processing of refuse is kept to a minimum. Handling is limited to the pickup and transport of the waste, the spreading of refuse, and covering with a suitable cover material.

The critical factors which must be considered include: the possibility of surface and groundwater contamination, explosions from gases generated by waste decomposition, airborne ash from incineration, odors from the composting process, and the lack of suitable sites with the capacity for long term use are critical factors which must be considered. Design

authorities must make decisions which are critical to the areas surrounding the proposed sanitary landfill [1-12].

Proper design is vital to the successful operation of a landfill disposal facility in even the most suitable location. All technological alternatives which meet equirements of the proposed landfill should be reviewed prior to incorporation into the design. The design should produce a landfill capable of accepting given solid waste materials for disposal. To serve as a basis for design, the types and quantities of all refuse expected to be disposed of at the landfill should be determined by survey and analysis.

The aims of the current study are:

- Evaluate the solid waste generation rate in Baghdad city.
- Determine the volume and surface area required for a landfill to dispose the municipal solid wastes generated in Baghdad city.

2. MEASUREMENTS OF PER CAPITA SOLID WASTES GENERATION RATE

The amounts of municipal solid waste generated by a family consists of 10 individuals per day were weighed using portable balance (type Salter, 0 to 130 kg) to determine generation rate in Kg/person.day.

3. STATISTICAL ANALYSIS OF THE COLLECTED DATA (SURVEY PLANNING AND DESIGN)

Statistical analyses are concerned with two aspects related to accuracy and precision. First, the level of accuracy must be specified. The parameter α is the error allowed and (1-α) is the corresponding confidence level. Secondly, a precision requirement (D) is the deviation from the true value [1,13-22].

If the measured values of the solid wastes generation rates are x_1, x_2, … x_n. Then the observed mean generation rates of samples of size n will be [1]:

$$\overline{X} = \frac{\sum_{1}^{n} X_i}{n} \quad \ldots (1)$$

and the sample variance, a measure of the spread of data about the mean, is [5]:

$$S^2 = \frac{\sum (X_i - \overline{X})^2}{n-1} \quad \ldots (2)$$

Sample precision is promoted by collecting an adequate number of samples, which is apparent from inspection of equation (2). The variance, which is indirect measure of precision because it describes the spread of data about the mean, decreases as the number of samples (n) increases.

Initial or previous data are usually necessary to determine the number of samples required to achieve a given level of precision. The initial data provide preliminary estimates

of $\overline{X}$ and S^2 before the random sampling design is finalized. The number of samples required for a designated level of precision may be calculated by:

$$n = \frac{t^2 S^2}{D^2} \quad \ldots (3)$$

where t = students two-sided t-distribution with (n-1) degrees of freedom for a confidence level of (1-α)%.

S^2 = the sample variance for the initial data.

D = a specified limit relative to the sample mean.

The interval $\overline{X} - (b \times S/\sqrt{n-1}), \overline{X} + (b \times S/\sqrt{n-1})$ [6] is a random interval having a probability of 95% of including the true mean solid wastes generation rates. The value of b is selected from the t distribution table [6].

4. VOLUME REQUIRED

To estimate the volume required for a landfill, it is necessary to know the amount of refuse being produced and the density of the in-place, compacted refuse. The volume of refuse differs markedly from one city to another because of local conditions. The recommended formula for estimating the annual volume required [2]:

$$V_{LF} = \frac{PEC}{D_c} \quad \ldots (4)$$

where V_{LF} = volume of landfills, m^3, P = population, E = ratio of cover (soil) to compacted fill,

$$E = \frac{V_{sw} + V_c}{V_{sw}} \quad \ldots (5)$$

V_c = volume of cover, m^3,

V_{sw} = volume of solid waste, m^3,

C = average mass of solid waste collected per capita per year, kg/person,

D_c = density of compacted fill, kg/m^3.

5. RESULTS AND DISCUSSION

Six preliminary per caput solid wastes generation rates measurements were carried out with the following results: 0.05, 0.033, 0.05, 0.075, 0.3, and 0.15 kg/capita.day. Based on this information, the observed samples mean and variance are estimated to be 0.109 kg/capita.day and 0.0104 $(kg/capita.day)^2$, respectively. A specified error level of 5% is selected

corresponds to 95% confidence that the samples mean value is an accurate estimate of the true value. For the students t table, $t_{95\%}$ = 2.571 (the α = 0.025 column is used because 2×0.025 = 0.05 or 5% which is the error level for the 95% confidence level). The number of measurements required for 95% confidence limits with 0.067 kg/capita.day deviation from the true value is estimated to be 15.27 samples, round up to 16 samples.

Seventeen solid wastes generation rate measurements were carried out in Baghdad Al-Jadida district. The observed mean generation rate is 0.107 kg/capita.day. Accordingly, the interval from $\overline{X} - 2.120 \times 0.075 \div \sqrt{17-1}$ = 0.066 kg/capita.day to $\overline{X} + 2.120 \times 0.075 \div \sqrt{17-1}$ = 0.147 kg/capita.day or 0.1708 ±0.044482 kg/capita.day is an approximate 95% confidence interval for the true solid wastes generation rate. The variation of solid wastes generation rate along the sampling period is shown in Fig. (2). The observed solid wastes generation rate range from 0.015 to 0.3 kg/capita.day. The frequency distribution of the observed solid wastes generation rate is shown in Fig. (3). 41% of the observed generation rates fall in the range from 0.015 to 0.072 kg/capita.day.

Table (1) shows comparison between the estimated amount of solid waste generated per person created by residences over one day on Baghdad city and other worldwide values. The data listed in Table (1) shows that the solid waste generation rates differ considerably from country to another due to different income rates and life styles. Generally, the value estimated in Iraq – Baghdad is approximately close to the value reported in Nigeria, Vietnam and Ethiopia, but considerably lower than the values reported in USA and Poland.

The landfill space does Baghdad city requires for 20 years of operation is computed by using the following assumptions: A cell height of 2.4 m, 0.15 m of soil is used for daily cover, 0.3 m to complete the cell; and a final cover of 0.6 m for every stack of three cells. The compaction is assumed to be normal.

For assumed Baghdad's population of 7 million persons, the mass generated per year is estimated as below:

$$\text{Mass} = 0.107 \frac{\text{kg}}{\text{day.person}} \times 365 \frac{\text{day}}{\text{year}} \times 7 \times 10^6 \text{persons} = 373.385 \times 10^6 \frac{\text{kg}}{\text{year}}$$

The mean density of the compacted solid waste is 106 kg/m^3 [2], with a compaction ratio of 4.18 (compaction ratio is the ratio of the density after compaction to that as discarded, that is, before pickup by collection vehicle [2]), the density of the compacted fill is estimated to be:

$$D_c = 106 \frac{\text{kg}}{\text{m}^3} \times 4.18 = 443 \frac{\text{kg}}{\text{m}^3}$$

For a five-day week, the daily volume of solid waste and the area over which it will be spread are estimated as follows:

$$V = \frac{373.385 \times 10^6 \text{kg/year}}{443 \text{kg/m}^3} \times \frac{1}{52 \text{week/year}} \times \frac{1}{5 \text{days/week}} = 3241.7 \frac{\text{m}^3}{\text{day}}$$

If this is spread in 0.3 m layer, then the area would be:

$$\frac{3241.76 m^3/day}{0.3m} = 10805.666 \frac{m^2}{day}$$

This is equivalent to 103.95 m on each side. This seems to be reasonable for a large community such as Baghdad.

If 0.15 m of soil is used as cover each day, then 0.45m will be placed each day and it will take (2.4 m – 0.15 m)/0.45 m/day = 5 days to complete the cell (the 0.15 m is the addition to daily cover to complete the cell with 0.3 m of cover). At this rate, a stack of three cells will be completed every three weeks (15 working days).

The soil volume separating a stack of three cells will be about:

0.3 m (thick) × 2.4m (high) × 103.95 m (long) × 3 cells = 224.53 m^3

To account for two sides of the cell, this number needs to be multiplied by two:

224.53 m^3 × 2= 449.06 m^3

The soil volume per stack of three cells is calculated as follows:

$$3 \frac{cells}{stack} \times 5 \frac{lifts}{cell} \times 10805.666 m^2 \times 0.15m = 24312.748 m^3$$

Plus the 0.15m of additional soil to bring the weekly cell cover to 0.3m is:

$$3 \frac{cells}{stack} \times 10805.666 m^2 \times 0.15m = 4862.54 m^3$$

Plus the additional 0.3m to bring the final cover to 0.6m:

10805.666 m^2 × 0.3 m = 3241.6998 m^3

The total soil volume, including the 449.06 m^3 for the sides of the stack, is:

24312.748 m^3 + 4862.54 m^3 + 3241.6998m^3 + 449.06 m^3 = 32866.047 m^3,

The volume of V_{sw} would then be:

$$V_{sw} = 3241.6998 \frac{m^3}{day} \times 15 \frac{day}{stack} = 48625.497 \frac{m^3}{stack}$$

The value of E in equation (4) would then be:

$$E = \frac{48625.497 + 32866.047}{48625.497} = 1.675$$

Then equation (4) is used for estimation of volume requirement for 20 years:

$$V_{LF} = \frac{373.385 \times 10^6 kg/year \times 1.675}{443 kg/m^3} \times 20 years = 1.411 \times 10^6 m^3$$

Since the average landfill depth will be three 2.4 m cells plus an additional 0.3 m final cover, the area will be:

$$A_{LF} = \frac{1.411 \times 10^6 \, m^3}{3(2.4) + 0.3} = 0.1881 \times 10^6 \, m^2$$

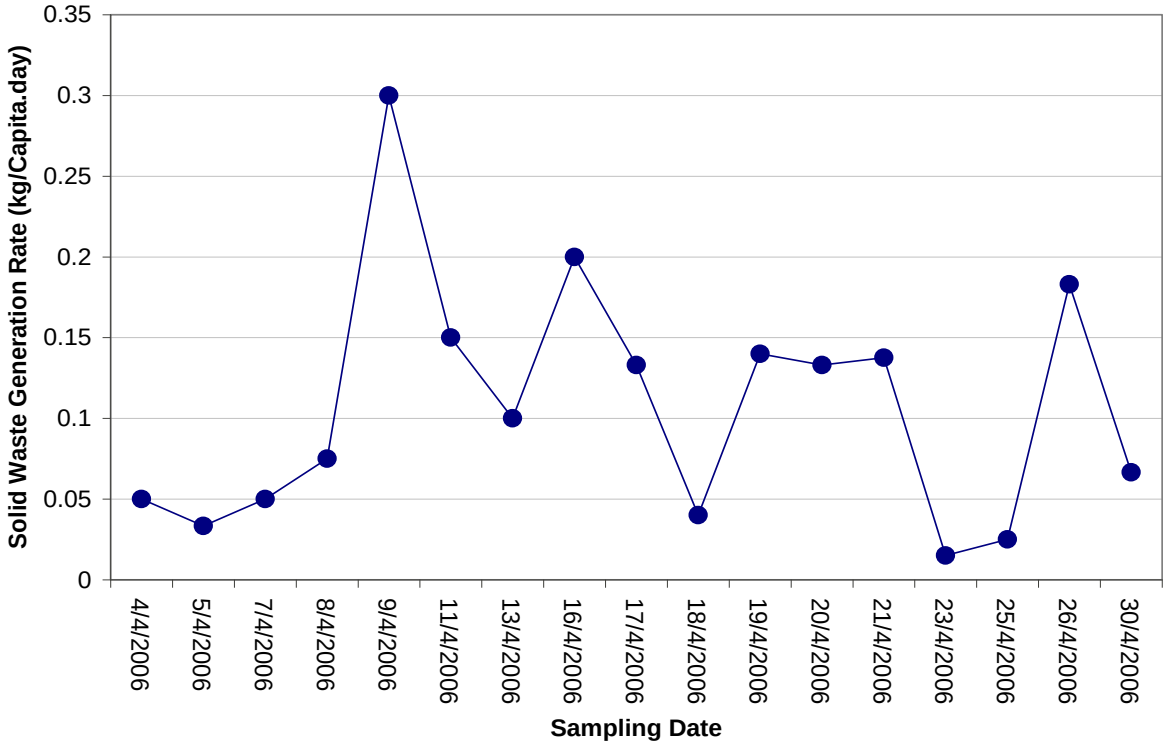

Figure 2. The variation of solid wastes generation rates along the sampling period

Table 1. Comparison between the estimated municipal solid waste generation rates per capita on a daily basis on Iraq and other worldwide values.

Country – city	Solid waste generation rates (kg/capita.day)	Reference
Iraq – Baghdad	0.107	Current study
Kashmir – Pakistan	0.484	[7]
California – USA	5.4	[8]
Poland – Oregon	3.19	[9]

Nigeria – Port Harcourt	0.22	[10]
Vietnam – Mekong Delta	0.285	[11]
Ethiopia	0.253	[12]
South Africa	0.7	[13]

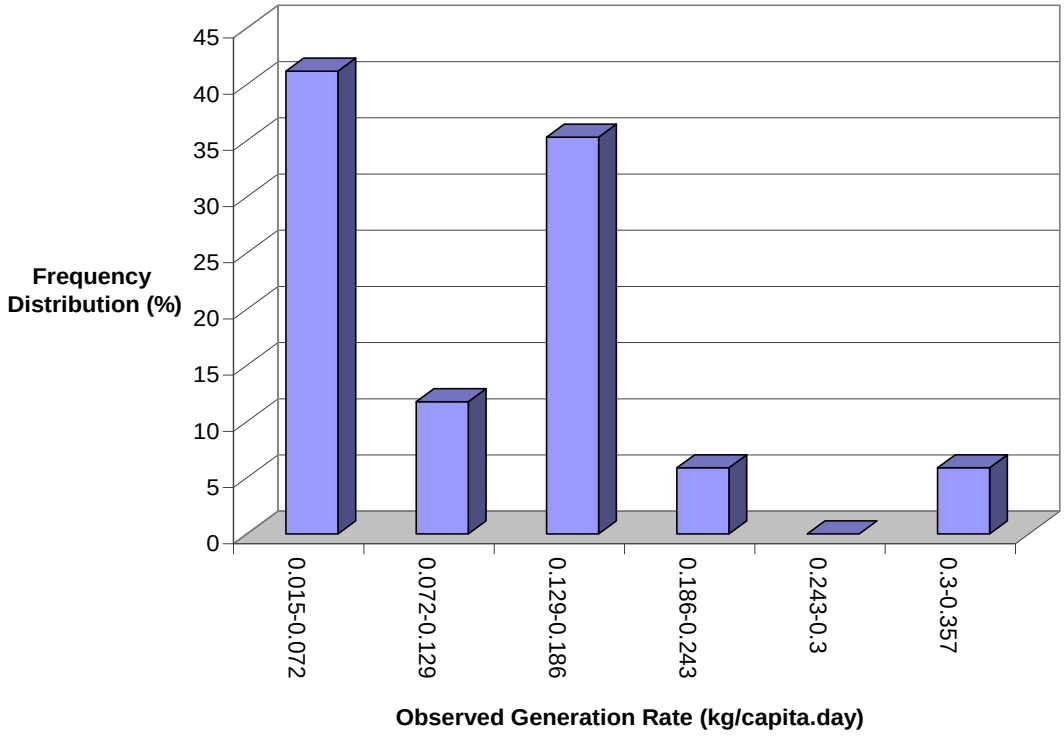

Figure 3. Frequency distribution of the collected data

6. CONCLUSION

A simple method for estimating the solid waste generation rate in Baghdad city was developed by weighing the amounts of municipal solid waste generated per day by a family consists of 10 individuals. A total of 17 measurements were taken at 2006 to determine the average solid waste generation rate. The mean solid waste generation rate estimated in this study (0.107 kg/capita.day) was found to be lower than values reported in the literature. An area of approximately 0.1881×10^{6} m^2 would be required for the next 20 years for disposal of solid wastes generated in Baghdad city.

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