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Efficient Resource Recovery Options from Municipal Solid Waste: Case Study of Patna, India

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ABSTRACT

Solid waste management is one of the biggest issues in India as well as in the world. The generation of solid waste should be estimated for proper management of municipal solid waste (MSW) of the cities. The segregation, collection, transportation and disposal of MSW are currently done in very unscientific and causal way in India and in many other developing countries. This creates problem for environment in terms of water, air and odour pollution. In this study, the characteristics of MSW have been estimated for Patna city and management has been carried out for recovery of resources. The components of MSW have been estimated and based on that, moisture, density and energy content have been quantified. Afterwards, chemical compositions have been calculated and chemical formula has been made for MSW. This composition can help to estimate requirement of oxygen to degrade MSW and recovery of methane and carbon dioxide from MSW. Generally, landfill for solid waste management is planned for fifteen years or more than that. It is carried out in several parts or layers which take many years. In this paper, the calculation of energy content, requirement of oxygen to degrade MSW and recovery of methane, carbon dioxide from MSW have been carried out for a year which can be done for whole landfill period.

Keywords: Physical Characteristics, Energy Contain, Chemical Characteristics.

INTRODUCTION

Uncontrolled growth of the urban population in developing countries in recent years has made solid waste management an important issue[1]. The rate of urbanization has improved quality of life but at same time it has adverse effect on environment. Urbanization is increasing the level of air, noise, water pollution and solid waste generation their complexities[2]. Few decades ago, environment was not of any concern of scientific efforts for developing countries like India and even solid waste management was not prime concern in developing countries. The quantity of municipal solid waste (MSW) has increased tremendously with improved life style and social status of the populations in urban centers[3]. Waste management and disposal is a big issue that India is facing today, since about 90% of waste is currently disposed of by open dumping[4]. The generation of solid waste causes air, water and odour pollution. The municipal solid waste management is not well structured at many places in India[5]. Municipal corporations in developing countries are not able to handle increasing quantities of waste, which results in uncollected waste on roads and in other public places[6]. Solid waste management is one among essential services provided by municipal authorities in the country to keep urban centers clean. It has been noticed that 90% is dumped in open area which creates problem to public health and the environment[7]. The mixed municipal solid waste are dumped at the site and left to self-degradation and management[8]. Looking at the situation of MSW, some non-governmental organizations initiated working in the direction to highlight the pathetic situation of MSW of Indian cities. The activities of the public and various organizations resulted in the importance of MSW aspects of environmental management. MSW is an essential by-product of everyday living[9]. The proper segregation at the site, collection from the site, transportation and disposal to landfills site could be effective to manage MSW[10]. Geographical Information System (GIS) based approach is used for selecting optimum routing option for transportation of MSW[1]. The important role also can be seen of Zero waste technology using reuse and recycling the waste.

The study is carried for solid waste management in Patna city. It generates 511 Ton/day solid waste where 51.96% compostable, 12.57% recyclable, 36% moisture and 0.37 kg/c/day waste generation rate with 18.62 C/N ratios [11]. MSW in Patna is disposed of in an unscientific manner without considering environmental impacts[2]. The amount of recovered methane gas is estimated here.

Study Area

Patna city is situated at Southern Bank of Ganga with 'B' category of town. The city is approximately 35 km long and 16 km wide and divided into seventy two wards. This is the capital of Bihar state of India whose population is 13.7 lakh as per 2001 Census and area is 107 km^2. Studies are done for the solid waste problem in six areas of Patna with reference to the total generation of solid waste/day/household, quality of the solid waste, awareness level and performance of Patna Municipal Corporation (PMC).

Methodology

A review for municipal solid waste management of India reported physical characteristics of municipal solid waste for many metrocities[12]. So, the physical characteristics of solid waste for Patna city were taken from a study [12]. The typical percentage of moisture content, density and energy content for each component were used to calculate the same for MSW in this study[13]. Chemical composition was estimated for MSW using typical values of MSW component[14]. Chemical characterization was done for carbon, hydrogen, oxygen, nitrogen and sulfur for each component of MSW then the same was calculated for MSW. Afterwards, mass was calculated for chemical composition and chemical formulation was made using molar weight.

RESULTS AND DISCUSSION

Moisture content (%), dry mass (kg), volume and total energy for MSW have been calculated in Table 1. The overall moisture content and density for MSW is 35.43% and 204 kg/m^3. The energy content as discarded solid waste is 8.4 MJ/kg while energy content for dry ash and ash free dry ash are 13 and 14.1 MJ/kg respectively. Here, 5% ash content was assumed.

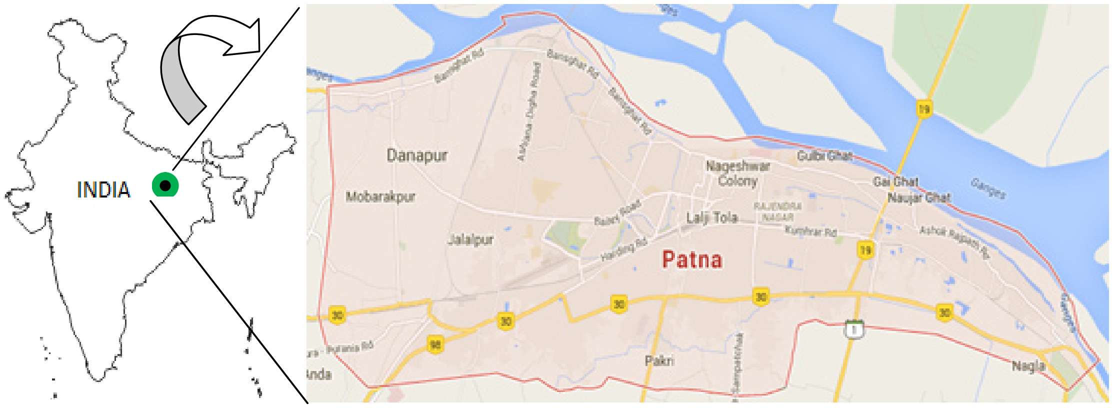

Fig. 1: Study area "Patna"

Moisture Content (MC) = $\frac{\frac{100-64.57}{100}\times 100}{}$ = 35.43%

Density = $\frac{mass}{eqv\ volume}=\frac{100}{0.49}$ = 204 kg/m^3

Energy Content = $\frac{total\ energy}{tatal\ mass}=\frac{840}{100}$ = 8.4 MJ/kg as discarded

Energy Content (dry ash) = $E\times\frac{100}{100-\%MC}$

= $8.4\times\frac{100}{100-64.57}$ = 13 MJ/kg

Energy Content (Ash free dry ash) = $E\times\frac{100}{100-\%MC-\%Ash}$

= $8.4\times\frac{100}{100-5-64.57}$ =14.1 MJ/kg

The total MSW generation in Patna city is 511 tons/day and the total dry mass of MSW is 330 tons/day. The total energy content (Dry Ash) is 4.3×10^6 MJ/day while energy content (Ash free Dry Ash) is 4.4×10^6 MJ/day. The chemical composition of MSW has been shown in Table 2 and Table 3.

The oxygen requirement for MWS is 1.9×10^5 kg O_2/day or 1.33×10^8 L of O_2 /day to degrade MSW. The present MSW of Patna city

Table 1: Physical characteristics of solid waste for Patna city (By weight)

Name of Component	% of Composition	Moisture Content %	Dry Mass (kg)	Density (kg/m^3)	Volume (m^3)	Energy (MJ/kg)	Total Energy (MJ)
Paper	4	6	3.76	85	0.047	16.75	67
Textile	5	10	4.5	65	0.078	17..45	87.25
Leather	2	10	9.8	160	0.031	17.45	34.9
Plastic	6	2	5.88	65	0.092	32.60	195.6
Metal	1	3	0.97	320	0.003	0.70	0.7
Glass	2	2	1.96	198	0.010	0.15	0.3
Ash, fine other	35	8	32.2	480	0.073	7	245
Compostable	45	70	13.5	290	0.155	4.65	209.25
Total	100		64.57		0.49		840

Table 2: Chemical Characteristics of Solid Waste

Component	Wet mass (Kg)	Dry mass (kg)	C	H	O	N	S	Ash
Paper	4	3.76	1.64	0.864	5.076	0.351	0.054	0.675
Textile	5	4.5	2.475	0.23	1.65	0.0112	0.007	0.23
Leather	2	9.8	1.08	0.03	1.404	0.207	0.007	0.112
Plastic	6	5.88	3.53	0.144	0.208	0.18	0.007	0.18
Metal	1	0.97	-	0.42	1.34	-	-	0.59
Glass	2	1.96	-	-	-	-	-	-
Ash, fine other	35	32.2	8.47	-	-	-	-	-
Compostable	45	13.5	6.48	0.97	0.64	0.161	0.06	21.896
Total	100	64.57	23.68	2.76	10.32	0.910	0.13	23.68

Table 3: Ultimate Analysis of Combustible Components

Component	Mass (kg)	Kg/mole	Mole	Ratio w.r.t. S	Ratio w.r.t. N
C	23.68	12	1.97	492.5	28.14
H	2.67	1	2.67	667.5	38.14
O	10.32	16	0.645	161.25	9.14
N	0.91	14	0.07	17.5	1
S	0.41	32	0.004	1	

can generate methane gas (CH_4) 2.46×10^5 kg/day 3.44×10^8 L/day and carbon dioxide (CO_2) 5×10^5 kg/day or 2.55×10^8 L/day. The recovery from solid waste can be utilized to proper landfilling of MSW.

$C_{492.5}H_{667.5}O_{161.25}N_{17.5}S$ ... (1)

$C_{28.14}H_{38.14}O_{9.14}N_{17.5}$ ...(2)

Molecular weight = 536.06 kg

Oxygen required for complete aerobic stabilization

$$C_aH_bO_cN_d + \frac{4a+b-2c-3d}{4}O_2 \rightarrow a\,CO_2 + \frac{b-3d}{2}H_2O + dNH_3$$

a = 28.14, b = 38.14, c = 9.14, d = 1

$$\frac{4a+b-2c-3d}{4} = 32.35$$

Since 536.06 kg solid waste requires 32.35×32 kg O_2

So 5.1×10^5 kg solid waste requires

$$\frac{32.35\times 32}{536.06}\times 5.1\times 10^5 \text{ kg } O_2 = 1.9\times 10^5 \text{ kg } O_2\text{/day}$$

At S.T.P.

32 kg O_2 = 22.4×10^3 lit of O_2

$$1.9\times 10^5 \text{ kg } O_2 = \frac{22.4\times 10^3}{32}\times 1.9\times 10^5$$

L = 1.33×10^8 L of O_2 /day

Recovery of Methane gas

$$C_aH_bO_cN_d + \frac{4a-b-2c+3d}{4}O_2 \rightarrow \frac{4a+b-2c-3d}{8}CH_4 + \frac{4a-b+2c+3d}{4}CO_2 + dNH_3$$

$$\frac{4a+b-2c-3d}{8} = 16.175$$

Since 536.06 kg solid waste produced 16.175×16 kg CH_4

So 5.1×10^5 kg solid waste required

$$\frac{16.175\times 16}{536.06}\times 5.1\times 10^5 \text{ kg } CH_4$$

= 2.46×10^5 kg CH_4/day

At S.T.P.

16 kg CH_4 = 22.4×10^3 lit of CH_4

2.46×10^5 kg CH_4 = L = 3.44×10^8 L of CH_4/day

Recovery of Carbon dioxide gas

$$\frac{4a-b+2c+3d}{4} = 11.96$$

Since 536.06 kg solid waste produced 11.96×44 kg CO_2

So 5.1×10^5 kg solid waste required

$$\frac{11.96\times 44}{536.06}\times 5.1\times 10^5 \text{ kg } CO_2$$

= 5×10^5 kg CO_2/day

At S.T.P.

44 kg CO_2 = 22.4×10^3 lit of CO_2

$$5\times 10^5 \text{ kg } CO_2 = \frac{22.4\times 10^3}{44}\times 5\times 10^5$$

L = 2.55×10^8 L of CO_2/day

CONCLUSIONS

In India and many other developing countries, the segregation, collection, transportation and disposal of municipal solid waste (MSW) are generally done in a very unscientific way presently. This leads problems for environment in terms of water, air and odour pollution. This paper presented a study for solid waste management for an urban city Patna of India. The components of MSW have been estimated and based on that, 35.43% moisture, 204 kg/m^3 density and 14.1 MJ/kg (dry ash) energy content have been quantified. Afterwards, chemical compositions have been calculated and chemical formula has been made as $C_{28.14}H_{38.14}O_{9.14}N_{17.5}$ for MSW. This composition can help to estimate 1.33×10^8 L of O_2/day requirement of oxygen to degrade MSW and recovery of 3.44×10^8 L of methane/day and 2.55×10^8 L of carbon dioxide/day from MSW.

Generally, landfill for solid waste management is planned for fifteen years or more than that. It is carried out in several parts or layers which take many years. The calculation of energy content, requirement of oxygen to degrade MSW and recovery of methane, carbon dioxide from MSW have been carried out for a year which can be extended for whole landfill period.

REFERENCES

1. M. K. Ghose, a K. Dikshit, and S. K. Sharma, "A GIS based transportation model for solid waste disposal-a case study on Asansol municipality," *Waste Manag.*, **26**(11): pp. 1287–1293 (2006).
2. K. Kumari, N. Ranjan, and R. C. Sinha, "Solid waste management in Patna – analyses of ambient air and ground water pollution," *Int. J. Environ. Technol. Manag.*, **14**: 310–325, 2011.
3. S. Kumar, J. K. Bhattacharyya, A. N. Vaidya, T. Chakrabarti, S. Devotta, and A. B. Akolkar, "Assessment of the status of municipal solid waste management in metro cities, state capitals, class I cities, and class II towns in India: An insight," *Waste Manag.*, **29**(2): 883–895 (2009).
4. T. Narayana, "Municipal solid waste management in India: From waste disposal to recovery of resources?," *Waste Manag.*, **29**(3): 1163–1166, (2009).
5. N. Gupta, K. K. Yadav, and V. Kumar, "A review on current status of municipal solid waste management in India," *J. Environ. Sci.*, **37**: 206–217 (2015).
6. S. Rathi, "Alternative approaches for better municipal solid waste management in Mumbai, India," *Waste Manag.*, **26**(10): 1192–1200, (2006).
7. M. Sharholy, K. Ahmad, G. Mahmood, and R. C. Trivedi, "Municipal solid waste management in Indian cities – A review," *Waste Manag.*, **28**(2): 459–467 (2008).
8. S. Gupta, K. Mohan, R. Prasad, S. Gupta, and A. Kansal, "Solid waste management in India: Options and opportunities," *Resour. Conserv. Recycl.*, **24**(2): 137–154 (1998).
9. P. K. Srivastava, K. Kulshreshtha, C. S. Mohanty, P. Pushpangadan, and A. Singh, "Stakeholder-based SWOT analysis for successful municipal solid waste management in Lucknow, India," *Waste Manag.*, **25**(5): 531–537, (2005).
10. K. Kumari, S. R. Singh, and R. C. Sinha, "Role of pollution control boards in municipal solid waste management Kanchan Kumari," *Int. J. Environ. Technol. Manag.*, **17**: 100–112 (2014).
11. CPCB, "Management of Municipal Solid Waste," *Cent. Pollut. Control Board (Ministry Environemntal For.*, p. Government of India, (2000).
12. M. Sharholy, K. Ahmad, G. Mahmood and R. C. Trivedi, "Municipal solid waste management in Indian cities – A review". *Waste Manag.* **28**: 459–467(2008). doi:10.1016/j.wasman.2007.02.008
13. S.M. Ali, A.P. Cotton, and K. Westlake,. "Down to Earth: Solid Waste Disposal for Low-Income Countries", WEDC, Loughborough University, UK (1999).
14. G. Tchobanoglous, H. Theisen, and R. Eliassan, "Solid WastesEngineering Principles and Management Issues", McGraw-Hill Book Company, New York, (1999).