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Evaluation of Energy Potential And Methane Generation From Municipal Solid Waste (MSW) of Gujranwala City (Pakistan)

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Submitted: 06/07/2022, Accepted: 25/05/2023, Online: 27/06/2023

Abstract

The worldwide atmosphere has been seriously deteriorating due to the poor handling of waste produced in order to get useful products for achieving the high living standards and technological development. Therefore, waste management is a serious concern to avoid ecological damage. Methane gas generated on waste landfill sites is the source of greenhouse gas that is prime contributors to environmental degradation. The main intention is to measure the amount of methane gas produced from Municipal Solid Waste (MSW) at the site of Bakhrewali in the Cantonment (Rahwali), Gujranwala, Pakistan and to estimate the extent of energy that potentially could be retrieved from the MSW site. The waste samples were gathered to evaluate the energy content, composition, and methane concentration. The findings from the MSW characterization revealed that the primary constituent of Bakhrewali site, Gujranwala MSW is organic waste. The concentration of methane from sites 1, 2 and 3 were analysed to be 118.45, 35.32, 48.26 ppm methane/g waste. The calorific value of samples 1, 2 and 3 were determined to be 13.45, 12.24, and 11.01 MJ/kg respectively. The outcomes confirm that there is production of methane at the waste sites and the municipal waste could be utilized for energy recovery. The analysis of samples collected from MSW sites shows that there is great potential in the waste to be combusted and used for electricity generation.

Keywords: Municipal solid waste, Rahwali cantt, Gujranwala city, Methane, Calorific value.

1. Introduction:

Global warming remains a global concern whose diminution has been debated for the recent times. The usage of different waste materials for getting valuable products could be a good way out to retain reserves for future use and also to avoid additional burden on the environment [1]. Worldwide, municipal solid waste (MSW) is considered among the largest sources of global warming, with current trends showing 16% emissions of greenhouse gases

(GHG) are caused by MSW [2]. The rapid population expansion, technological development and rise in living standards accelerated the MSW in countries like Pakistan. Assessment of methane discharge from landfills site is vital in order to reduce GHG and global warming [3]. Methane may be utilized as green energy source has been highlighted in various studies [4]. In the present study, an accurate measurement of MSW composition, assessment of emission of methane by organic waste anaerobic

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digestion at laboratory scale and energy content of MSW was examined of Gujranwala city, Pakistan.

Gujranwala city, sited in north-eastern part of Punjab territory of Pakistan and has a 2.81 million people population [5], the growth rate of this population is estimated to be 3 % per annum. With this growth rate, there is a continuous rise in the quantity of waste produced in the city. The generation, collection, treatment and disposal activity of solid waste poses a grave ecological challenge to the city. Presently 360 tons of MSW is produced per day as per Gujranwala waste management company (GWMC) [6]. GWMC holding responsibility for collection of waste generated in the city, collects 120 tons of waste daily that accounts for 33% of the total waste produced [7]. The un gathered waste is usually disposed of in various unauthorized areas of the city creating solid waste hazards and thus leading to environmental and health issues [6]. This problem has called for the city authorities to formulate an integrated methodology of solid waste collection, recycling and combustion so that maximum energy can be recovered from the city's waste. Incineration plant can be utilized to generate power from MSW [8, 9]. Sadly, in order to get power from MSW, the data of characteristic of the solid waste is necessary. The landfill sites in Gujranwala city are mostly non-

engineered with open dumps where there are no bottom liners nor treatment systems and leachate collection [10] as shown in figure 1. Leveling and compaction of garbage and layering by earth is not accomplished while these sites are short of landfill gas collection and monitoring devices [11]. This type of waste management approach is dangerous as it causes greater emission of methane gas until the gas is not recovered or flared. Such a waste management also increases the atmospheric and underground water pollution that give rises to serious environmental degradation [12].

Man made activities are the main sources of methane gas liberation from the landfill sites throughout the world. Therefore, it is important to estimate the methane gas generation to evaluate the amount of energy recovery from the waste dumping sites. So, by estimating and collecting the methane from landfills the quantity of methane in air can be lowered. The rates and amount (mass) of methane production rely on various parameters that are hard to measure, and these differ from place to place [13]. The tools for onsite estimation of generation of methane are expensive and are in scarce in the developing nations. Most models-based studies using available data usually deliver unreliable results. The purpose of this investigation is to estimate the generation of methane from chosen waste sites in Gujranwala City.





Fig.1 Waste Landfill sites of Gujranwala city (a) Bakhrewali (b) Gondhlanwala and (c) Khiali.

2. Methodology:

2.1 Site selection:

Gujranwala is seventh biggest city in Punjab state, Pakistan with total area covering of 3198 km² and located in north-east part of the country as shown in figure 2. It is fifth most populous (2.81 million) metropolitan city of Pakistan. The area has five weather seasons specifically summer, winter, autumn, spring and monsoon season. The temperature in the city varies from 2 °C to 42 °C and can fell down to -2 °C in winter and rise up to 46 °C in

summer. The city has four waste disposal sites namely Bakhrewali, Gondhlanwala, Jhandyala baghwala and Khiali drain as shown in figure 1. Bakhrewali and Gondhlanwala sites are operational while Jhandyala baghwala and Khiali are exhausted and thus non-operational. The waste that arrives at these sites is not segregated. The general waste characterization of the Gujranwala city is presented in figure 3 [6] with highest amount of waste comes from kitchen waste 44% followed by animal manure of 10%.



Figure 2: Map of the study area Gujranwala City.

This study was conducted on samples from three waste producing sites in Rahwali cantonment area (Bakhrewali). The samples include (1) Mixture of wastewater and manure (from cattle farming site in

cantonment area) (2) Organic waste (decomposed vegetables) and (3) Municipal solid waste from mainly colony waste bins, household waste and waste dumping site.

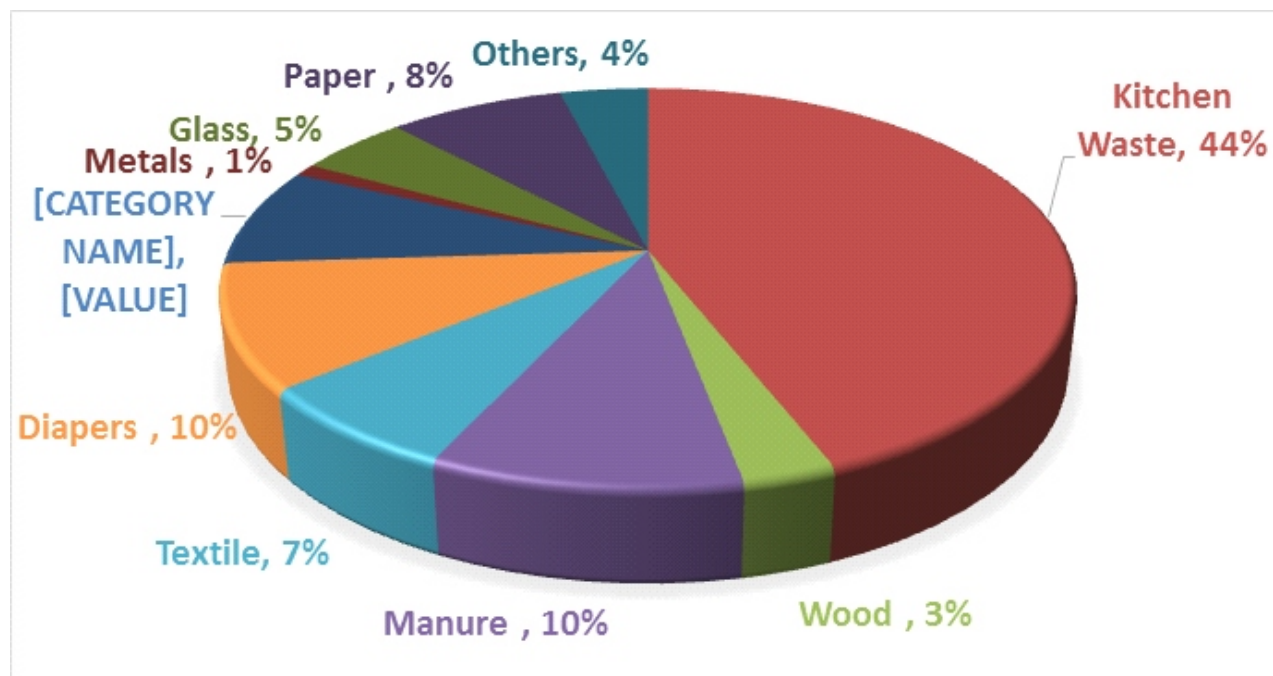


Figure 3: Municipal solid waste (MSW) composition of Gujranwala city.

1.1 Proximate and ultimate evaluation

Proximate evaluation were performed of collected specimen to find out the values of moisture content, volatile matter, ash content and fixed carbon. The moisture content was calculated by ASTM E1756-08 standard [14]. The 10 g organic waste sample was put in an oven at temperature of 105 °C for 2h. After heating samples were allowed to cool and weighted again. The difference in weight before and after heat treatment gives the moisture content and is expressed in percentage. The volatile matter was estimated by method described by ASTM standard E-872 [15]. The samples mentioned above utilized for moisture content, was put in a vessel and covered. The crucible was placed in a furnace where the sample was heated for 2h. After that crucible was taken out and the sample was allowed to cool in a desiccator and weighted again. The quantity of volatile a matter is indicated by the difference in weight. Ash content was evaluated by putting the same sample after volatile matter calculation again in a furnace at 600 °C for 1h for combustion. When all of the carbon was charred, the specimen was allowed to cool in a desiccator and reweighted. The ash content was measured by weight difference. Fixed carbon in sample was calculated by subtracting moisture, volatile matter and ash

content from 100. The analysis (proximate) was performed three times and the mean value was presented.

$$FC = 100 - M - VM - ASH$$

Here, FC- Fixed Carbon, M- Moisture, VM Volatile matter, ASH- Ash Content

Ultimate analysis was performed using CHNS analyser (Leco) that involves the complete and instantaneous oxidation of the sample by “flash combustion”. Organic sample 0.5 g was desiccated in an oven at 105 °C for 3 h. After cooling it was grounded into powder form and then converted into pellets. These pellets were placed in CHNS analyser for 3 min where the temperature was raised up to 950 °C for Carbon 'C', Hydrogen 'H' and Nitrogen 'N' determination and 1300 °C for Sulphur 'S' determination.

1.2 Determination of calorific value:

The calorific value of solid waste was measured using Leco Bomb calorimeter model A500. 100 g of solid waste was gathered from each location, desiccated and grounded. 1 g of solid particles were weighed and compacted to form pellets. These pellets were then put in the calorimeter pan. The samples were treated one by one and the amount of energy was measured using the procedure of Jesup in 1960 [16]. The samples were tested in triplicates

from each site and average value of each sample was taken.

2.4 Generation of Methane Gas:

Three waste samples from a selected site were used to generate gas under anaerobic environment. About 50 g of waste sample from each site were transferred in to 250 ml glass bottles. In that 50 ml of distilled water were added slowly and the bottles were firmly stored. The samples were kept at room temperature ($35 \pm 2^\circ\text{C}$) and the formation of gas was analyzed after ten days of process. Gas samples of 10 μl were collected from digester utilizing syringe and was instantly inserted to Gas chromatography (GC).

2.5 Methane Estimation:

Methane in the head space was analyzed by injecting 100 μl into a gas chromatograph fitted with FID and TCD. The column was a packed 1.5 m stainless steel column stuffed with 5 Å carbon molecular sieves. The injector and detectors were kept at 200°C , the column was first kept at 50°C for 5 min. Later increasing the temperature to 200°C ($15^\circ\text{C}/\text{min}$) and kept for 15 min.

3. Results and Discussion:

The results obtained in this study are presented in Table 1.

3.1. Proximate And Ultimate Analysis Of Waste Samples:

Moisture content of samples were found out to be 19.06%, 8.41 % and 7.05 % respectively as presented in Table 1. The results were not very high as the

analysis was performed in summer when the temperatures reaching ($40\text{--}45^\circ\text{C}$) in the vicinity of sampling sites. The observation in the present study is similar to other findings reported by other researchers [2, 17-19]. Moisture content in the sample 1 was highest as compared to sample 2 and 3. This is due to the occurrence of higher percentage of cattle manure mixed with wastewater at the sites in Rahwali cantonment area (Bakhrewali).

Volatile solids in the three samples were recorded to be 32.24, 50.67 and 48.78 % dry weight respectively. The volatile matter in sample 2 was highest among the three samples. This high volatile matter revealed that the amounts of organic components are high in this sample. Also high volatile matter gives an indication that high thermal energy can be generated from that waste. The amount of fixed carbon in the three samples was recorded to be 25.65, 12.45 and 14.21%. Sample 1 has higher amount of fixed carbon than sample 2 & 3 that shows that fuels from the sample 1 requires longer retention time for complete combustion [20].

DB = Dry basis

The ash content in the three samples varied between 22.33 and 26.35 wt % basis and fixed carbon varied between 25.65 and 12.45 wt % basis. The standard ash content that is (5-15 wt % dry basis) as described by EPA. US [21]. The ash content value in the present study is quite high as compared to the standards. The high ash content is due to increase number of inerts in waste samples.

Table 1 Outcomes of proximate analysis of different waste specimens from Rahwali Cantonment area.

<i>Samples</i>	<i>Moisture Content (Wt% DB)</i>	<i>Ash (wt% DB)</i>	<i>Volatile matter (wt% DB)</i>	<i>Fixed carbon (wt% DB)</i>
Sample 1	19.06	22.33	32.24	25.65
Sample 2	8.41	26.76	50.67	12.45
Sample 3	7.05	26.35	48.78	14.21

The ultimate analysis of three samples is presented in Table 2. The ultimate analysis of the specimens showed very little differences in the elemental composition among the three samples. The mean carbon, nitrogen, sulphur, hydrogen, and oxygen of the sample 1 was 34.77, 1.44, 3.43, 0.33 and 17.61

respectively. The nitrogen, hydrogen and sulphur percentages were low whereas carbon and oxygen values were higher in the three samples. The high carbon percentage is due to the presence of large quantity of organic matter. Similar results are shown in other studies [22, 23].

Table 2: Results of ultimate analysis of waste samples and gross calorific value

<i>Samples</i>	<i>C(%DB)</i>	<i>H(%DB)</i>	<i>N(%DB)</i>	<i>S(%DB)</i>	<i>O(%DB)</i>	<i>Gross Calorific values (MJ/Kg)</i>
Sample 1	34.77	3.43	1.44	0.33	17.61	13.45
Sample 2	32.26	3.82	1.12	0.14	27.73	12.24
Sample 3	24.67	4.66	1.41	0.22	27.52	11.01

DB-Dry basis

3.2. Calorific value of Municipal Solid Waste:

Based on results from laboratory analysis, the calorific value (dry basis) of the three samples was recorded to be 13.45 MJ/kg, 12.24 MJ/kg and 11.01 MJ/kg of sample no. 1, 2 and 3 respectively as presented in Table 2. The calorific value of sample 1 was highest among the three samples. The solid waste with calorific value of 11-17 MJ/kg or higher is more likely to be utilized as refused-derived fuel (RDF) [1]. Hence waste samples are eligible to be employed as energy use. The calorific value recorded in the present study is also comparable to

other such studies [2, 24].

3.3. Estimation of Methane gas:

The concentration of the methane gas from three samples taken from Bakhrewali was analyzed using Gas Chromatography (GC) in parts per million (ppm). The average gas readings were noted highest from sample 1 as 118.45 ppm methane/g OW with sample 2 and sample 3 gives concentration of 35.32 ppm methane/g OW and 48.26 ppm methane/g OW as presented in Table 3. These amounts of methane gas are sufficient to be used for electricity generation through combustion process in the biogas generator [25, 26].

Table 3: Methane formation from three different waste samples

<i>Samples</i>	<i>Concentration (ppm methane/g waste)</i>
Sample 1	118.45
Sample 2	35.32
Sample 3	48.26

The higher amount of methane concentration among three samples was recorded from sample 1 due to higher concentration of moisture and organic contents in that sample. Gurijala and Suflita [27] confirmed that more gas formation was attributed to higher moisture content, whereas Kazuyuki & Katsuyuki [28] found that higher organic matter had an influence on increased methane production from rice paddy fields in Japan.

4. Conclusions:

The waste management has become a serious concern in developing cities like Pakistan owing to the rapid growth in population, economic growth, technological development and desire to achieve high living standards. The study of physical composition of waste samples from Bakhrewali waste collecting site in the cantonment area of Gujranwala city showed that the waste is relatively

organic in nature. The results showed that there is relation between composition of waste, moisture content and quantity of gas. The higher the organic waste and moisture content and lower ash content, the higher the production of gas. Hence, sample 1 consisting of manure and wastewater produced more methane as compared to other two samples. The methane production from the samples of three sites suggests that the landfill sites are source of potential energy generation, but more research requires to be done for economic and technical evaluation of the power production. Sample no 1 was recorded with highest production of methane gas with the calorific value of 13.45 MJ/Kg. The utilization of waste sources as energy will reduce the dependance on fossil fuels and can simultaneously solve the environmental and waste disposal issues.

Acknowledgement:

The facility support offered by research laboratory of department of Chemical Polymer and composite materials Engineering UET, New Campus, KSK is acknowledged.

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