Solid Waste Management of Dehradun City based on its Physical and Calorific Energy Potential.

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DOI: 10.29322/IJSRP.11.05.2021.p11361
http://dx.doi.org/10.29322/IJSRP.11.05.2021.p11361

Abstract- Due to increase in population the rate of generation of solid waste keeps on accumulating, putting pressure on the city and its environment. Municipal solid waste in city is unorganized due to deficiency of infrastructure, proper disposal plan and well managed dumping site. In this case study, an attempt has been made to quantify the sanitation facilities in Dehradun city for both present and future populations with respect to solid waste management system (SWMS). This study aims to find solutions related to (SWMS) and possibilities of resource recovery. It is done by collecting data through visits to organizations such as Pay Jal Nigam, Uttarakhand Jal Sansthan, Municipal Corporation, Solid waste plants, STPs and survey from local people. It has been observed that segregation of solid waste, negligence of waste collection, segregation, inadequate numbers of bins and transfer stations are the main issues that need to be addressed for effective solid waste management facilities in the city. Experiments involved proximate analysis, calorific content of MSW and reduced derived fuel (RDF) from MSW. The results of proximate, and calorific value test shows that municipal solid have high organic content, high moisture content and C/N ratio shows acceptable criteria for anaerobic digestion which can produce 1.5 m^3 of biogas/ kg of biomass. MSW of Dehradun city has potential to generate power of 8.68 MW, thus waste to energy plant is recommended near the waste treatment plant in the city as waste management option. Shishambada waste treatment plant generates around 200MT of RDF per day which can be used for energy generation.

Index Terms- Municipal Solid Waste (MSW), Waste to Energy (WTE), Pollution, Sanitation, Reduced Derived Fuel (RDF)

I. Introduction

There is a great impact on the environment due to the growth of civilization, population, industrialization and subsequent need for better living standards of human being. The major environmental problems are contamination of drinking water due to discharge of household and industrial effluents without proper treatment in nearby water bodies, land pollution due to disposal of solid waste and air pollution due to release of contaminants in atmosphere. This has adverse effects on natural resources even on underground water storage and air which further affects health of living beings [1]. Sanitation is the alarming issue in developing countries and still being neglected in most of the cases. Sanitation hygiene and cleanliness are the key factors of a civilized society. Sanitation is very important for social and economic development but increased population, increased rate of urbanization and industrialization coupled with improved life style is affecting the environment and natural resources which in turn affect human health and hygiene [2]. According to World Health Organization, "Sanitation is defined as the provision of the facilities and services for the safe disposal of human urine and feces". It refers to the maintenance of hygienic environment through services such as garbage collection, treatment and disposal. It is the hygienic way of promoting health through prevention of human contact with the hazardous waste as well as the treatment and disposal of sewage waste water [3].

The MSW management and handling regulation 2000 of India states that all local authorities including municipalities are responsible for the management of the wastes including collection, segregation, and transportation and recycling. After segregation, transportation and recycling the unwanted inert material should be separated and disposed separately [4].

For a fast-growing economy like India, it is necessary to have economical MSW strategic plans and their implementation in sustainable manner. Different waste to energy (WTE) technologies developed up to date such as biological, thermal, landfill gas utilization and bio-refineries have been assessed and suggested that these technologies are best way to manage waste and recover energy in developing countries [5]. The study on composition and characteristics of municipal solid waste, from various city of India such as Jaipur, Delhi, Northeast India etc., have high fraction percentage of degradable organic matter in waste which was one of main reasons for emitting methane gas and found that the waste can be converted to biogas since waste meets all the criteria for anaerobic digestion [6][7][8]. Municipal solid waste to formed by different types of waste, different composition of waste has its own combustibility and energy potential [9]. Siddharth and Sharma (2008) studied the energy potential of MSW of Haridwar city, India. The results of physical, proximate analysis show that bio gas production from waste was most appropriate method of waste to energy conversion [10]. In view of the poor management of MSW in open dump coupled with associated climate change issues, study by Choden et al., 2019 & 2020, reported that Roorkee city, Uttrakhand, India, generates 104 metric tons of MSW every day and average GHG emissions from Roorkee city estimated to 0.69 Gg/yr. As a waste management option, MSW of the city can generate 0.978 m^3/kg of biogas and has potential to generate 1.88 megawatt of electricity provided waste are immediately handled properly after its generation [11][12].

Kumar and Sharma (2013) estimated the GHG emission and its energy recovery potential from MSW landfill sites of Ghazipur (GL), Bhalswa (BL) and Okhla (OL) Delhi by using software LandGEM version 3.02. Results shows that after dynamic analysis of three landfill site, they have potential of total 6.5 MW electricity without subsidy and CDM [13].

This paper aims to study the potential of Municipal solid waste of Dehradun Uttarakhand, India as source of energy. The samples were collected, processed and analyzed for proximate and calorific content analysis. The data was used, to perform the suitability of conversion method and associated energy potential available provided the waste is managed properly as soon as it is generated.

II. MATERIALS AND METHODS

1.1 Site description

Dehradun is the capital city of Uttarakhand state and one of main administrative centers of North India. Dehradun city is well known for its natural beauty and its pleasant climatic condition throughout the year. Dehradun is surrounded by Himalaya range in north and Shivalik range in its south, Ganga River is flowing in its east and river Yamuna to the west side. The Doon valley is located between two holy Rivers i.e., Ganga and Yamuna. Dehradun city is surrounded by beautiful dense forest in its all directions and lots of streams and canals is flowing in the city from north to south direction. All the hills which surround the Dehradun city are rich in lime stone reserves [14].

Dehradun, the capital city of Uttarakhand is a famous educational hub of north India where people are migrating from different states. City is a tourism attraction point as it is in vicinity of hill station Mussoorie and yoga capital of the world Rishikesh. In the recent decades, there is sudden jump in population thus increasing number of residents and commercial buildings, educational buildings and hospitals, thus city needs a planning process for sanitation services. Under Swachh Bharat mission, Dehradun city got 384th rank out of 450 cities having population more than one lakh in Swachh Survekshan 2019, which was 259th in last year's ranking.

The city scored only 1342 out of 5000 in Swachh Survekshan 2019. This ranking indicates the requirement of planning for improvement in sanitation services in city. Many prestigious institutions of national importance like Indian Military Academy, Forest Research Institute, Indian Institute of Petroleum, Oil and Natural Gas Commission, Indian Institute of Remote Sensing, Wadia Institute of Himalayan Geology, Survey of India and National Institute of Visually Handicapped etc. are located in Dehradun city [14].

To study the general sanitation status based on MSW management, the following data are collected.

1. As per the population census 2011, the total population of Dehradun is 574,840 out of which 301,207 are males and 273,633 are females thus the average sex ratio of Dehradun is 908. Population is projected till 2041 using arithmetic increase method (Dehradun Municipal office, 2018).
2. According to the "Dehradun Nagar Nigam (DNN)" the city on an average generates about 250 MT of MSW per day at present. The assessment is based on the assumption of per capita generation @ 0.4kg/capita/day. At present MSW treatment plant at Shishambada is processing about 250 MT per day although its capacity is 400 MT (Dehradun Municipal office, 2018) .

Table 1: Shortage and surplus in SWM

Year	Population	Waste generation (MT)/day	Solid waste treatment /day (MT) capacity	Gap in service (MT)
2011	574840	229	250	21
2021	727180	290	250	-40
2031	879521	352	250	-102
2041	1031861	413	250	-163

As per the calculations, the waste treatment facility is sufficient at present but from 2021 onwards existing solid waste treatment facility in Dehradun will not be sufficient, we will need a plant with treatment capacity of 413 MT/day till 2041 (Refer Table 1).

1.2 Waste Characterization method

SWM plant at Shishambara was visited and samples of Compost collected from the plant were analyzed for it physical characteristics based on ASTM D 5231-92(2003) guidelines [15] and the results (refer Table 2) were compared with the standards of City Compost provided in the Manual for Bio fertilizers and Organic Fertilizers in Fertilizer (Control) Order, 1985.

Table 2: Physical characteristics of MSW

Samples	Paper	Organic matter	wood	textile	plastic	Glass	Rubber	Inert materials	Total (kg)
1	0.25	3.2	0.03	0.27	0.027	0.04	0.01	1.17	5
2	0.37	2.5	0.07	0.16	0.04	0.13	0.05	1.68	5
3	0.17	2.8	0.08	0.20	0.05	0.16	0.03	1.51	5
4	0.32	3.0	0.09	0.18	0.06	-	-	1.35	5
5	0.39	2.83	0.04	0.11	0.078	0.08	0.08	1.39	5

6	0.40	2.5	0.10	0.20	0.08	0.07	-	1.65	5
Total	1.9	16.83	0.41	1.12	0.335	0.48	0.17	8.75	30

Table 3: Average Chemical Composition of MSW

Parameters	**Average value**	**Standards**
pH	7.2	6.5-7.5
Moisture Content (% dry basis)	23.6	15-25
Total organic matter (% dry basis)	27.57	>20
Nitrogen content (% dry basis)	0.82	>0.80
Total organic Carbon (% dry basis)	15.99	>12
C/N ratio (% dry basis)	19.5	<20

1.1 Proximate analysis of MSW samples.

Proximate analysis was carried out to determine moisture content (MC), volatile matter (VC), ash contents and fixed carbon (FC). It is done in order to determine the heating potential of MSW as source of fuel. Test and analysis were conducted using standard procedure [16] [17] [18]. Results are presented in Figure 2. Table 3 shows the average chemical composition of MSW taken as % dry basis.

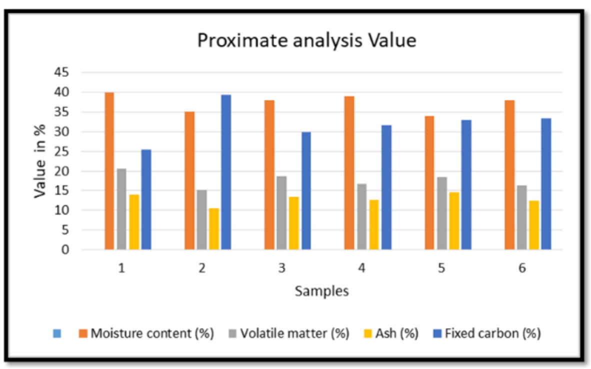

Figure 1: Proximate analysis Value

The calorific value is the energy content in waste based on its carbon, hydrogen content and moisture. The calorific value of the sample was determined using standard bomb calorimeter. The waste was dried and grinded into small pieces then they are made into small capsules. The bomb was assembled and filled with pressurized oxygen. The firing circuit was set and calorimeter was adjusted by weighing sufficient water into the vessel so that bomb is completely submerged in it. The bomb was fired and after the temperature stabilization the difference were noted and recorded as shown in figure. The calorific values of solid waste were calculated according to ASTM D240 [19].

$$\textbf{HHV}= \frac{\Delta T C_p}{Mg}$$

Where ΔT, Cp and Mg are change in temperature in K, heat capacity in MJ/Kg and mass of sample in Kg. The heating value can be calculated using following equation below:

$$CV = \frac{W * T}{M}$$

Where,

W= water equivalent of calorimeter (2218 cal/ºC)
T= Rise in Temperature in ºC (Temperature difference)
M= Weight of Sample (gm)
CV= Calorific value (Kcal/kg)

Given,

W= 2218 cal/ºC
T= 1.15 º C
M= 0.77 gm

CV= 2218 * 1.15ºC/ 0.77 = 3312.59 kcal/Kg

The calorific value obtained is observably high as per the standard. It could be due to high content of organic matter in waste composition. Proper segregation is required where organic matter can be composted and used as different source of energy such as biogas and converting to manure which was confirm by the RDF samples collected from SWM plant Dehradun. Its calorific value and moisture content are calculated using standard procedures and the results shows Moisture content as 36% dry basis and Gross Calorific Value 3200 (Kcal/kg).

III. RESULTS AND CONCLUSION

There is urgent need of awareness generation regarding solid waste management rules and policies in Dehradun and especially about the importance of solid waste segregation at source. Dehradun city generates around 250MT/day, city needs development of more transfer stations which should be completely covered so that garbage will not spread around.

Municipal solid waste generated in city is analyzed based on its physical composition. Major percentage of waste consist of organic food, textiles, paper and plastic. The results of proximate, and calorific value test shows that municipal solid waste cannot support incineration, but having high organic content, high moisture content and C/N ratio (refer table 3) shows acceptable criteria for anaerobic digestion which can produce 1.5 m^3 of biogas/ kg of biomass (theoretical calculation) and calorific content of 3312.59 kcal/Kg. Power generation from waste has become very efficient method to generate revenue and also solve the issue of solid waste accumulation and if handled properly, MSW of Dehradun city has potential to generate power and Shishambada waste treatment plant generate around 200MT of RDF per day which can be used for energy generation. An 8.68 MW (based on Calorific Value) waste to energy plant is recommended near the waste treatment plant in the city.

This case study shows that there is potential for energy recovery from MSW, study can be done for suitable plant for energy recovery from MSW and its cost analysis. Also, periodical education and awareness on waste management on at source level is suggested.

REFERENCES

[1] S. Mor, K. Ranvindra, A.D. Visscher, R.P. Dahiya and A. Chandra. Municipal solid waste characterization and its assessment for potential methane generation: a case study. Science of total environment, 2006, vol. 371, pp.1–10.

[2] CPCB Report. Municipal solid wastes (management & handling) rules, 2002, vol. 8(2).

[3] CPCB Report. Status of MSWS in Gwalior city, India, 2010.

[4] H.M. Murphy, E.A. McBean and K. Farahbakhsh. Appropriate technology- A comprehensive approach for water and sanitation in the developing world. Technology in Society, 2009, vol. 31(2), pp.158-167.

[5] D. Moya, C. Aldas, G. Lopez and P. Kaparaju. Municipal solid waste as a valuable renewable energy resource: a worldwide opportunity of energy recovery by using waste-to-energy technologies. Energy procedia, 2017, vol.134, pp.286–295.

[6] M. Gollapalli and S. H. Kota. Methane emissions from a landfill in north-east India: Performance of various landfill gas emission models. Environment Pollution, 2018, vol.234, pp. 174–180.

[7] J. Abhishek and M.K. Singhal. An Analysis of Treatment Options for Solid Waste by Characterization

[8] and Composition Study-A Case of Jaipur City. International journal of Emerging Trends in Science and Technology, 2014, vol. 1(03), pp.374–379.

[9] S. Mor, K. Ravindra, A. De Visscher, R. P. Dahiya, and A. Chandra. Municipal solid waste characterization and its assessment for potential methane generation: A case study. Science of total Environment, 2006, vol. 371, pp. 1–10, 2006.

[10] E. M. Khamala and A. A. Alex. Municipal Solid Waste Composition and Characteristics Relevant to The Waste – To-Energy Disposal Method for Nairobi City. Global Journal of Engineering, Design and Technology, 2013, vol. 2(4), pp. 1–6.

[11] S. Jain and M.P. Sharma. Feasibility study of power generation from municipal solid waste of Haridwar city. International Journal of Chemistry Science, 2008, vol. 6(4), pp.1920–1941.

[12] Y. Choden and M.P. Sharma. Energy Potential of Municipal solid waste of Roorkee city. Indian journal of Environmental Protection, 2020, vol. 40(4), pp.408-412

[13] Y. Choden and M.P. Sharma. 2019. Greenhouse gas estimation from municipal solid waste dump site in Roorkee (Uttrakhand), India. International Journal of Research in Environmental Studies, 2019, vol.6, pp. 39-46

[14] A. Kumar and M. P. Sharma. Estimation of GHG emission and energy recovery potential from MSW landfill sites, Sustain. Energy Technol. Assessments, 2014, vol. 5, pp. 50–61.

[15] JNNURM. City Development Plan: Dehradun Revised Under Jawaharlal Nehru National Urban Renewal, 2018.

[16] ASTM. Standard test method for determination of the composition of unprocessed municipal solid waste. D 5231 – 92. ASTM International, West Conshohocken, PA 19428-2959, U.S, 2003.

[17] ASTM. Standard test method for Ash in biomass. E1755 − 01. ASTM International, West Conshohocken, PA 19428-2959, U.S, 2015.

[18] ASTM. Standard test method for volatile matter in the analysis of particulate wood fuels. E872 − 82. ASTM International, West Conshohocken, PA 19428-2959, U.S, 2013.

[19] ASTM. Standard test method for Ash in wood. D1102 − 84. ASTM International, West Conshohocken, PA 19428-2959, U.S, 2013.

[20] ASTM. Standard test method for gross calorific value of solid fuel by the adiabatic bomb calorimeter. US, 1975.

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