

## CHARACTERIZATION OF OFFICE WASTE AND DETERMINATION OF COMBUSTIBLE PROPERTIES: A TANNER DIAGRAM APPROACH

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### ABSTRACT

Waste management has become a crucial global concern due to rapid urbanization, industrialization and high population growth. The increased amount of waste generated is raising concerns as a result of limited landfill space, microplastic contamination through landfills and many other raised environmental issues. So, sustainable waste management has become a priority and for a country like Bangladesh it has become a must need necessity. This study focuses on the characterization of office waste and evaluation of its combustible properties with the help of Tanner diagram. The Tanner diagram which helps us visualize the relationship between different waste components and the combustibility is used here to assess the fuel value and calorific content of the office waste. The methodology involves classification of waste materials by segregation, moisture content analysis and ash content determination. Results indicate a significant amount of office waste exhibits desired combustible characteristics which helps to make energy recovery. The study aims in identifying the potential for energy generation from office waste and thus contributes to sustainable waste management practices.

**Key words:** waste management, office waste, combustible, tanner diagram, sustainability

### INTRODUCTION

Rapid urbanization, industrialization, and a burgeoning global population have exacerbated the waste management crisis. An average of 55% of solid waste remains uncollected in urban areas, with a variation of collection efficiency from 37% to 77% (Islam, 2021). The ever-growing volume of waste generated poses significant environmental challenges, including limited landfill space, pollution of air, water, and soil, and the release of greenhouse gases (Hoorweg et al., 2013). Consequently, sustainable waste management practices have become imperative for a habitable future. In developing nations like Bangladesh, where rapid development is often accompanied by inadequate waste disposal infrastructure, the need for effective waste management strategies is particularly acute (Islam et al., 2018).

This study delves into the characterization of office waste within the Bangladeshi context, focusing on its potential for energy recovery. By employing the Tanner diagram, a valuable tool for visualizing the relationship between waste components and their combustibility, we aim to assess the fuel value and calorific content of office waste. Through meticulous analysis, including waste segregation, moisture content determination, and ash content analysis, we seek to identify the feasibility of utilizing office waste as a renewable energy source. This research contributes to the growing body of knowledge on sustainable waste management practices and explores innovative solutions for addressing the waste challenges faced by developing countries.

The escalating global waste crisis has spurred extensive research into sustainable waste management solutions. A significant focus has been on waste-to-energy (WTE) technologies, which aim to convert waste into valuable energy resources such as electricity and heat (Abushammala, 2018). Office waste, a significant contributor to the overall waste stream, presents a unique opportunity for energy recovery. Studies have shown that office waste often contains a substantial number of combustible materials, including paper, cardboard, and plastics, making it a potential feedstock for WTE processes (Wahyono et al., 2022). The Tanner diagram, a graphical tool widely used in waste management has proven valuable in assessing the suitability of various waste streams for combustion. By plotting the relationship between volatile matter, fixed carbon, and ash content, the

diagram provides insights into the fuel value and combustion characteristics of different waste materials (Ozyuguran et al., 2019).

Previous research has successfully utilized the Tanner diagram to evaluate the combustion potential of diverse waste streams, including municipal solid waste, agricultural residues, and industrial byproducts (Dolgen et al., 2005). This study builds upon existing research by applying the Tanner diagram to characterize office waste within the specific context of Bangladesh. By understanding the composition and combustibility of office waste, this research aims to contribute to the development of more effective and sustainable waste management strategies for the country.

## METHODOLOGY

### Study Area

For this experiment, we have chosen the KUET campus as our study area. We obtained office waste from the administration building (22°54'2.74"N, 89°30'8.95"E) and department of civil engineering of KUET (22°54'1.53"N, 89°30'10.75"E), depicted in the figure 1. A preliminary site investigation was carried out to determine the study area, sampling process, amount of sample to be collected and necessary equipment required. Then after selecting the sites and sampling process, samples were collected from the study area.

### Waste collection & sorting

At first office waste from the dustbins of the located study area have been collected manually by using a plastic bag (Fig 1). Then the collected samples were gathered in a place. After that, quartering method has been used to collect the samples. Quartering is a technique widely used to obtain representative solid waste samples. It involves dividing the sample into four equal parts, discarding two opposite quarters, and thoroughly mixing the remaining two until the desired sample quantity is achieved. (Valencia & Aguilar, 2012).



Figure 1: (a) & (b) Waste collection from study area, (c) accumulation of waste in an area, (d) sample collection using coning and quartering method.

After achieving the desired quantity by coning and quartering method, the collected samples were sorted manually in three primary categories such as: organic materials (such as tree leaves and roots), paper & tissue and plastic materials. The sorted samples were then taken in three separate plastic bags and taken to the laboratory for further testing.



Figure 2: Sample Testing from Laboratory

Tables 1: Waste Characterization

Categories	Types of Waste	Sample Quantity after quartering method (gm)
<b>Organic Waste (Tree leaves, roots etc.)</b>	Organic waste primarily consists of arboreal components, including tree leaves, roots, branches, and other lignocellulosic materials. These biodegradable fractions contribute to the overall biomass and are significant in processes such as composting, bioenergy production, and soil amendment due to their high organic matter content.	216.3
<b>Paper &amp; Tissue</b>	Paper and tissue waste, classified as organic and biodegradable, includes all forms of paper products, paper-derived materials, tissues, and similar fibrous substances. These materials decompose naturally and are commonly generated from domestic, commercial, and industrial activities, contributing to the organic fraction of municipal solid waste streams.	181.10
<b>Plastic Materials</b>	Plastic materials, though organic in composition due to their polymeric structure, are non-biodegradable and resistant to natural degradation processes. This category includes all plastic-related items such as packaging materials, containers, bottles, and wrappers from products like biscuits and cakes, contributing significantly to persistent environmental waste.	302.50

#### Moisture Content Analysis of Segregated Waste

Moisture content in waste have significant influence on decomposition, restoring of energy, and processing efficiency. Analyzing moisture levels in segregated waste help in optimizing treatment methods like composting, incineration, and landfill management. Before analyzing moisture content, wastes were segregated into different categories as stated earlier.

The moisture content was determined in compliance with ASTM 3173. Before drying, the waste samples were weighted as wet sample. Then they were placed in an oven at 105°C for 24 hours. The samples were allowed to cool in a desiccator before being reweighed to determine their dry weight. The moisture content (MC) is calculated using the following formula:

$$\text{Moisture Content, M.C (\%)} = \frac{(W_3 - W_2)}{(W_3 - W_1)} \times 100 \quad (1)$$

- W1 = Weight of the empty container
- W2 = Weight of the container + wet sample
- W3 = Weight of the container + dried sample

### Determination of ASH content

Assessing the ash content of solid waste is vital for various purposes, especially in waste management, energy generation and recovery. The ash content of the waste sample was determined by heating the samples in an open crucible at 550°C for 15 minutes. The ash content was then calculated using Equation (2)

$$\text{Ash Content (\%)} = \frac{\text{Residue weight}}{\text{Dry weight}} * 100 \quad (2)$$

## RESULTS AND DISCUSSION

### Moisture Content Analysis

To understand and compare the physical characteristics and potential implications of office wastes, the moisture content of various office waste components was determined and analyzed. As illustrated in Figure 3, the moisture content varied significantly across the different waste categories.

Organic Waste (comprising tree leaves, roots, and other vegetative matter) exhibited the highest M.C of 76.33 % and showed the water retention properties of plant-based materials, which can significantly change biodegradation rates and the calorific value during waste-to-energy processes. Paper and Tissue Waste showed a moderate moisture content of 13.63%. While paper-based products are hygroscopic and capable of absorbing ambient moisture, their overall water retention is considerably lower compared to organic vegetative waste. This characteristic may affect their combustion efficiency and suitability for recycling. Plastic Materials recorded the lowest moisture content at 2.70%. Plastics, being hydrophobic and non-porous, inherently withstand moisture absorption. This low moisture content increases their energy recovery potential in incineration processes but also emphasizes the environmental existence of plastic waste due to its non-biodegradable nature.

These findings show that the material composition has a noteworthy impact on the moisture content of office waste, which affects the effectiveness of resource recovery plans as well as the choice of suitable waste treatment techniques.

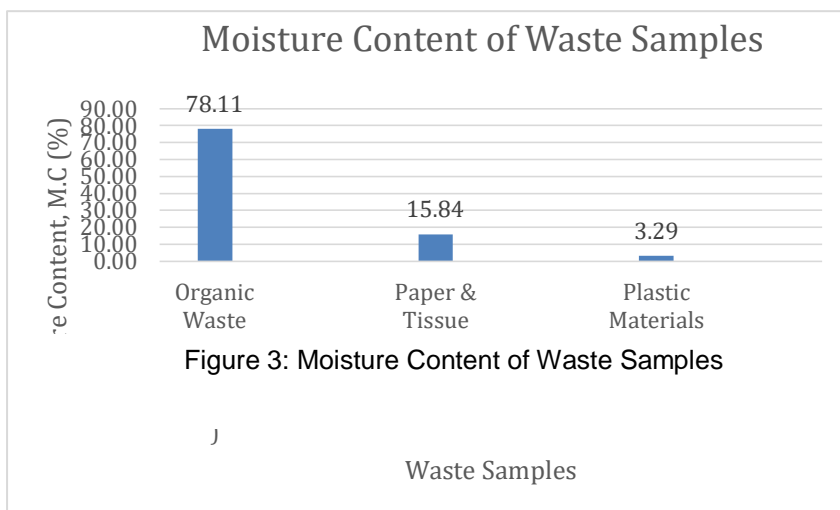


Figure 3: Moisture Content of Waste Samples

### Ash Content & Combustible Fraction Analysis

The ash content and combustible fraction are two important parameters in evaluating fuel potential of solid waste. A higher percentage of non-combustible material is indicated by a higher ash content, whereas the waste's burnable portion is represented by the combustible fraction. In these areas, the examined office waste samples—plastic materials, paper and tissue, and organic trash—showed unique traits.

Organic waste (tree leaves, roots, etc.) had a mean ash content of 21.20% and a combustible fraction of 2.47%. The high moisture content (76.33%) significantly reduces its combustion efficiency, making it less appropriate for direct incineration even though the low ash concentration indicates a respectable amount of burnable material. Paper & tissue waste however exhibited a higher mean ash content (78.33%) but also the highest combustible fraction (8.04%), proving it a comparatively better fuel potential. But the high ash concentration indicates that a sizable amount of the trash is left over as residue after burning, which requires appropriate ash disposal. Plastic materials had the highest mean ash content (90.03%) and a combustible fraction of 7.28%. Although they showed a lower ash content (2.70%), their high ash production lessens their effectiveness as a direct fuel source. Additionally, due to environmental risks, plastics require controlled incineration for proper disposal.

The results that while paper & tissue waste has the best fuel potential despite not being placed in the ideal fuel zone on the tanner diagram, organic waste is unsuitable for direct combustion, and plastic waste demands specialized incineration technologies due to high ash residue and emission concerns.

Tables 2: Moisture Content, Ash Content & Combustible Fraction of Waste Samples

Sample	Trial No.	Moisture Content (%)	Mean Moisture Content (%)	Ash Content (%)	Mean Ash Content (%)	Combustible Fraction (%)
<b>Organic Waste (Tree leaves, Roots etc.)</b>	1	75.88	76.33	21.11	21.20	2.47
	2	76.78		21.30		
<b>Paper &amp; Tissue</b>	1	15.22	13.63	76.66	78.33	8.04
	2	12.03		80.01		
<b>Plastic Materials</b>	1	2.30	2.70	89.95	90.03	7.28
	2	3.09		90.10		

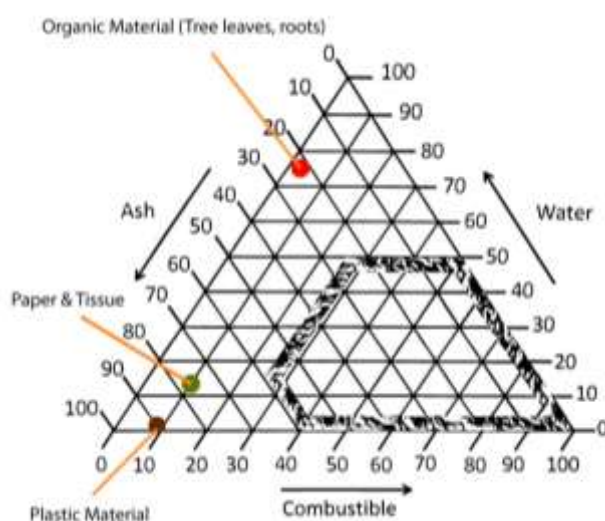


Figure 4: Tanner Diagram of Waste Samples

## CONCLUSION

The Tanner Diagram approach helps in classifying waste treatment methods, focusing on the alternative processing methods (e.g., composting for organics, recycling for plastics) which can be more sustainable than incineration. Among the three types of waste, no one falls within the "Ideal Fuel" zone of the Tanner Diagram.

Paper & Tissue is the nearest one to be a potential fuel, though its high ash content is limiting factor. Plastic Waste has low moisture but excessively high ash content, making it inefficient for energy recovery without the using advanced incineration technology. Organic Waste is the least suitable for combustion due to very higher water content and low combustible fraction. This makes it more suitable for composting or anaerobic digestion rather than controlled burning.

Though no idea fuel had been identified from the experimental results but this data can be extremely helpful to make waste management strategies, particularly in selecting appropriate treatment methods such as incineration, landfill disposal, or composting, based on the waste composition.

## ACKNOWLEDGEMENT

We would like to express our heartfelt gratitude to Dr. Quazi Hamidul Bari Sir for his constant guidance, encouragement, and support throughout this research. His insightful suggestions and expertise have been instrumental in shaping our work. Our appreciation also goes to Nafis Ahmed Pantho, Research Assistant, Department of Civil Engineering, KUET, for his valuable assistance

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