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CHARACTERIZATION AND CATEGORIZATION OF MUNICIPAL SOLID WASTE OF A DISPOSAL SITE: AN INVESTIGATION FOR SCIENTIFIC MANAGEMENT

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ABSTRACT

Appropriate disposal of solid waste is the most crucial concern in the contemporary urban localities especially in developing countries. Assessment of municipal solid waste composition was carried out from May to October 2019 in Hisar, India in order to amend the management approaches. The major fractions of the total wastes were food waste (34.82%), polythene (16.39%), paper (4.02%) and plastic (3.69%). The laboratory assessment was also performed for various physico-chemical characteristics of the solid waste. The observed value of different parameters were pH = 8.21, moisture content = 33.95%, volatile content = 44.38%, total organic carbon (TOC) = 20.19% and calorific value = 7165.47 kJ/kg. Without proper segregation almost all of waste generated is disposed of on dumping site. The paper, plastic and cardboard can be recycled, but were not recycled.

KEY WORDS : Municipal solid waste composition, Physico-chemical characteristics, Dumping site, Biodegradable waste, Calorific value

INTRODUCTION

The per capita solid waste generation has increased tremendously with changing life style, growing population, urbanization, socio-economic growth and industrial or technical development (Rong *et al.*, 2017). Globally, urban solid waste was accounting to 2.01 billion tons (BT) in 2016 and it is estimated to increase about 3.4 BT by 2050 (Kaza *et al.*, 2018). Yearly, India produces about 62 million tons of municipal solid waste (MSW) with generation rate of 0.4 kg/capita/day (Choudhury and Dutta, 2017).

In India, open dumpsites had been a prevalent approach for the disposal of MSW. Most of the solid waste is dumped on road side and low lying area of urban locations (Nain and Lohchab, 2015; Kumar *et al.*, 2017). More than 90% of total MSW is dumped on landfill site without any scientific planning such as waste segregation at source, recycling, reuse, treatment and proper disposal of waste (Ramachandra *et al.*, 2018). However, this leads to mixing of wet and dry waste without proper segregation and waste disposal in drainage system or open dumping. The inadequate and inappropriate disposal of solid waste can contaminate the air, water and soil which have hostile effect on human health and natural environment (Yildiz *et al.*, 2013; Snehlata *et al.*, 2015). Furthermore, the existing dumpsites are also facing numerous other problems. In India, mostly dumping sites have exhausted their ability and are operating beyond their lifespan (Sharholy *et al.*, 2008). Bhalaswa, Okhla and Ghazipur dumping sites in Delhi and Deonar dumping site in Mumbai have spent their capability, although are still running due to shortage of land for waste disposal (Kumar, 2013). In India, 20 m height is the maximum permissible limit for rubbish dump, but most of the dumpsites have already traversed the limit. For example, Ghazipur dump site crosses the height of 50 m (Singh and Chandel, 2020).

Most of studies related to characterization of solid waste performed primarily comprise of manual segregation of waste into various components i.e. paper, fabric, plastic, wood, glass, metal and inert matter. The physio-chemical characteristics of MSW are essential for testing the viability of dumping site. For instance, bulk density is a crucial constraint to determine the capability of recycling and retrieval facility. Likewise, moisture content of MSW is significant to assess the valorization approach (thermal, biological or recycling) of the solid waste. The MSW composition has more or less a similar trend all over the world with change in proportions because of variation in economy, traditional customs and climatic conditions (Khajuria *et al.,* 2010).

On the other hand, there was few comprehensive scientific information and data available about chemical and physical characteristics of MSW of Hisar. Moreover, composition analysis of solid waste is essential to enhance management of solid waste. Hence, as the research was conducted to examine composition and characteristics of MSW from dumping site of Hisar city to understand existing solid waste management and recognizing factors accountable for inappropriate MSW management in the city.

MATERIALS AND METHODS

The study was carried out from May to October, 2019 on the basis of seasonal variation which considers the periods of pre-monsoon, monsoon and post-monsoon. The pre-monsoon period is representative of the two months of dry hot climate (May and June with average temperatures of 35–42 ^{o}C). Likewise, the monsoon period is considered to represent the two months with rainfall (July and August with average temperatures of 28–35 ^{o}C) and the post-monsoon period is representative of the two months with humid climate (September and October with average temperatures of 25-32 ^{o}C).

Site description

The research was performed at the main dumping site of Hisar city which is located in Dhandoor village, 8 km from Hisar at Sirsa Road on National Highway 9 (Fig. 1). The site is open dumping type having disposable area 19 acre which was build up in year 2010. According to municipal corporation Hisar, the population of Hisar city is 367,472. There are 20 wards and 120 solid waste collection points in the city. The MSW generated is collected or managed by Nagar Nigam Hisar.

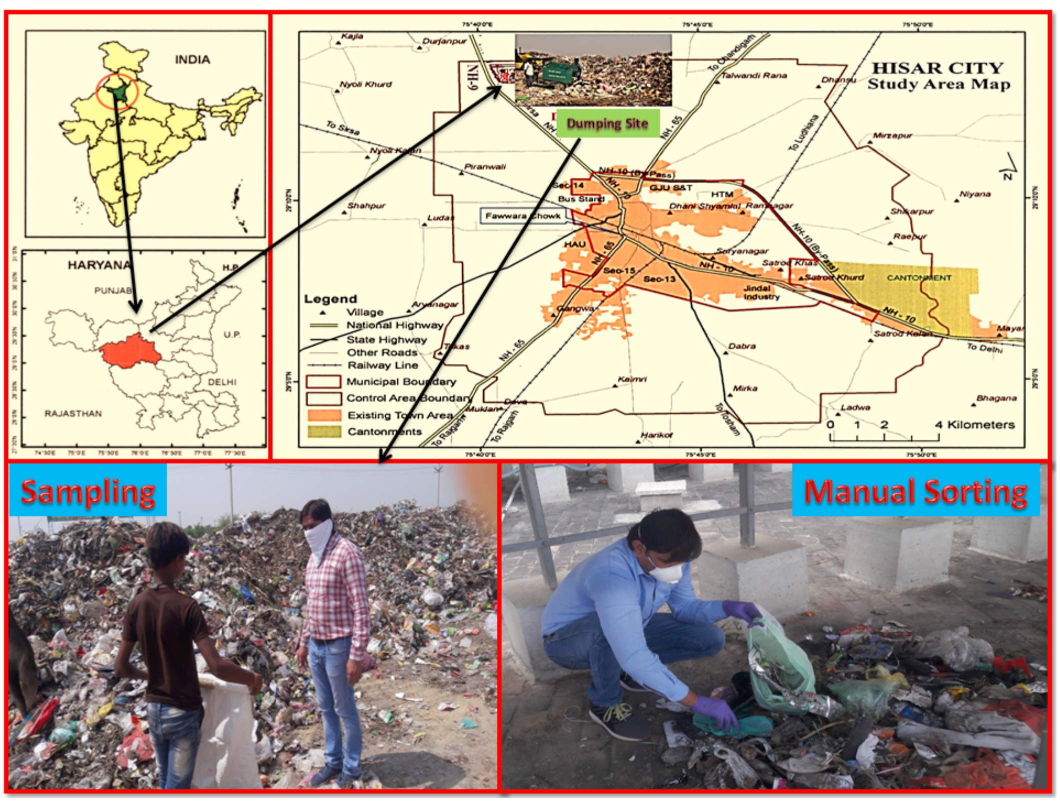

Fig. 1. Map of MSW dumping site of Hisar city at Dhandoor

Determination of generation rate

The data of MSW generation was collected from municipal authority and generation rate was calculated by using equation (Palanivel and Sulaiman, 2014).

$$\text{Generation Rate (Kg/capita/day)} = \frac{\text{Total waste generated/day}}{\text{Total population}}$$

Composition of MSW

The municipal solid waste composition was assessed according to standard method (ASTM D5231-92, 2016). MSW samples were randomly collected from the dumpsite at Dhandoor village, the main dumping site of Hisar city. The sample was properly mixed and coned and quartered to reduce the weight of MSW. This sample was then manually segregated into various fractions such as food waste, cardboard, paper, sanitary waste, textile, yard waste, polythene, plastics, glass, metals etc.

Physico-chemical assessment

After finding the composition, 2 kg of this mix sample was carried to the laboratory to analyze different physico-chemical parameters. The characteristics of MSW samples like moisture content and volatile contents were analysed according to (ASTM D2974-20e, 2020). Calorific value of mixed sample was determined with the help of bomb calorimeter (MAC) using standard method (ASTM D5468-02, 2007). Ultimate analysis of total organic carbon was carried out with the help of TOC-V analyzer (Shimadzu) using zero air as a carrier gas and pH, EC, TKN, sulphur and phosphorus were analyzed in laboratory by using standard methods (APHA, 2015).

RESULTS AND DISCUSSION

Generation of MSW

During 2001, the per capita MSW generation rate of Hisar city was 349 g per day and population of the city was 263186. But population of the city was increased to 346879 in 2011 and rate of waste generation raised to 398 g/capita/day (Annepu, 2012). But in 2019, the average total MSW generated in Hisar city was about 169 MT/d with the population 367,472 and per capita rate of waste generation was 0.460 kg per day (Fig. 2).

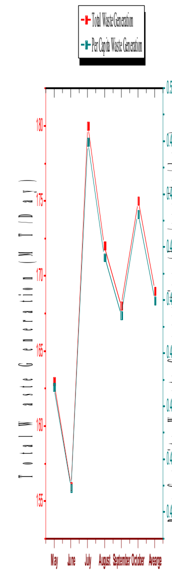

Fig. 2. Municipal solid waste generation rate of Hisar city

MSW disposal practices

Hisar municipality collects MSW every day except Sundays. The manpower involved for MSW collection were one chief sanitary inspector, two sanitary inspectors, four assistant sanitary inspectors, six operation supervisors, forty nine drivers and seven hundred twenty sweepers. Municipal solid waste is door-to-door collected or dumped by populations in large and small communal bins. The MSW in the community bins is transferred to the dumping site. The municipality has 8 auto-tippers of 1.0 metric tons capacity, 13 tractor-trailers of 1.5 metric tons capacity, 6 dumpers of 2.5 metric tons, 20 E-rickshaws of 100 kg capacity, 140 tricycles, 50 handcarts and 2 JCB to transport solid waste to the dumping site. Currently, the city has only one dumping site on the Delhi-Sirsa National Highway (NH-9) where garbage is frequently dumped on open land beside the road. Such kind of dumping along a National Highway is illegal. The site does not have leach-proof systems, gas and leachate collection or treatment systems.

A severe restraint in locating a dumpsite for Hisar municipality region is the adjacency of the National Highway. There have been calamities due to scavenger animals strike with vehicles. Another major problem is closeness of dumping site to residential area. The dumping site is close to Dhandoor village, a densely populated residence area on the side of NH-9 which is hardly 300 m away from site. As per schedule-I(A)(vii) of solid waste management rules 2016, the location of any dumping site should be at least 200 m away from the highways and human settlements. The perennial fire in the garbage dump is polluting the village which causes several diseases like tuberculosis, respiratory diseases, skin problems etc.

Composition of MSW

The composition of MSW represents the biodegradable, non-biodegradable and inert fractions of the waste which assist in determining the procedures of waste treatment and disposal. In this study, the MSW samples have been segregated in 17 different fractions. The solid waste comprises 56.85% biodegradable waste which is mainly organic in nature and 26.58% non-biodegradable waste which is mainly inorganic in nature (Table 1). The major fraction of total waste was food waste which accounts 34.82%. The food waste generally includes vegetable waste, fruit pill off, leftover food residue and decayed vegetables. The second most dominated component in MSW was polythene bags, which accounts for 16.39% by weight. The high fraction of polythene bags can be attributed to the extensive utilization of packing materials in the city. The third most represented waste component at dumping site was papers (office papers, newspapers, books and magazines) which accounts 4.02% followed by plastic and cardboard which accounts 3.69% and 3.44%. The fractions of paper, plastic and cardboard were low as compared to food, polythene bags and inert portions due to activities of rag picking during collection and disposal of waste. The samples also contained textiles and sanitary waste which accounts 3.66% and 2.27%. The textiles include old and torn clothes and gunny bags whereas sanitary waste includes sanitary pads, tissue paper and cottons. Glass, metal and wood observed in least quantity which accounts 2.12%, 2.04% and 1.27%. The miscellaneous waste was observed 6.34% which includes waste like straw, dry leaves, hair and dung. Hospital waste was also noticeable in the MSW which accounts 1.05%. It includes syringe, bandages, blood stained cotton and gloves etc. The MSW sample also contained high quantity of inert material which accounts 16.57%. This high quantity of inert material in waste of Hisar region is mainly because of street sweeping waste, demolition and construction waste in MSW. The similar study conducted in Jalandhar city also showed that 21–33% inert material was present in MSW (Sethi *et al.*, 2013).

Seasonal variation in composition of MSW

The seasonal variation in MSW composition is

Table 1. MSW composition of Hisar city at dumping site

Components	Composition by weight (%)						
	Pre-Monsoon		Monsoon		Post-Monsoon		Average
	May	June	July	August	September	October	
Biodegradable							
Food Waste	33.41	32.76	36.23	35.07	36.19	35.24	34.82
Paper	3.96	3.79	4.48	4.23	3.75	3.91	4.02
Textile	3.76	3.41	4.13	4.66	2.84	3.16	3.66
Cardboard	3.45	2.65	3.81	3.55	4.02	3.13	3.44
Sanitary waste	2.81	1.98	2.32	1.43	2.71	2.35	2.27
Wood	1.29	1.83	0.82	0.56	1.67	1.45	1.27
Leather	0.77	1.69	0.96	1.34	1.09	0.32	1.03
Miscellaneous*	5.62	5.94	7.37	6.68	5.23	7.18	6.34
Total	55.07	54.05	60.12	57.52	57.50	56.74	56.85
Non-biodegradable							
Polythene	16.19	15.59	17.28	16.82	17.12	15.37	16.39
Plastic	4.15	3.44	3.35	3.18	3.51	4.53	3.69
Glass	2.39	2.71	1.64	2.37	2.21	1.42	2.12
Metal	2.24	2.52	1.43	2.14	1.78	2.11	2.04
Hospital waste	0.75	1.64	0.91	0.62	0.86	1.54	1.05
Thermocole	0.61	0.73	0.28	0.52	0.45	0.59	0.53
Medical waste	0.48	Nil	0.66	0.89	0.52	Nil	0.42
Electrical Waste	0.37	0.51	Nil	0.65	Nil	0.49	0.34
Total	27.18	27.14	25.55	27.19	26.45	26.05	26.58
Inert**	17.75	18.81	14.33	15.29	16.05	17.21	16.57

* Includes waste like straw, dry leaves, hairs and dung

**Includes waste contains sand, ash, dust, gravel and demolition shown in Table 1. The seasonal variation probably arises due to diverse weather conditions and cultural traditions and customs. There was no substantial variation remarked in the other MSW components except food waste, polythene bags and inert. Food waste was considerably higher (35-36%) during monsoon period than the pre-monsoon (32-33%) which was probably a result of more consumption of vegetables and fruits during monsoon and availability of higher moisture content. There was slightly decline in proportion of food waste during post-monsoon period. The inert fraction was found greater during pre-monsoon period (17-18%) as compared to monsoon period (14-15%) because of more activities of construction and bad weather conditions like dust storm. The proportion of paper and textile were extreme during monsoon period because these materials absorb moisture during rainy season which increase the weight on wet basis.

Comparison of MSW composition

The MSW composition from various Indian cities and different countries are compared with Hisar dumping site and results are presented in Table 2. The composition represent that Hisar dumping site contains mostly similar proportion of compostable/food waste (food, vegetable and fruits) to the Indian cities, but higher than that of Oman and France. The waste from Indian cities comprises higher amount of food waste due to more consumption of fresh vegetables and fruits on daily bases. In compare to Hisar, numerous cities/countries have described compostable/food waste varying from 11.5% to 48.05 % of the total waste. The composition of Hisar MSW demonstrates greater portion of polythene bags because of larger utilization of these bags in wrapping and packaging. Recyclable items i.e. paper, cardboard, plastic, fabrics and metal are lower proportion in developing countries than those of developed countries as these countries consume larger quantity of plastic and paper in addition to electronic media. In India, recyclable materials are generally segregated from waste by rag picker at collection and disposal points. The inert matter (includes dirt, sand, soil and demolitions) is also present in large quantity because of the large activities of street sweepings, construction of buildings and burning of coal or wood.

Physico-chemical characteristics of MSW

The average values of various parameters are presented in Table 3. Density of solid waste performs a crucial role in establishing different techniques of waste handling during the collection, storage and transportation. The density of MSW of Hisar city was observed 486 kg/m^3 (±6.56). The pH of solid waste sample was 8.21, which was slightly alkaline in nature. The moisture content (MC) of solid waste was 33.95% (± 2.40). The study conducted in tricity (Chandigarh, Mohali and Panchkula) and Jalandhar city also presented 34–59% and 25-34% moisture content in the MSW (Sethi et al., 2013; Rana *et al.,* 2018). The moisture content personates a significant role to identify the constitution of the waste as high MC demonstrates existence of higher portion of compostable and organic materials. Volatile content (VC) of solid waste was 44.38% (±2.91). Total solids (TS) are the solids remained after the sample has been dried at 103–105 ^{o}C in an oven. When TS are ignited at 550±50 ^{o}C in a muffle furnace, the portion of

Table 2. Comparison of MSW composition among different Cities/Countries

Composition By weight (%)	This Study	Jalandhar[1] (India)	Solan[2] (India)	Nahan[2] (India)	Muscat[3] (Oman)	Ghana[4]	France[5]
Food/Compostable	34.82	35.0	46.93	37.88	12.31	48.05	11.5
Paper/Cardboard	7.46	3.2	7.31	6.59	19.25	5.36	18.7
Polythene/Plastics	20.08	6.5	3.68	11.27	28.75	14.30	15.7
Textile/Rags	3.66	12.3	4.22	5.87	7.21	1.16	0.3
Sanitary Waste	2.27	-	-	-	7.16	-	2.3
Metals	2.04	0.1	2.72	3.34	3.28	2.77	5.5
Glass	2.12	0.2	1.42	1.54	3.89	2.46	9.1
Leather/Rubber	1.03	0.5	4.18	3.97	-	1.07	-
Wood	1.27	2.0	4.55	6.29	1.49	1.31	3.1
Miscellaneous/Others	6.34	12.4	-	-	-	5.37	-
Inert	16.57	28.0	17.17	16.27	12.15	6.14	21.6

[1](Sethi *et al.,* 2013), [2](Verma and Tripathi, 2018), [3](Baawain *et al.,* 2017), [4](Miezah *et al.,* 2015), [5](Bayard *et al.,* 2018)

Table 3. Physico-chemical characteristics of municipal solid waste

Parameters	Pre-Monsoon	Monsoon	Post-Monsoon	Average
Density (kg/m^3)	479	492	487	486 ± 6.56
pH	7.85	8.56	8.34	8.21 ± 0.50
MC (%)	31.96	36.62	33.28	33.95± 2.40
VC (%)	44.26	41.54	47.35	44.38 ± 2.91
TS (%)	68.04	66.72	63.28	66.01 ± 2.46
FS (%)	23.78	24.18	17.93	21.96 ± 3.50
TOC (%)	18.47	22.31	19.78	20.19 ± 1.95
TKN (%)	0.79	1.08	0.91	0.93 ± 0.15
Phosphorus (%)	0.75	0.63	0.89	0.76 ± 0.13
Sulphur (%)	0.28	0.42	0.35	0.35 ± 0.07
C/N Ratio	23.38	20.66	21.74	21.92 ± 1.37
Calorific Value (KJ/Kg)	7089.74	7238.27	7168.40	7165.4 7± 74.31

residual solids is referred as fixed solids (FS) (Kumar and Goel, 2009). The TS and FS of the waste sample were 66.01% (±2.46) and 21.96% (±3.50). The total organic carbon (TOC) within sample was discovered to be 20.19% (±1.95). The other parameters like total kjeldhal nitrogen (TKN), phosphorus and sulphur contents were 0.93% (±0.15), 0.76% (±0.13) and 0.35% (±0.07). The information of calorific value of solid waste is essential to regain energy from the solid waste. The calorific/heating value of mixed solid sample was 7165.47kJ/kg (±74.31). This is generally because of the presence of higher polythene and plastic fractions in the waste which contribute more than two-thirds in the total content of energy. The calorific value more than 1000-6000 kJ/kg represented as a high heating value (Tian *et al.*, 2001). This very high calorific value of waste of Hisar city can be harnessed and recovered with the help of waste-to-energy processes (Bosmans *et al.*, 2013). The C/N ratio of the waste sample was 21.92 (± 1.37). The similar studies conducted in Asian countries reported the C/N ratio of 17 to 52% (Kumar *et al.*, 2009).

RECOMMENDATION AND SUGGESTIONS

The biodegradable and non- biodegradable components of MSW should be segregated at source so that organic portion of MSW can be utilized for composting. Composting involves home composting, complete aerobic or anaerobic composting and vermicomposting (Goel, 2008). The MSW component like plastic, paper, glass and metals can be recovered and reused at commercial in different manufacturing and industrial activities. The municipality area of Hisar requires more than one dumping site at different corners of the city. This will reduce the travel distance for the waste carrying vehicles and allow them to perform extra trips per day, thereby enhancing collection efficacy in the city.

CONCLUSION

Municipal solid waste characteristics of Hisar city represents that it has high proportion of organic material (56.85%) and inert (16.57%) in total waste generated. The organic waste present in MSW can be converted in organic manure with the help of composting process. Inert segments, involving street sweepings and construction and demolition waste, must be strictly banned from mixing with MSW. MSW of city has high bulk density because of larger quantity of organic and inert components of the waste. High calorific value of MSW suggests that energy recovery and waste to energy option is best for their management. Moreover, instead of the recent approach of open dumping, engineered or sanitary landfilling need to be planned.

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REFERENCES

Annepu, R. K. 2012. Sustainable Solid Waste Management in India. *Department of Earth and Environmental Engineering at Columbia University*. 1-189.

APHA. 2015. Standard methods for the examination of water and wastewater. *American Public Health*

Association, Washington, DC, *23rd ed.*

ASTM D2974-20e1. 2020. Standard Test Methods for Determining the Water (Moisture) Content, Ash Content, and Organic Material of Peat and Other Organic Soils. *ASTM International, West Conshohocken, PA*.

ASTM D3175-07. 2007. Standard Test Method for Volatile Matter in the Analysis Sample of Coal and Coke 1. *ASTM International, West Conshohocken, PA*. https://doi.org/10.1520/D3175-07.2

ASTM D5231-92. 2016. Standard Test Method for Determination of the Composition of Unprocessed. *ASTM International, West Conshohocken, PA*, (Reapproved).

ASTM D5468-02. 2007. Standard Test Method for Gross Calorific and Ash Value of Waste Materials. *ASTM International, West Conshohocken, PA*, 1-8.

Bosmans, A., Vanderreydt, I., Geysen, D. and Helsen, L. 2013. The crucial role of Waste-to-Energy technologies in enhanced landfill mining/: a technology review. *J Clean Prod.* 55 : 10-23. https://doi.org/10.1016/j.jclepro.2012.05.032

Choudhury, M. and Dutta, J. 2017. A comparative study of municipal solid waste management status for three major towns of Upper Assam-India. *Int J Waste Resour.* 7 (3). https://doi.org/10.4172/2252-5211.1000291

Goel, S. 2008. Muncipal solid waste management (MSWM) in india a critical review. *J Environ Sci Eng*. 50(4) : 319-328.

Kaza, S., Yao, L., Bhada-Tata, P. and Woerden, F. V. 2018. *What a Waste 2.0/: A Global Snapshot of Solid Waste Management to 2050.* Urban Development, Washington, DC: World Bank. © World Bank. Retrieved from https://openknowledge.worldbank.org/handle/10986/30317

Khajuria, A., Yamamoto, Y. and Morioka, T. 2010. Estimation of municipal solid waste generation and landfill area in Asian developing countries. *J Environ Biol.* 31(5) : 649-654.

Kumar, A. 2013. Existing situation of municipal solid waste management in NCT of Delhi , India. *Int J Soc Sci.* 1(1) : 6-17.

Kumar, K. N. and Goel, S. 2009. Characterization of Municipal Solid Waste (MSW) and a proposed management plan for Kharagpur, West Bengal, India. *Resour Conserv Recy.* 53(3) : 166-174. https://doi.org/10.1016/j.resconrec.2008.11.004

Kumar, S., Bhattacharyya, J.K., Vaidya, A.N., Chakrabarti, T., Devotta, S. and Akolkar, A.B. 2009. 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 Manage.* 29(2) : 883-895. https://doi.org/10.1016/j.wasman.2008.04.011

Kumar, S., Smith, S.R., Fowler, G., Velis, C., Kumar, S.J., Arya, S., Rena, Kumar, R. and Cheeseman, C. 2017. Challenges and opportunities associated with waste management in India. *R Soc Open Sci.* 4(3): 160764.

Nain, A. and Lohchab, R. 2015. Anaerobic treatment of MSW of Hansi in leachate recirculation bioreactor. *Ann Biol.* 31(1) : 46-50.

Palanivel, T.M. and Sulaiman, H. 2014. Generation and composition of municipal solid waste (MSW) in Muscat, Sultanate of Oman. *APCBEE Procedia*. 10: 96-102. https://doi.org/10.1016/j.apcbee.2014.10.024

Ramachandra, T.V., Bharath, H.A., Kulkarni, G. and Han, S.S. 2018. Municipal solid waste: Generation, composition and GHG emissions in Bangalore, India. *Renew Sust Energ Rev.* 82 : 1122-1136. https://doi.org/10.1016/j.rser.2017.09.085

Rana, R., Ganguly, R. and Gupta, A.K. 2018. Physico-chemical characterization of municipal solid waste from Tricity region of Northern India: a case study. *J Mater Cycles Waste Manag.* 20(1) : 678-689. https://doi.org/10.1007/s10163-017-0615-3

Rong, L., Zhang, C., Jin, D. and Dai, Z. 2017. Assessment of the potential utilization of municipal solid waste from a closed irregular landfill. *J Clean Prod.* 142 : 413-419. https://doi.org/10.1016/j.jclepro.2015.10.050

Sethi, S., Kothiyal, N.C., Nema, A.K. and Kaushik, M.K. 2013. Characterization of municipal solid waste in Jalandhar city, Punjab, India. *J Hazard Toxic Radioact Waste.* 17 (2) : 97-106. https://doi.org/10.1061/(ASCE)HZ.2153-5515.0000156.

Sharholy, M., Ahmad, K., Mahmood, G. and Trivedi, R.C. 2008. Municipal solid waste management in Indian cities - A review. *Waste Manage.* 28(2) : 459-467. https://doi.org/10.1016/j.wasman.2007.02.008

Singh, A. and Chandel, M.K. 2020. Effect of ageing on waste characteristics excavated from an Indian dumpsite and its potential valorisation. *Process Saf Environ Prot.* 134 : 24-35. https://doi.org/10.1016/j.psep.2019.11.025

Snehlata, S., Lohchab, R. and Nain, A. 2015. Anaerobic treatment of MSW using leachate recirculation bioreactor: A case study of Rohtak City. *Nat Environ Pollut Technol*. 14 (4) : 919-922.

Tian, W.D., Wei, X.L., Wu, D.Y., Li, J. and Sheng, H. Z. 2001. Analysis of ingredient and heating value of municipal solid waste. *J Environ Sci.* 13(1) : 87-91.

Verma, N. and Tripathi, A.K. 2018. Municipal solid waste (MSW) composition, quantification and characterization at the three MSW dumping sites of Himachal Pradesh/: A case study. *Indian J For.* 39(1) : 31-36

Yildiz, S., Yaman, C., Demir, G., Ozcan, H.K., Coban, A., Okten, H.E., Sezer, K. and Goren, S. 2013. Characterization of municipal solid waste in Istanbul, Turkey. *Environ Prog Sustain Energy.* 32(3) : 734-739. https://doi.org/Doi 10.1002/Ep.11640.