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Characterizing / Segregating Municipal Solid Waste and Finding its Recycling Potential in Bannu District

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Abstract

Escalating with rapid population growth and urban sprawl, unregulated Municipal Solid Waste (MSW) poses serious threats to public health and environmental safety. The current study examines the performance and physiological features of MSW and evaluates its potential as a renewable energy source in the Bannu region of Khyber Pakhtunkhwa (KPK) province, Pakistan. Depending on the average MSW generation of 0.439 kg/capita/day, the daily production of MSW in the city can reach up to 2000 tons/day. However, its safe treatment is inhibited by the lack of planning, public services, political determination, and public awareness. Various samples of MSW were collected for characterization/segregation purposes. Amounts of MSW in Bannu have been found to be declining through the use of decaying material, plastic bags of nylon, cloth, nappy, and paper. A close assessment of the recycling potential of MSW was performed by obtaining temperature values from combustion. The maximum energy output from MSW combustion was found to be 13369.935 kJ/kg. The power output of 44.29 MW is continuously tested from 2000 ton-of-MSW/day. The results of this study are expected to help policymakers develop management strategies for MSW in order to utilize these wastes for power generation.

Index Terms: *Burning, Garbage Disposal, Solid Municipal Waste, Renewable Power, Waste Management*.

I. INTRODUCTION

Over the last century, the burning of fossil fuels like coal and oil has increased Greenhouse Gas (GHG) emissions. Researchers have been continually striving to find ways for utilizing Municipal Solid Waste (MSW) through incineration to generate energy and reduce GHG emissions [1]. In terms of energy production, many advanced countries have previously developed MSW managing strategies such as incineration, gasification, Refuse Derived Fuel (RDF) production, and anaerobic digestion [2]. Recent advances in thermal technology and Air Pollution Control Systems (APCS) in developing countries have been offered as positive steps toward sustainable development in the energy sector. It has also been highlighted as a way to turn MSW into less expensive power sources, as well as to give commodities the opportunity to continue their use [3].

The most common concerns encountered during the burning of MSW in poor countries are those related to low energy content, excessive moisture content, and uneven proportion of materials. The International Energy Agency (IEA) estimates that for efficient incineration with energy retrieval performance, the normal calorific value of MSW should be greater than 7942 kJ/kg [4]. The waste streams, i.e., the life cycle of waste from its source up until and including its disposal, of developed countries have higher calorific values than the waste streams of developing countries. This is because the MSW of advanced countries contains higher percentages of paper, plastic, and textiles but lower biodegradable amounts [5], and [6]. The burning of RDF has been used in developed countries as a means of simultaneously addressing energy challenges [7].

From MSW collected in Lahore, the Lahore Waste Managing Company generates 500 and 700 tons/day of compost and petrol (RDF), respectively. The flammable part of MSW is mechanically removed and processed to produce RDF [8].

Access to energy is seen as a means of subsidizing the country's economy to keep profitable, national, and industrial activities going. Pakistan's energy crisis is largely due to shortages of pure gas, and high dependence on fossil fuels. To meet the power needs, most of the areas in the country face severe blackouts. In 2008-2009, the Pakistani government spent $9 billion on oil to pay for the hottest crops. This has placed a heavy burden on the country's economy and has polluted the environment [9].

The production of energy from MSW is highly dependent on the value of plastic and paper in the waste stream. In the energy renewal process, the fraction of the high-term paper in MSW contributes to the high-temperature values with low firing temperatures and low ash content. As a result, a fraction of the lower paper in MSW can contribute to the efficiency of the energy acquisition process [10].

Waste-To-Energy (WTE) is now an effective way to create green energy that is less expensive and more environmentally friendly. This is of great economic benefit, especially to the poor nations that rely heavily on fossil fuels. Despite the fact that many studies have found WTE to be environmentally safe, its economic performance has long been questioned due to its high operating and maintenance costs [11]. However, waste segregation remains a factor to be explored in the use of technology. Waste segregation refers to the separation of wet and dry waste. For the high moisture content of organic waste, anaerobic digestion is the most selective process of waste conversion. In many cases, heat and gasification are used for the disposal of fabrics and plastics [12].

According to reports from the World Bank and IEA, garbage should have a caloric value of more than 1700-1900 kcal/kg to be burned [13]. Pyrolysis is a process that is far more efficient than arson, which occurs at temperatures between 400 and 800 degrees Celsius in the presence of oxygen. The main products of pyrolysis are gas, oil, and char. The price of these products depends upon the temperature range and the temperature obtained. Gasification takes place in a controlled environment, and the living component is converted into syngas, the main product, which can be used to generate energy [14].

Peshawar (the capital city of KPK) produces 1331 tons of MSW on a daily basis. With a 20 percent thermal power plant, this waste can generate around 12.4 MW of energy [15]. Annual waste disposal in Karachi (the former capital of Pakistan) is 1.9 kg per person per day, 90% of which is dumped into the open. When the average caloric content of waste is 512 kcal/ton, research is being done on this waste management, which reveals that it can generate 1512 kWh/ton of energy [16].

The 4R-E principle i.e., first-order reduction (R) in the source, then (R) recycle, reusing (R), and renewal (R) before completion (E), as well as citizen knowledge, understanding, and education to reduce the amount of waste directed at landfills are emphasized. The simulation of Residual Household Waste (RHW) can assist in the development of waste treatment equipment by measuring the quantity of 4R-E available materials, identifying the sources of raw substances, and determining the physical, thermal, and chemical assets of RHW [17], and [18]. This information can be used to formulate an efficient management strategy to achieve goals and adhere to provincial, national, and local waste management standards.

Waste data collection and structure is an important means of developing waste management policies [19]. Cities in less developed countries, on the other hand, lose this information, and waste-related decisions are often made indiscriminately or on the basis of national standards that may be far from local if any data is available at all [20], and [21].

Municipal or local waste is usually made from a variety of sources due to various human activities. According to a number of studies, households produce the largest municipal solid waste in developing countries (55-80%), followed by commercial or market facilities (10-30%), and various contributions from street, industrial, and institutional sources [22-24]. In this study, we have provided an overview of MSW and its management, physical features, and capacity as a source of renewable energy founded on data composed with the MSW Centre in Bannu, KPK Pakistan.

II. METHODOLOGY

A. Study Area

Located in the southern part of Khyber Pakhtunkhwa province of Pakistan, Bannu has been given the status of a district during the British Raj period in 1861. As can be seen in figure I, the district shares borders with North Waziristan on the northwest, Karak on the northeast, Lakki Marwat on the southeast, and South Waziristan on the southwest.

More specifically, the region selected for the current study was Bannu city, which lies at the center of the district spreading over an area of 1227 Km^2 with a population density of 552/Km^2. Solid waste management is a big problem in the city of Bannu due to improper disposal and lack of treatment. For the research survey, we have selected two wards comprising eight streets (Mohallas).

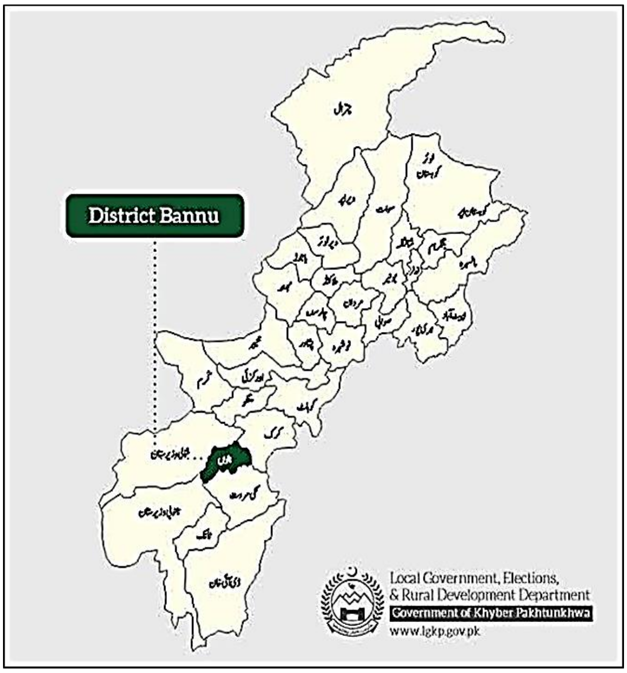

Figure I: The Map of Khyber Pakhtunkhwa Highlighting Bannu

B. Data Collection

The waste classification data was obtained by taking samples and separating them into different categories such as metals, papers, plastics, glass, organic, construction, and hazardous wastes. Figure II illustrates the characterization/segregation process. These samples were taken from landfills and transfer stations where all solid wastes had accumulated from residential, commercial, and agricultural uses. In some circumstances, samples from individual units have been used to produce waste data for specific categories, often referred to as generator-designed study.

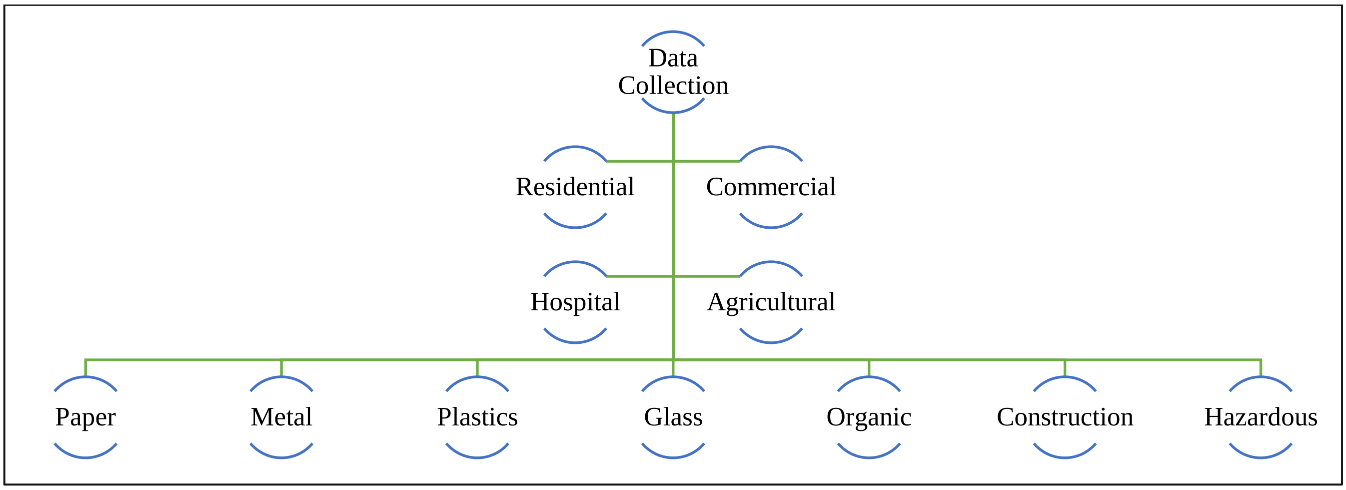

Figure II: The Characterization/Segregation of MSW

C. Method

Initially, a random sample of 20 kg weight was collected. The waste was thoroughly mixed to get a nearly homogenous distribution. Then the sample was divided into four quadrants and the two diagonal quadrants were mixed again, i.e., by quaternary method, as shown in figure III.

Figure III: The Characterization of Solid Waste by Quartering Method

Figure IV: Weighing the Sample

An empty container was taken and weighed see figure IV. The sample formed by mixing the two quadrants was put in the container. The container was carefully left to a height of 30 cm and then released to fall free. The weight of the sample was calculated by subtracting the weight of an empty container from the sum of the weights of the container and sample. Different types of wastes (paper, glass, wood, etc.) were separated manually from the sample, and the amount of each type was weighed and recorded. The rate of generation of solid waste was calculated using eq. (1).

$$R = \frac{N \times V \times M}{D \times A} \quad (1)$$

Where;
R = Per Capita Waste Production Rate
N = Total Number of Containers
M = Total Amount of Waste in kg
D = Average Number of Days Required to Generate a Container full of Waste
And,
A = Study Area in m^2
The percentage of the weight of each waste category was calculated using eq. (2).

$$P = \frac{m}{M} \times 100 \quad (2)$$

Where;
P = Percentage of Waste Category by Weight
m = Weight of Waste Category in kg
And,
M = Total Amount of Waste Sample in kg
For the analysis of moisture content, at least 1 kg of waste material was placed in a plastic bag to avoid loss of moisture. The bag was kept in an oven at a temperature of 100 °C for 24 hours. Then the following equation was used to find the value of moisture content:

$$MC = \frac{W_W \times W_d}{W_W} \quad (3)$$

Where;
MC = Moisture Content
Ww = Weight of Sample before Oven-Drying
And,
Wd = Weight of Sample when Oven-Dried
The following empirical models were used to calculate the energy content of MSW:

$$H_n = 88.2R + 40.5\,(G + P) - 6W \quad (4)$$

Where;
Hn = Energy Content in kJ/kg
R = Weight of Plastic in Percentage
G = Weight Waste Glass in Percentage
P = Weight of Paper in Percentage
W = Percent of Water (air dry)

III. RESULTS AND DISCUSSION

The quantity and quality of MSW produced are influenced by a variety of social and economic factors such as population density, life expectancy, per capita income, and human progress. The vitality and physical composition of MSW is highly dependent on social and economic standards. Results obtained from the current study are summarized in table I. Figure V shows the average weight of each waste category.

Table I: Composition (Percent by Weight) of Solid Waste Generated in Bannu District

S. No.	Waste Categories	Residential	Garden	Hospital	City	Average
1	Paper and Cardboard	4.46	2.36	2.11	1.9	2.7075
2	Plastics	6.69	9.45	9.12	6.94	8.05
3	Organic	81.71	63.78	32.98	72.65	62.78
4	Metals	0	0	0.35	0	0.0875
5	Glass	1.11	1.57	0.7	0.82	1.05
6	Construction/ Demolition	3.71	1.57	1.4	0	1.67
7	Hazardous	0	0	38.6	14.97	13.3925
8	Other	2.32	21.26	14.74	2.72	10.26

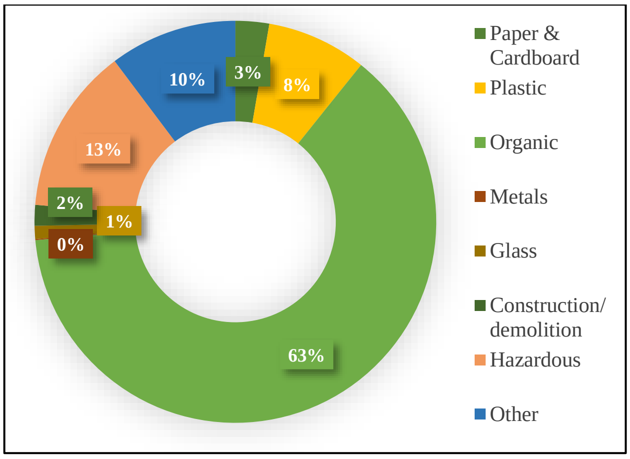

Figure V: Percent by the Average Weight of each Waste Category

The prevalence of waste in all social and economic levels declined (62.78%), followed by plastic bags of nylon (8.05%) and paper and cardboard (2.70%). High levels of biodegradable, especially food scraps, can lead to high humidity content in MSW. The MSW in Bannu has shown significant differences related to those of advanced countries, where the systematic arrangement of materials (i.e., paper, textiles, and plastics) leads to significant construction of MSW. The effects of local hospitalization are evident. A high percentage of plastic bags (9.45%) in the high-income area (cities) was seen as a sign of high levels of wealth. It should also be noted that the availability of large amounts of plastic bags and building materials at all levels of the economy is a serious concern. Figure VI presents the content of moisture recorded in the waste samples of Bannu District. Due to the inadequate garbage collection system, its presence in undesirable areas such as sewers, storm dumps, and roads can cause many unpleasant situations. Non-perishable plastic bags do not fit into the composting and recycling process. In commercial and institutional areas, the amount of unwanted hazardous waste was found to be the highest. Nearby hospitals have been a major source of hazardous waste as there is a shortage of landfills. At all social and economic levels, the percentage of the paper mark was not significant. Note that energy production from MSW is highly dependent on the high percentage of plastic and paper. The energy content obtained during the study is shown in figure VII. The high level of the paper fragment in MSW contributes to high temperatures with low ash content in the energy acquisition process. Therefore, the low level of the paper fragment in MSW can affect the efficiency of the energy acquisition process.

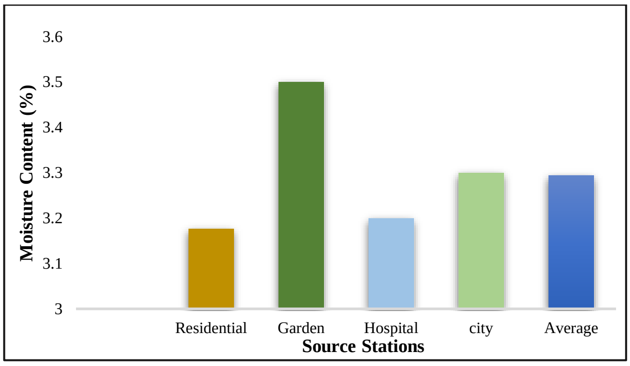

Figure VI: Moisture Content (%) of Waste by Source Station for Bannu District

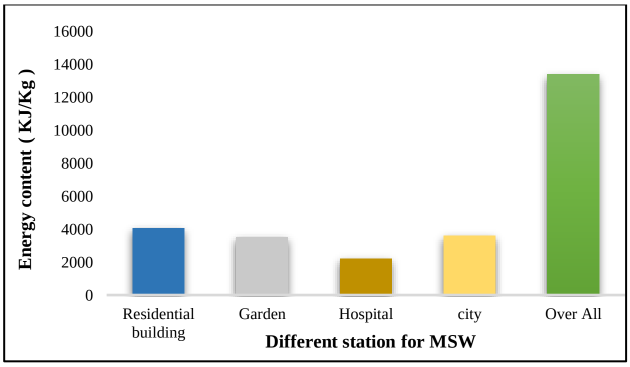

Figure VII: Energy Content (kJ/kg) of Waste by Source Station for Bannu District

IV. CONCLUSIONS AND RECOMMENDATION

Municipal solid waste is one of the most serious environmental issues. The lack of proper waste management causes environmental changes such as contamination of air, water, and soil, posing a serious hazard to human health. Other research has found signs of birth abnormalities (e.g. low weight), and a variety of cancers in MSW-surrounding areas. The increase in solid waste generation became a burden on the high cost of the municipal budget. The quantity and quality of MSW have been dramatically accelerated by population growth, fast urbanization, economic growth, and growing living standards. Natural fragmentation of MSW through time is a key element in determining the amount of recoverable materials, particularly organic content.

The impact of improper collection, transfer, and/or transport systems on solid waste signals is significant. Plastic garbage disposal is a huge environmental issue all over the world. Plastics have a calorific value of between 30 and 40 MJ/kg since they are hydrocarbons. As a result, they can be burned by municipalities or other entities devoted to creating energy and heat.

Many countries around the world are facing a major challenge in managing household food waste. House bread crumbs have been used to produce amylase. By using the orange peel as a substrate, the cultivation of selected types of industrial yeast has resulted in a higher yield of aromatic esters. Mixed food waste collected from restaurants and infused with an inoculum fungus can produce glucoamylase-rich media and protease-rich media with SSF. These media are ready to be used as feedstock for the production of succinic acid. Later, there are various uses for the manufacture of medicines, plastics, and laundry detergents.

There is a need for sensitization the households to create awareness of the importance of separating the waste into different streams to facilitate recycling. This awareness would change the attitude of households. Educating and sensitizing can be done in schools through environmental based clubs on the importance of waste management and separation of waste at the source. This can also be done through the introduction of waste management in the school curriculum by the Ministry of General Education so that right from the early stage, awareness is created.

The government and/or local authority needs to find a way of reducing the use of, or reusing, plastic waste as it is non-biodegradable. The unregulated use of plastic bags should be prohibited as opposed to the current practice. Moreover, those willing to have a plastic bag should pay for it, which will reduce its use. The reduction of plastic waste can also be done by asking households to sort out plastic waste which they can later sell to earn a living.

Understanding the structure of MSW is very important in terms of future planning and management of MSW. The establishment of the "Waste to Energy" program will be beneficial to the Bannu district in terms of proximity results and MSW temperatures. Indeed, the burning of 2000 ton-of-MSW/day has a recovery power of 44.29 MW and a high return on environmental benefits, including a reduction in GHG emissions. However, high humidity content, inadequate collection methods, and efficient collection of municipal departments remain challenges.

Because each district municipality is in charge of waste planning and management in its region, the proposed technique has demonstrated that waste management managers can detect the structure of their deposits using simple, easily accessible technologies.

At the local permit level, the definition of MSW can be done as:

1. Establishing a year-round database of home trash indications in order to evaluate the effectiveness of waste management systems and to recognize the appearance of new waste categories.
2. Recognizing the influence of seasonal variations on waste physical characteristics.
3. Providing adapted and appropriate services for specific waste types and facilities.
4. Measuring the quantity of organisms that need to be collected and treated.
5. Selecting appropriate biological treatment technologies.
6. Determining the seasonal inclusion that includes a biological analysis system.
7. Being aware of the economic impact of 4-R items still being completed.
8. Providing information, awareness, and translated education on the rest of the material.
9. Taking into account the needs of the provincial level (and other spheres of government) and program objectives for waste management and waste minimization.

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Authors Contributions

The contribution of the authors was as follows: Abdul Ghani’s contribution to this study was correspondence.
The rest of the authors (Jehangeer Alam, Mian Said Kashif, Sareer Ahmad, and Muhammad Irfan) jointly performed all tasks.

Conflict of Interest

The authors declare no conflict of interest and confirm that this work is original and not plagiarized from any other source, i.e., electronic or print media. The information obtained from all of the sources is properly recognized and cited below.

Data Availability Statement

The testing data is available in this paper.

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