

Composition and Characteristics Analysis of Municipal Solid Waste using Proximate Method and Estimation of Greenhouse Gases from Landfill Sites in Punjab a State of India

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Abstract— given the rate of towns inhabitants growth the amount of leftover produced per person from different sources, in different ways and types in most of the Indian cities, managing this municipal solid waste is a major problem. Poor handling of municipal solid waste can harm the environment, can endanger public health and cause further socioeconomic issues. To gain a better understanding of the existing state of management of municipal solid waste, we conducted projections and analyses of the content, features, and greenhouse gas emissions from landfill sites in four different zones in Punjab. A combined methodology of quantitative and qualitative analysis was used for the investigation of primary and secondary data from the landfill site. We used uninformed samplings to determine the configuration of waste and performed a proximate analysis, which includes Lower Heat Value (LHV), Ash Content, Volatile Matter (VMC), Moisture Content (MC), and Fixed Carbon (FC). According to the study's proximate analysis findings, Zone II dumpsite has the highest VMC at 57.8% but the lowest MC (38.279%). In contrast to this, the Zone IV dumpsite solid waste has the highest MC of 48.046%. Ash content ranged between 39.2% and 46%, with the Zone III dumpsite solid waste having the highest and the Zone II dumpsite solid waste having the lowest levels. In addition, among the four dumpsites, solid waste from Zone III has the highest FC The LHV for the municipal solid waste varied from 2042.724kcal/kg (in zone iii) to 2493.798kcal/kg (in zone iv), demonstrating the viability of planning trash to energy production in cities. Subsequently, with the aid of IPCC methodology using the Default Method and First Order Model, we calculated the emission of greenhouse gases from the landfill sites, which are a major contributor to methane gas (CH₄) emissions that are produced in favourable conditions by microorganisms, it was found out that the Default Method gave a better picture of the emission values of greenhouse gases.

Index Terms— characterization, composition, proximate analysis, calorific value, and greenhouse gases of municipal solid waste.

I. INTRODUCTION

India, which has nearly 1.47 billion inhabitants is currently the world's most populated country after China, with a population growth of 1.2% yearly this is the fastest growing nation-state (Census of India, 2023). The amount of solid trash created will only increase manifold with the economic success and the increasing percentage of people

living in cities (Hoornweg and Bhada, 2012). The central board for pollution control (CPCB) of India reports that the amount of garbage produced per person has climbed steadily from 0.26 kg/day to 0.85 kg/day (CPCB India, 2018).

It has been discovered that the efficiency of the assortment parameters varies between 70 and 80 percent in the metro city whereas its efficiency is below 50 percent in the smaller cities and that this enormous growth in the generation of solid waste is due to changes in lifestyle, eating habits, and ideals of living in the urban population (CPHEEO, 2000). In nations with high incomes, trash creation per capita is predicted to increase by 19% by 2050, whereas it will increase by roughly 40% in low-income countries (Burke et al., 2018).

In most region of the countries, solid waste is gotten ridded of either in an open landfill site a salubrious landfill and with the help of the combustion. However, both the combustion and salubrious landfills are expensive and require proper operations and maintenance. The cost for developing countries is relatively low therefore developing countries typically use landfill sites for solid waste disposal (Nas and Bayram, 2008). Emerging nations like India are still making changes to improve their waste management for the most part, a solid waste dump is used without the required safeguards and proper operational controls in low-lying locations. Unsuitable solid waste management is causing environmental issues in major Indian cities (Sharholly et al., 2008).

The major issue is that in India only a few cities collect mixed forms of waste (Ahluwalia and Patel, 2018). Due to lack of awareness and accurate information, regarding the impact of trash on health, and the lack of adequate safety equipment for municipal workers, many gaps in waste management and employee safety have been discovered (Zhu et al., 2008).

Front-line workers and garbage pickers may suffer from several health problems and occasionally even pass away as a result of the improper management of waste at dump sites that frequently attracts animals, mice, mosquitoes and scavengers (Bercegol et al., 2017). The administration of solid waste, their characterization, their compositions along with their analysis in different weathers and emission of greenhouses gases like methane from landfill sites are discussed in this paper.

II. LITERATURE REVIEW

Any organic or inorganic waste produced by the households or commercial activities that has some potential to be reused in any scientific manner but has lost its value in its first owner's eye referred as waste, the proper involvements of municipal authorities', private agencies and the government sector are so essential for the achievement of long-term objectives of MSWM (Agarwal et al., 2015).

Garbage that is generated in kitchens, businesses, and construction sites, or that the municipality collects from the streets can either be solid or semisolid and can be either dangerous or not. This garbage is also referred to as urban waste or solid waste (Sridevi et al., 2012). Population, average annual income level, social behaviour, product demands, the amount and makeup of solid waste are influenced by a number of factors, including industrial production and the market for waste products., and they vary and depend on the source of origin (Yadav and Devi (2009); Late and Mule (2013)).

Numerous variables, including income, cultural traditions, dietary preferences, and climate, affect the makeup of solid waste (Srivastava et al., 2014). 48 million tons in 1997, 90 million tons in 2009, up from 6 million tons in 1947, and it is projected to rise to 300 million tons by 2047, the generation of solid trash has expanded significantly in recent years (Teddy, 2010; Sharholey et al., 2005). The disposal of rubbish in India is extremely improper and unorganise even the majority of metropolitan areas lack proper solid waste storage and collection facilities the trucks and bins used to collect solid waste are improperly designed, located, and maintained and the workers lack the necessary tools like masks, gloves, and disinfectant, which leads to inefficient collection. Only approximately or about 70% of municipal solid garbage gets collected on an average throughout the town and city (Saxena et al., 2010). The successful handling of solid waste is affected by a number of aspects that includes quality controls, improved training programs, teamwork, support management, and ratings of good performance (Sarok, 2013).

Fernando (2019), estimated and recognised a few key elements, such as pay and other benefits for employs, the commitment of society and business group, governmental backing, inspiration, etc. that can aid in the effective operation of the solid waste management agenda. Solid waste management entails innovating and sustainably implementing all of a waste management plan's component that can help control waste in that location. The existing waste management plan must be combined and implemented so that the local governing bodies are prepared to address any issues that may arise. Innovations should also be brought into the planning process (Shekdar, 2009).

Below "Fig. 1", shows the flowchart of existing municipal solid waste management system in Indian cities from that we can see the generation of waste from different sources likes commercial buildings, houses, street, hotels,

parks etc., later all of the wastes are collected by sweepers or by different tools and ragpickers then all the collected waste is then transferred to either junkyard or community bins depends upon the wastes type the recyclable waste sent towards recycling site for recovering it for next use and remaining waste sent to landfill sites through cart or automobiles.

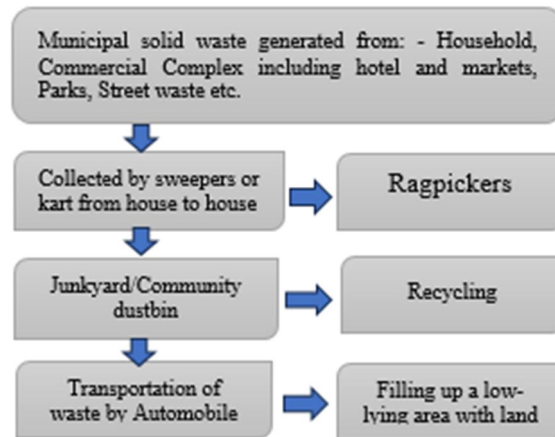


Figure 1. The flow diagram for India's current municipal solid waste management system (Singh et al., 2011).

III. AREA OF STUDY

This research was done in a landfill site in the city of Kharar in the state of Punjab, India. Kharar is nearby Mohali city and comes in greater Mohali region having coordinates of 30.74°N 76.65°E with having elevation of about 309 metres or 1014 feet.

It is the first town in Punjab to convert wet waste into organic manure using latest tools and techniques. The present research is lugged in conformance to find out the practices and approach accomplished by Municipal Corporation of Kharar for the proper solid waste management, below “fig.2” shows the map of kharar region where landfill site is located and al the testing samplings and collection of waste were done.



Figure 2. Image showing map of Kharar, SAS Nagar, Greater Mohali, Punjab, India (Kaur and Kaur, 2022).

IV. MATERIALS AND METHODS

A. Collection of primary data

The data of waste and samples of garbage were taken from the dumpsite of Kharar which is being managed by Municipal corporation of Kharar where collection of waste is being separated into four different zones namely Zone I, Zone II, Zone III and Zone IV. We collected the waste generation data from all the four zones. The average data of daily, monthly, and annual time periods are given below in the “Table I”.

B. Composition and classification of waste

The classification of solid garbage from the landfill sites were done on the standard basis of American Society for Testing and Materials (ASTMR, 2022). Based on the suggestion by Wilson, the collection of wastes from all four zones were done in the month of November, February, and April with the help of a weighing machine having the sensitivity of 0.1kg. All the samples were weighed in pre-weighted tray. After this, all samples were spread on plane sheets and divided into four categories, namely waste of food, plastic squander, dry waste, and other waste. Further, their average weight % were calculated.

C. Proximate Analysis

In order to determine the amount of ash, moisture, volatile materials, and fixed carbon of the solid waste samples that were collected from the four zones of dumpsites, we used the ASTM 3175-3175 standard procedures for the proximate assessment of solid waste. In this procedure, 1000gm of sample was collected from each of the four dumpsite zones and taken to a lab for examination.

1. Moisture content

The level of moisture of solid waste samples was calculated according to ASTM 3173 method. In this, 1000gm of solid waste was taken and placed in pre-weighted tray and then samples were put into an oven for 24hrs at 105°C to obtain a stable weight. With the help of below “(1)”, the % of moisture content was calculated.

$$\% \text{ Moisture content} = \{(\text{Wet weight} - \text{Dry weight}) / (\text{Wet weight})\} \times 100 \quad (1)$$

2. Volatile Matter content

We used the ASTM 3175 method, in which 5gm of dry waste sample was obtained and placed inside a muffle furnace for 8 minutes at a temperature of 950°C in order to estimate the proportion of volatile matter present in the solid waste samples. Following full combustion to determine the dry weight of the ash, the samples were weighed, and the volatile matter was determined using “(2)”, below and the percentage provided in “Table I”.

$$\% \text{volatile matter} = \{(\text{Dry sample weight} - \text{Ash weight}) / (\text{Dry sample weight})\} \times 100\% \quad (2)$$

3. Ash and fixed Carbon content

By heating the waste samples in an oven at 750°C, the ash content of the samples was determined under ASTM 3174 method. Ash content was the amount of residue left after combustion and the Fixed carbon content were determined using the following “(3)”.

$$\% \text{FC} = 100 - \text{weight } (\% \text{moisture content} + \% \text{ Ash} + \% \text{ Volatile matter}) \quad (3)$$

4. Lower Heat Value

The main advantage of using this model is that it gives results based on the size of samples (Liu et al., 1996) in order to calculate the calorific values correctly (Amin et al., 2011). To calculate the Calorific value or Lower Heat Value (LHV), we used the Proximate Analysis models. The ratio of fixed carbon to volatile carbon in weight served as the foundation for the Proximate Analysis model's creation. The following “(4)”, can be used in order to determine calorific value of solid waste samples using Proximate Analysis (Rajesh et al., 2013).

$$\text{LHV} = 44.75\text{VM} - 5.85\text{W} + 21.2 \quad (4)$$

Where LHV = lower heating Value (kcal/kg)
VM = Volatile matter (%)

D. Emission of Methane

As it is common knowledge that all landfill sites involve the disposal of solid waste under ideal conditions for anaerobic decomposition of organic materials, which releases methane gas the IPCC (Intergovernmental Panel on Climate Change) recommends two techniques to estimate the quantity of methane gas emissions the IPCC default method and the second is the first order decay model the main distinction between the two approaches is that the, IPCC-default method undertakes that all potential methane will be released in the year in which solid waste was disposed whereas the FOD method considers the precise timing of the emissions (Froiland et al., 2006).

1. IPCC Default Method

With this approach it is considered that all potential methane emissions are discharged the same year as garbage disposal with the use of this model it is possible to compute methane emissions with a minimal amount of input for a set of parameters whereas IPCC allow default values in the absence of precise data the “(5)”, below forms the basis of the default method.

$$\text{Methane emissions} \left(\frac{\text{Gg}}{\text{yr}} \right) = \left(\text{MSWT} \times \text{MSWF} \times \text{MCF} \times \text{DOC} \times \text{DOCF} \times F \times \frac{16}{12} - R \right) \times (1 - \text{OX})$$

Where:

MSWT= total MSW generated (Gg/yr).

MSWF= fraction of MSW disposed at disposal site.

MCF= methane correction factor.

DOC= Fraction of degradable organic carbon in the waste.

DOCF= Fraction of DOC dissimilated.

F= Fraction of methane in the landfill gas.

R= Recovered methane (Gg/yr).

OX= Oxidation factor.

2. Method of First Order Decay

Quantity of methane produced at the dumpsite is calculated by using this method. According to this method, the amount of methane produced at the dumpsite is based on time. The FOD model has been used to estimate the annual emissions of methane from sites where waste has been placed, with the use of the following “(6)”.

$$QT_x = k \times \text{MSWT}(X) \times \text{MSWF}(X) \times \text{MCF}(X) \times \text{LO}(X) \times e^{-k(T-X)} \times F \quad (6)$$

Where: QT, x= The amount of methane generated in the current year from waste disposed in the year X.

X= the methane gas generated in the current year from waste disposed in the year X.

K= $\ln(2)/t_{1/2}$. (1/yr) and $t_{1/2}$ is half-life period for degradation process.

MSWT (X)= total MSW generated (Gg/yr) in year X.

MSWF (X)= Fraction of MSW disposed to solid waste disposal sites in year X.

MCF (X)= Methane correction factor (fraction) for year X.

LO (X)= DOC x DOCF for the year X (Gg CH₄/Gg waste).

Where: DOC= fraction of degradable organic carbon in the waste.

DOCF= fraction of DOC dissimilated.

T= the current year (year of the emission estimate) Gg/yr.

V. RESULTS AND DISCUSSION

The primary data of solid wastes that was collected daily, monthly and annually average generation from the landfill sites of the four zones are shown in the “Table I”.

TABLE I. AVERAGE SOLID WASTE GENERATION IN TONNES AT KHARAR LANDFILL SITE VIA MUNICIPAL CORPORATION OF KHARAR, MOHALI, PUNJAB.

Sources	Average Waste Generation in Tonnes		
	Daily	Monthly	Yearly
Zone I	13.12	393.6	4723.2
Zone II	12.8	384	4608
Zone III	14.87	446.1	5353.2
Zone IV	11.47	344.1	4129.2
Average	13.065	391.95	4703.4

In this landfill site the solid waste is collected from all sources with the help of trucks and hand carts. From the above table, we found out that among all four zones, the highest amount of waste generation is in Zone III i.e., 14.87 tonnes/day while Zone IV has the lowest generation of solid waste at 11.47 tonnes/day.

1. Physical composition

The results of the data of four zones at landfill sites that were conducted in the month of November, January, and May (2022-2023) are shown in the “Table II”.

On the bases of physical classification of solid waste at four zones, the results show that food waste has the highest % composition ranging between 22-27.5%. The next is the composition of dry waste which varies from 15.5-

19.5%. Other types of waste have the lowest % composition which lies between 0.4-1.25% and the plastic waste composition is limited to 7-9.5%.

TABLE II. AVERAGE % PHYSICAL COMPOSITION WEIGHT OF WASTE.

Category	WASTE IN TONNES				Average
	Zone I	Zone II	Zone III	Zone IV	
Food waste	27.5	24	29.5	22	25.75
Dry waste	16.5	17	19.5	15.5	17.125
Plastic waste	8	6.5	9.5	7	7.75
Other	0.5	1.25	1	0.4	0.7875

Below “fig.3” shows the average % division of Solid waste in the landfill sites of Kharar, Punjab at four zones.

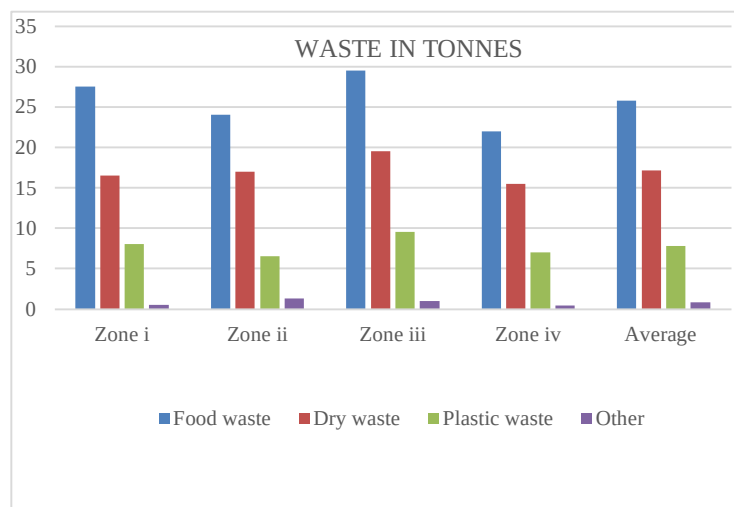


Fig.3 - Average solid waste weight% composition in four zones of dump sites

2. Proximate Analysis

On the basis of Proximate Analysis, we determined the content of volatile substances, moisture, ash, and fixed carbon from all the four zones of landfill sites which was collected in different months of the year. “Table III” demonstrates the median outcome of the Proximal Analysis over all four waste site zones.

TABLE IV. AVERAGE % OF MC, VMC, ASH AND FC FROM LANDFILL

Sources	Zone I	Zone II	Zone III	Zone IV
MC %	6.149	8.279	8.046	16.867
VMC %	33.8	37.8	31.8	20.6
Ash %	24.4	31.2	26.2	22.2
FC %	35.651	22.721	33.954	40.333

From the result of the above equation “(1)”, “(2)”, “(3)” and “(4)”, it is found out that the MC of solid waste samples from Zone IV have the highest content i.e., 16.867% but it contains low VMC i.e., 20.6. Whereas, in Zone I the MC is the lowest i.e., 6.149%. The VMC in Zone II is higher i.e., 37.8% than other zones. The content of ash

% varies from 22.2-31.2 %. The content of Fixed Carbon in Zone IV is higher at 4.033% and lower in zone II at 22.721%. Figure 2 represent the graphical data of the proximate analysis of all four zones.

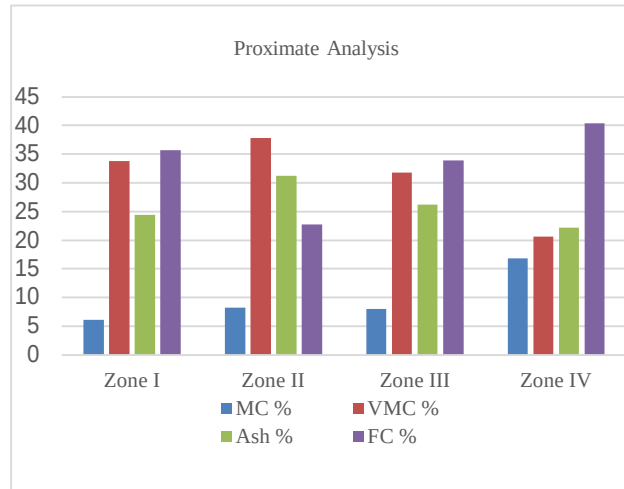


Fig.4 - Average % of MC, VMC, Ash and FC from landfill sites

3. Calorific Value

Equation 5 has been used to compute the solid waste's lower heat value based on the Proximate Analysis. "Table IV" depicts the lower heat value from all four zones.

TABLE.IV – CALORIFIC VALUES OF FOUR ZONES AT LANDFILL SITE

	Calorific Value			
Zone I	Zone II	Zone III	Zone IV	
1484.106	1651.326	1382.724	825.798	

From the above table we can find out that in all four sites or zones the LHV varies between 825.798- 1651.326 kcal/kg, whereas Zone II has the most calorific content of 1651.326 kcal/kg and Zone IV has the lowest calorie content of 825.798 kcal/kg.

4. Methane Emission

The Landfill site of Kharar, Punjab was started around year 2008 with an area of around 4 acre and a depth of around 15 feet. This site is managed by Municipal Corporation of Kharar, Punjab. The daily waste receives here is 13.12 tonnes/day from four different zones. With the help of IPCC methods, we have found out that the emission of methane slowly decreased in past few years by the Default method, but the FOD method showed that it gradually increased in past few years by at Gg/yr.

From both the methods we observed that DM produces greater value of methane gas emission than FOD method since any alteration in the amount of solid waste projected faster on the result of IPCC-DM, whereas the FOD method is slow to adapt the changes.

The implementation of DM is easier as well because it gives eloquent result whereas implementation of FOD methods is a little complicated since it requires vast knowledge of decaying process and many more data related to disposal at sites. Further, in the Kharar landfill sites, the emissions of methane were found to be at a standard deviation of 33.165 in DM and in FOD it is nearly 7.467.

VI. CONCLUSION

It is evidently known, the solid waste management practices have got better in recent years however, looking at the pressing environmental concern and increased in urgency of concrete and cooperative action, we need to utilize the resources efficiently and accelerate the process in this era of technology, we must focus on better waste management, and technology-based entrepreneurship.

An increased involvement of NGOs, Municipal bodies, governing bodies, and authorities towards enhancing public awareness should be ensured because participation of public in an efficient management of solid waste is one of the most crucial steps, along with that, proper measurements and mitigation policies should be implemented as per the guidelines of SWM.

This paper reached on conclusion that composition and classification of Solid waste from the landfill sites of the city of Kharar, Punjab as MSW is a potential source of energy, our analysis has also demonstrated the heat values ranges which clearly shows the viability of waste-to-energy plans like power production through incineration. Further, our paper concluded that the generation of solid waste or organic waste has increased because of a This paper reached on conclusion that composition and classification of Solid waste from the landfill sites of the city of Kharar, Punjab as MSW is a potential source of energy, our analysis has also demonstrated the heat values ranges which clearly shows the viability of waste-to-energy plans like power production through incineration. Further, our paper concluded that the generation of solid waste or organic waste has increased because of a multifold increase in population, as there is an unprecedented increasing in methane gas from landfill sites. Hence, there is a pressing necessity of initiation of mitigation for controlling the greenhouse gases emissions which could become a great source of energy, and solve the issue of power shortage in many places.

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