ASSESSMENT OF ENERGY RECOVERY POTENTIAL OF MSW USING MASS INCINERATION IN MORADABAD CITY, UTTAR PRADESH

Farheen Warid, Ateeque Ahmad

Department of Geography, Aligarh Muslim University

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Abstract: In cities of developing countries, municipal solid waste (MSW) typically has a highly heterogeneous composition due to variations in economic activity, cultural practices, climate, and waste collection efficiency. In this study, proximate, ultimate and heating value was found out based on received basis of MSW. In this organic waste is segregated for composting only recyclable and inert material is left to find out the heating value of MSW. The energy recovery potential of MSW is 1164.47 Kh/tonne with 30% energy conversion efficiency.

Keywords: MSW, Proximate, Ultimate, heating value and energy recovery

1. Introduction

Incineration and heating value prediction

Incineration is the most prevalent and efficient method for recovering energy from MSW(Ibikunle et al., 2020). Modern air pollution control (APC) systems remove fly ashes, gasses, heavy metals, and dioxins from flue gas through multiple stages and incineration is an effective waste to energy options(Vehlow, 2015).However, the composition of MSW varies significantly and can include organic matter, plastics, metals, glass, and other materials. Understanding this composition is crucial for optimizing the incineration process. The physical and chemical characteristics are essential for an effective incineration process. The proximate analysis, ultimate analysis and heating value of MSW is to be known for incinerator to be operated. The proximate analysis involves determining the moisture content, ash content, volatile matter, and fixed carbon in the waste. These factors influence the combustion process and the efficiency of energy recovery. In ultimate analysis the elemental composition of the waste (e.g., carbon, hydrogen, nitrogen, sulfur, and oxygen). It helps in understanding the combustion characteristics and the potential emissions produced during incineration. The heating value of waste can be determined using a bomb calorimeter in the presence of excess of oxygen. The calorific value (or heating value) is critical as it determines the amount of energy that can be recovered from the waste. Basically, heating value is of two types, higher heating value and lower heating value. HHV can be calculated from bomb calorimeter and it indicate more energy can be extracted, making the waste more suitable for incineration as an energy recovery option While LHV can be calculated by the latent heat of vaporisation of water.

1.2 Objective

To estimate the electrical energy potential of MSW (on received basis)

2. Study Area

2.1 Material and Methods

Moradabad city is the administrative center of the Moradabad district in Uttar Pradesh, India. It is a city with a population of 887871 people and a land area of 75 square kilometers. Geographically, Moradabad City spans between 28°47'20" to 28°54'3" N Latitude and from 78°41'59" to 78°48'23" E Longitude in the western region of Uttar Pradesh. On the banks of the Ramganga River, a branch of the Ganga River that flows northeast of the city is where the city is situated. Moradabad City, known for its brass industry and vibrant markets, generates a substantial amount of solid waste daily. The city's increasing population and industrial activities contribute significantly to its waste production.

The samples of mixed MSW were collected from the Trenching ground (Ramnagar Mazra Ahatamali landfill) near Dear Park. The transfer station receives MSW from 9 Zones in MMC and then transfers it to the trenching ground. Around 350 tonnes/day of MSW is generated in Moradabad city. Special permission was obtained from the supervisor concerned about the trenching ground to conduct the sampling. A 100 kg sample of mixed garbage was collected from each truckload discharge and reduced to 6.25 kg utilizing the coning and quartering process(Anders, 2008). MSW was divided into two categories: combustible and non-combustible. The combustible fraction includes the food waste, plastic, paper & cardboard, textile & rubber, and non-combustible materials include metals, glass, and inert. Representative samples were manually separated and weighted using an electronic weighing for each specified waste component. Representative samples were collected from each segregated waste component and analysed in the laboratory on the received basis.

3. Characterization of Municipal Solid Waste

To assess the energy recovery potential of MSW by thermal conversion, it's essential to understand the fundamental physicochemical properties of waste components(Aleluia & Ferrão, 2016). The obtained samples underwent laboratory analysis to determine moisture content. The materials were ground at room temperature to create a more uniform mixture. Plastic samples were chopped into smaller sizes since they could not be ground, but paper, cardboard, and textile samples were combined to create a uniform combination of wool-like materials. The produced samples were placed in sealed containers for further analysis. All analyses were performed using standard methods for three samples of each component.

Table 1. Methods and equipment

Analysis	Equipment	Methods	References
Moisture content	Hot air oven	IS:1350 Part 1	IS 1350-1 (1984)
Proximate Analysis Ash content Volatile matter Fixed carbon	 Muffle furnace Muffle furnace	 IS:1350 Part 1 IS:1350 Part 1 [100-(%VM + %Ash)]	 IS 1350-1 (1984)
Ultimate analysis Carbon(C) Hydrogen(H) Nitrogen(N) Oxygen(O) Sulphur (S)	 Elemental analyser (Elementar Vario micro cubes, GmbH/Germany)	 IS:1350 Part-4/Sec-1 IS:1350 Part-4/Sec-1 IS:1350 Part-4/Sec-1 ASTM D 3176 IS:1350 Part-3	 IS 1350-4-1 (1974) IS 1350-4-1 (1974) IS 1350-4-1 (1974) ASTM D 3176-15 IS 1350-3 (1969)
Calorific value (HHV and LHV)	Bomb calorimeter	IS 1350 Part-2	IS 1350-2 (1975)

3.1 Proximate Analysis

A proximate analysis is performed to determine the heating value of municipal solid waste fuel. It is done to ascertain the gross components of municipal solid waste's moisture, volatile matter, fixed carbon, and ash. The proximate analysis of MSW samples followed IS 1350 and ASTM standards methods for coal and coke analysis. Based on the samples received, the proximate analysis determines moisture content, volatile matter, ash content, and fixed carbon.

3.1.1 Moisture Content: To determine the moisture content of each MSW fraction, 100 g was dried in an oven at 105 °C until a consistent weight was attained. The sample was cooled in a desiccator and weighed after cooling. The moisture was determined using the eq.1

$$\textit{Moisture content}(\textit{wet basis}) = \frac{(\textit{Wet weight} - \textit{Dry weight})}{\textit{wet weight}} \times 100 \qquad \text{Equation 1}$$

3.1.2 Volatile matter: To evaluate volatile matter, a dried sample of MSW components was ignited in a closed crucible at 950°C for 7 minutes in a muffle furnace. The crucible was allowed to cool in a desiccator before the weight was measured. The percentage of volatile matter is the difference between the dry weight of the sample before burning and the residue that remained in the crucible after burning, as determined by eq.2

$$\textit{Volatile matter} = \frac{\textit{weight of residue}}{\textit{Dry weight}} \times 100 \qquad \textbf{Equation 2}$$

3.1.3 Ash Content: To evaluate the ash content, a dried sample of MSW components was ignited in an open crucible at 550°C in a muffle furnace for two hours, was determined using eq 3

$$\textit{Ash content} = \frac{\textit{weight of residue}}{\textit{Dry weight}} \times 100 \qquad \textbf{Equation 3}$$

3.1.4 Fixed Carbon: The percentage fixed carbon was obtained by subtracting the percentage of volatile matter and ash content from 100 (eq 4)

$$\textit{Fixed carbon}(\%\ \textit{of dry weight}) = [100 - (\%\ \textit{of VM} + \%\ \textit{of Ash content})] \qquad \textbf{Equation 4}$$

3.2 Ultimate Analysis

The final analysis was performed to ascertain the elemental composition of MSW components, including the amounts of carbon (C), hydrogen (H), oxygen (O), nitrogen (N), and sulfur (S)(Shi et al., 2015). The ultimate MSW analysis is crucial because the percentages of C, H, and O give an indication of the fuel's thermochemical conversion capability, while the percentages of N and S help determine how MSW as a fuel would affect the environment (Vargas-moreno et al., 2012). The findings of the elemental analyser were expressed as percentages of C, H, N, and S, and the percentage of O was computed as [100 – (sum of % of C, H, N, S, and Ash content)] (Boumanchar et al., 2019)

O%= [100 – (sum of % of C, H, N, S, and Ash content)] **Equation 5**

3.3 Heating Value

When municipal Solid waste is to be burnt, it's important to determine its thermal energy or heating value(Finet, 1987). The heating value is used to evaluate the energy content and incineration of waste components(Wang et al., 2021).The formulation of correlations for the prediction of the higher heating value (HHV) of MSW is a sustainable and cleaner technique based on data from specific regions where MSW is collected(Ibrahim et al., 2020). Among the various physicochemical properties of biomass fuel, the gross calorific value is one of the major fuel qualities showing the energy contents in fuel and a crucial parameter playing a prominent role in the process design and numerical modelling of energy systems(Williams et al., 2001). The MSW comprises combustible and non-combustible materials. Food waste has a low heating value due to its high moisture content. Yard waste has moderate heating value, varying according to moisture and type. Paper and cardboard have high heating values due to cellulose; plastic has a very high heating value due to hydrocarbons; textile has moderate to high heating value depending on the fiber type; and wood has a high heating value and varies according to moisture contents. The non-combustible components, like inert materials and ash, have some heating value due to unburnt carbon and contamination with carbonaceous materials. However, their contribution to the overall heating value is minimal. Moreover, their inclusion in the combustion process results in increased ash formation, which could complicate the waste management process and reduce the efficiency of energy recovery systems. The components, such as food waste, yard waste, paper and cardboard, plastic, rubber, and textiles, contribute more significantly to the energy that can be recovered through combustion, so in this study, combustible materials are used for evaluating the energy recovery potential of MSW through thermal conversion technique. A bomb calorimeter was used to quantify the total heat released after the complete combustion of a solid waste sample. To determine the HHV, 1 g of dried and ground material was burned in a constant volume adiabatic bomb calorimeter in the presence of excess oxygen, as per standard IS 1350-2 (1975).

3.4 Energy Recovery Potential

Thermal decomposition of organic matter produces heat energy, which is beneficial for MSW with high organic non-biodegradable waste and low moisture content(Chakraborty et al., 2013).The electrical energy potential from incineration can be calculated by the following formula(Chakraborty et al., 2013)

$$E = 1.16 \times LHV \times W \times \eta \qquad \text{Equation 6}$$

Where, E is the electrical recovery potential(KWh), LHV is the low heating value(cal/gm),W is the quantity of waste generated(tonnes),1.16 is the factor of conversion from kcal/gm to KWh and η is the electrical conversion efficiency.The electrical conversion efficiency in the plants ranges between 20-40% (Ibikunle et al., 2019).In this, the conversion efficiency taken as 30%.

4. Result and discussion

In this, organic waste is removed for composting in trenching ground, and this is the leftover MSW after the segregation. This is on the received basis. On the trenching ground MSW about 60% is inert material, Wooden pieces is 5%, Paper is 4.2%, textiles is 9.5%, Plastic is 8.6%, Organic material is only 1%, glass is 2% and rubber and leather are 1.3%. Plastic, paper, and recyclable material are removed by rag pickers before reaching the trenching ground and this is the leftover MSW. Proximate Analysis, Ultimate Analysis and Heating Value of MSW find out the received basis of MS. Moisture content is 38.60%, Volatile Matter is 17.13%, Fixed Carbon is 20.85% and Ash Content is 23.42%. The C, H, N, O and S are 27.13,6.99,0.56,3.26 and 0.04 respectively. The HHV and LHV of MSW are 1384cal/gm and 1014 cal/gm respectively.

Table 2. MSW Components % by mass

S.No.	Types of waste	% by mass
A	**Fuels**	
1	Wooden Pieces	5
2	Dry Leaves/Matter	3
3	Paper	4.2
4	Textiles	9.5
5	Polythene/Plastic	8.6
B	**Organics**	
6	Green Leaves/Matter	0
7	Kitchen Waste	0
8	Flower	0.5
9	Vegetables	0.5
C	**Inert**	
10	Stone	8
11	Sand/Earth	50
12	Ceramics	1
13	Concrete/Bricks	5
D	**Recyclables**	
14	Glass	2
15	Rubber/leather/tire	1.3

Table 3. Proximate, Ultimate and Heating Value of MSW on received basis

Proximate Analysis	**Results**
Moisture Content	38.60%
Ash Content	23.42%
Volatile matter	17.13%
Fixed Carbon	20.85%
Ultimate Analysis	
C	27.13
H	6.99
N	0.56
O	3.26
S	0.04
Heating Values	
High Heating Value	1384cal/gm
Low Heating Value	1014cal/gm

4.1 Energy Recovery from Combustion of MSW

In this Study, the LHV of MSW was found to be 1014 Cal/gm, the MSW generated is 330 tons/day and energy conversion efficiency is 30%. The electrical energy recovery potential of MSW on a received basis was found to be 1164.47 kwh/tonne.

5. Conclusion

For thermal conversion systems to be designed and run successfully, an accurate understanding of heating value is required. The physical composition of MSW has been determined by carrying our sampling at the trenching ground, Moradabad city, India in oct 2023.In this organic waste is removed for composting and this is the leftover MSW after it includes inorganic, recyclable, and inert material. The proximate, Ultimate and heating value was found on the received basis of MSW. The LHV is 1014 Cal/gm. The conversion efficiency is taken to be 30%. The energy recovery is found to be 1164.47 KWh/tonne.

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Conflicts of interest

The authors have no conflicts of interest to declare that are relevant to the content of this article. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the funding agencies.

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References

1. Aleluia, J., & Ferrão, P. (2016). *Characterization of urban waste management practices in developing Asian countries : A new analytical framework based on waste characteristics and urban dimension*. *58*, 415–429. https://doi.org/10.1016/j.wasman.2016.05.008
2. Anders, L. (2008). *Methods for household waste composition studies*. *28*, 1100–1112. https://doi.org/10.1016/j.wasman.2007.08.014
3. Boumanchar, I., Chhiti, Y., Ezzahrae, F., Alaoui, M., Sahibed-dine, A., Bentiss, F., Jama, C., & Bensitel, M. (2019). *Municipal solid waste higher heating value prediction from ultimate analysis using multiple regression and genetic programming techniques*. *Lccm*. https://doi.org/10.1177/0734242X18816797
4. Chakraborty, M., Sharma, C., Pandey, J., & Gupta, P. K. (2013). Assessment of energy generation potentials of MSW in Delhi under different technological options. *Energy Conversion and Management*, *75*, 249–255. https://doi.org/10.1016/j.enconman.2013.06.027
5. Finet, C. (1987). *HEATING VALUE OF MUNICIPAL SOLID WASTE*. *March 1985*, 141–145.
6. Ibikunle, R. A1, Titiladunayo, I.F1, 2, Uguru-Okorie, D. C.1, Osueke, C.O1, O. A. (2019). *Predicting the Quantity of Municipal Solid Waste Required for Power Generation Using Power Plant Design Parameters*. *1378*, 1–14. https://doi.org/10.1088/1742-6596/1378/3/032090
7. Ibikunle, R. A., Titiladunayo, I. F., Lukman, A. F., Dahunsi, S. O., & Akeju, E. A. (2020). Municipal solid waste sampling , quanti fi cation and seasonal characterization for power evaluation : Energy potential and statistical modelling. *Fuel*, *277*(May), 118122. https://doi.org/10.1016/j.fuel.2020.118122
8. Ibrahim, M., Ullah, S., Al-sehemi, A. G., & Ahmad, S. R. (2020). Modeling the Higher Heating Value of Municipal Solid Waste for Assessment of Waste-To-Energy Potential: A Sustainable Case Study. *Journal of Cleaner Production*, 125575. https://doi.org/10.1016/j.jclepro.2020.125575
9. Shi, H., Mahinpey, N., Aqsha, A., & Silbermann, R. (2015). Characterization , thermochemical conversion studies , and heating value modeling of municipal solid waste. *WASTE MANAGEMENT*. https://doi.org/10.1016/j.wasman.2015.09.036
10. Vargas-moreno, J. M., Callejón-ferre, A. J., Pérez-alonso, J., & Velázquez-martí, B. (2012). A review of the mathematical models for predicting the heating value of biomass materials. *Renewable and Sustainable Energy Reviews*, *16*(5), 3065–3083. https://doi.org/10.1016/j.rser.2012.02.054
11. Vehlow, J. (2015). Air pollution control systems in WtE units : An overview. *Waste Management*, *37*, 58–74. https://doi.org/10.1016/j.wasman.2014.05.025
12. Wang, S., Li, W., & Alruyemi, I. (2021). *On the Investigation of Effective Factors on Higher Heating Value of Biodiesel : Robust Modeling and Data Assessments*. *2021*.
13. Williams, A., Pourkashanian, M., & Jones, J. M. (2001). *Combustion of pulverised coal and biomass*. *27*.

