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Biochar and Resource Convalescence Burgeoning from Municipal Solid Waste in Pakistan

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Abstract

Municipal Solid Waste Management System (MSWMS) has been a smoldering and exigent concern of most of the mounting economies. Inhabitants explosion, industrial expansion and economic development consequences serious outcomes such as catastrophic municipal solid waste management system, open dumping of organic waste and the associated Green House Gases (GHG) emissions are the key matters of the most of the developing economies. Contiguous psychoanalysis and experimental exploration in the current study concluded that higher proportion of organic waste (71%), combustible (19%) and recyclable (7%) in the current municipal solid waste stream at Mardan and Peshawar cities of Pakistan. The current waste collection efficiency (120-130 out of 300 tons per day) in the Mardan and Peshawar city has enough potential to produce Biochar of about 18.5-20 tons per day), Refuse Derived Fuel (RDF) of about 18.4 tons per day and recyclable of 11.5 tons per day can be recovered. These waste distraction routes built in with Biochar and Resource Recovery (RR) could steeply reduce the waste dumping quantity especially organic fraction disposal at landfill sites which otherwise require better management for safe and regulated disposal.

Keywords: Biochar; Contiguous psychoanalysis; Municipal solid waste management system; Organic waste; Refuse derived fuel; Safe disposal.

Introduction

MSWMS has been a fiery issue in the developing countries as hefty inhabitants has moved around towards the urban areas and permanently settled there. This inhabitant detonation, along with industrial expansion as well as economic development resulted number of issues such as disastrous municipal solid waste management system, open dumping of organic waste at landfill sites and the associated GHG emissions are the key issues of the most of the developing economies. According to, massive quantity of municipal solid waste (more than 67,500 tons per day) is produced daily with growth rate of 2.4% per annum, and these wastes are being simply treated as ordinary waste which is a serious issue of concern. Municipal Solid Waste (MSW) generated in Pakistan usually consists of 40%-70% of organic 14%-24% of recyclable and rest 6%-9% is expressed as others [1].

Improper MSWMS in Pakistan and many other developing nations is on the peak and regrettably no appropriate consideration has been given to them due to multiple issues such as: institutional, political, social, educational and capital. According to Pakistan Economic Survey 2014, there is an imperative necessitate to restrain the waste generation and to recycle and reuse them and latest waste treatment technologies should be explored in a sustainable way to turn them into constructive energy possessions tied with burnable and ecological recuperation in order to diminish waste quantities requiring improved supervision for undisruptive and synchronized disposal. This approach could encounter numerous tribulations at the same time such as to tackle depleting fossil fuel resources, the associated GHG emissions, energy deficit etc. to secure regional energy security and environmental sustainability [2].

Pyrolysis is one of the well-known thermo chemical renovation technologies that have been used for many centuries for the fabrication of charcoal from biomass. The procedure thermally decomposes organic solid waste and is performed under inert environment in the absence of oxygen which goes to chemical and substantial partition of dissimilar molecules for the fabrication of oil, gas and improved quality solids such as Biochar [3]. The Biochar, a carbon-rich solid material obtained from slow pyrolysis of organic waste has resourceful relevance. This thermo chemical procedure provides further remuneration such as more than 70% volume reduction as well as inferior emissions. But prior to biochar fabrication, it is very significant to forecast the impending and suitability of feedstock by determining their energy content; called Higher Heating Value (HHV). The higher heating value is the production of energy released from fuel upon combustion; denoted as HHV (Mj/kg), is determined experimentally via bomb calorimeter. This technique is valuable and time consuming and sometime yields inaccurate results. Immense literature has developed various empirical models to calculate calorific value of fuel from proximate analysis as there is high correlation exist between the two Therefore, it is wise to estimate accurately HHV values from the empirical investigation to save time and cost of equipment that would be used for the investigation [4,5].

The study is conducted to predict the impending of biochar and resources recovery (combustible and recyclable) from the MSW stream being generated at Mardan and Peshawar cities of Pakistan. This energy and resource recovery from the waste sector could finally diminish the massive organic waste, combustible and recyclable fraction dumping at landfill sites, which is one of the exigent issues for the developing economies. This could be a paradigm loom for the rest of the city of Pakistan in term of better solid waste management system coupled with sustainable energy production and resource recovery [6].

METHODOLOGY

Study area

Mardan and Peshawar are the largest cities of Khyber Pakhtunkhwa (KPK) with total area of about 1,632 sq km and 2,758 sq km respectively. The total population of Mardan and Peshawar districts is about 2.37 Million and 66.21 Million respectively.

Data regarding generation, collection and disposal of MSW were obtained from Municipal Authority, Water and sanitation Services Company of Peshawar and Mardan, established in December 2016, is providing municipal solid waste management, water and sanitation services in their respective areas.

Random sampling for analysis

For laboratory examination, stratified arbitrary samples of household municipal solid waste (only organic fraction) has been collected from diverse secondary points for repeated eight days and prepared by mixing and weighing as per standard procedure and packed in the sterile bags and then transported for laboratory investigation.

Proximate analysis

For moisture content fortitude, the sample weighing about One Kg apart from tray's weight was placed in the furnace. The furnace was set to 105°C with two hours sample retention time. The following expression was used to determine the proportion of moisture content (DIN-EN 14346).

$MC\%=(\Delta W/Wi) \times 100$

Whereas;

MC=Moisture Content (%)

W=Weight difference of the sample before and after oven drying

Wi=Weight of the sample before oven drying

The section used for moisture determination was covered and heated in a furnace for 2 hours. The sample were later cooled outside and then reweighed. The volatile matter was determined from the following formula.

%Volatile matter=(Dry sample weight-Ash weight/Dry sample weight) x 100

The dried sample was weighed and then combusted at a temperature of 600°C in the furnace for 1 hour. The sample was re-weighed and the following expression was used for ash content calculation.

%Ash(dry basis)=(Mass of ash/Mass of dry sample) x 100

Fixed carbon is determined by subtraction the moisture, volatile matters, and ash contents from 100.

$FC=100-(MC+VM+Ash)$

Where FC-Fixed Carbon; MC-Moisture Content; VM-Volatile Matter and Ash Content is the remaining ash.

The above mentioned analyses steps were iterated and average values were taken.

For calorific value determination the following linear equation has been used.

$HHV=0.1905VM+0.2521FC$

Results and Discussion

Scenario of solid waste generation in study area

By examining municipal solid waste generation pattern of Mardan city with 2.37 million populations; average per capita waste generation is estimated to be about 0.6 Kg per day, which in the range between 0.28 to 0.84 Kg per day at Pakistan is ascertained by an assortment of research studies [7-10]. However, this per capita waste generation rate is almost twice as much as generated in Peshawar city as well as in Sialkot city, but lowers than Lahore and Gujranwala city.

Composition of municipal solid waste

According to waste characterization study conducted for Mardan and Peshawar area; is comprised of about ten fractions consisting vegetables, bones, paper, textile, plastic, grass/wood, leather/rubber, metals, glass/ceramics and miscellaneous (consist of 90% organic) as shown in the following Figure 1.

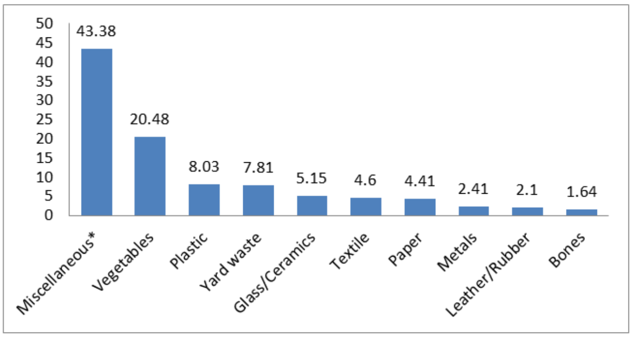

Figure 1: Municipal Solid Waste Composition.

Proximate analysis of organic waste

The proximate analysis of organic waste was performed in the laboratory and reported in the Table 1.

Proximate analysis	Food Waste	Yard Waste	Papers
Moisture Content (% by wt.)	<92.4	<58.6	<8.9
Volatile Matters (%)	78	82	80

Ash Content (%)	14	17	15
Fixed Carbon (%)	6	7	7
Energy content (MJ/Kg)	15.8	17.1	16.7

Table 1: Proximate analysis.

The above information signifying that more than 90 % (maximum) of moisture content has been predicted in the food waste, followed by about 58% and 9% in the yard waste and paper respectively. Ash content was found 15%, 17% and 14% in papers, yard waste and food waste respectively. The reason of highest ash value in paper was lowest moisture content and lowest value in food waste was due to higher moisture content, this inverse relation among moisture content and ash content has already been ascertained by various researchers. In addition, this ash content has also great effects on the yield of biochar.

The predictable values of HHV revealed that yard waste and paper have high energy recovery potential, with 17.1 and 16.7 MJ/Kg respectively due to minor moisture content. On other hand the energy content of food waste found was 15.8 MJ/kg due to high water content possession; inverse relation has also been investigated by. The predicted energy content in the organic waste stream is enough to use this fraction as a renewable energy source such as Biochar.

Energy and Resource Recovery Potential

The waste composition and generation rates revealed that Mardan and Peshawar cities have huge potential of biochar due to significant organic waste in municipal solid waste stream. About 95.1 tons per day of organic waste are being generated, is suitable for biochar production. Various research studies such as have been conducted for yield and biochar production from organic solid waste via slow pyrolysis. The former study has determined 35% Biochar yield for Belgium with 30% moisture content, while the latter study has predicted 20.4% yield of biochar with 55% moisture content in municipal solid waste stream for Haripur city of Pakistan. Variation in the yield of biochar is due to different moisture content in waste stream [11].

The combustible waste invention rate is estimated to be 18.4 tons per day. However, some studies have found momentous quantity of combustible fraction in MSW stream [12]. This combustible fraction is called RDF (Refuse Derived Fuel), which has higher concentrations, quality and uniformity of characteristics of combustible materials like plastic and paper etc. than their parent municipal solid waste stream which can be used as a fuel or as a supplement by different energy consumer for energy and heat production resulting reduction of mass and volume by 70% and 90% respectively. This route consequently reduces the waste quantity to be disposed-off at landfill sites [13-18].

The lowest fraction is recyclable, which is 9.2% of total waste; about 11.5 ton of recyclable produced daily [19]. The recyclable material retrieved from the waste stream, yields multiple benefits; such as reduction of production cost, minimizing burden on the indigenous resources, saving of procurement cost, and revenue generation from recyclable's selling as well as reduction of cost for waste dumping at landfill. The reason of low quantity of recyclable is due to scavengers' collection from waste primary points to disposal sites [20].

Conclusion

Based on the existing model and symphony of MSW produced in the study field, it can be proficient that only 120-130 tons of solid waste; is 40%-43% of municipal solid waste are being collected daily in the stated urban union councils, where daily 300 tons of municipal solid waste are being generated; is mainly comprised of 71% is organic; the combustible fraction found is about 19%, which is termed RDF. More than 7% of the recyclables can be recovered.

More importantly, the organic waste fraction was found with tolerable energy content that can be converted into Biochar. The current MSW generation rate and composition at Mardan city could yield about 18.5-20 tons of biochar per day with approximately 55% of moisture content in the waste stream, which has versatile application in many sectors. RDF production's potential is about 18.4 tons/day, while the recyclable recovery potential is 11.5 tons per day.

These waste diversion routes could steeply reduce the waste dumping quantity especially organic fraction disposal at landfill sites. By adapting the above mentioned routes in the Mardan region, could generate significant revenue from the waste sector. However, additional investigation is required to examine the waste composition as well as the quantity of MSW in the rest of the region of Mardan city to fully exploit these waste resources with full potential for better regional energy security and environmental sustainability.

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