POTENTIAL OF CONVERSION OF ORGANIC SOLID WASTE INTO BIOCHAR

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ABSTRACT: *From the past few decades, improper solid waste management in Pakistan has emerged out as a serious matter of concern. Arising quality of life, prompt increase in urban population and changing consumption patterns results in generation of huge piles of waste materials that are far beyond the carrying capacity of the earth and posing serious threats to public health and environment. On the other side with the onset of industrial revolution and increasing energy demands Pakistan is facing serious energy crisis. To combat these issues there is dire need to properly manage the solid waste and transfer the energy trends to renewable energy resources. Therefore, in the present study a disposal method is proposed as conversion of organic solid waste into Biochar with aim to explore context specific options for the disposal of solid waste that not only reduce the environmental burdens of Haripur but also serve as renewable energy source. The stratification sampling technique was used to collect waste from Households which was further characterized into different categories by following reduction method. The percentage of organic content in waste was found to be highest about 66% which was feasible for its conversion into biochar. Proximate analysis of organic waste were also done in lab, by following EU standard procedures; these include moisture content, ash content and energy content. Energy content was found out by bomb calorimeter method and was about 16 MJ/Kg which shows the suitability of sample for energy source. Afterwards the organic waste was subjected to slow pyrolysis in specially designed reactor with reaction conditions as temperature 600^{o}C, in absence of oxygen and retention time 4 hours that ultimately converted organic waste into biochar with yield about 20.4%. The results thus showed that organic waste has potential to form biochar which in turn reduces the loads on disposal sites and will be helpful to overcome the energy crisis.*

Key words: organic solid waste, biochar, proximate analysis, slow pyrolysis

1. INTRODUCTION

Nowadays, management of solid waste (SW) is a key challenge facing each country worldwide and the situation is getting even worse in developing countries. Pakistan, as like other developing countries, also experiencing solid waste management issues and it is a matter of serious concern for government and other municipal authorities [1]. This is attributed due to various reasons, chiefly the annual waste generation rate is increasing at an alarming level as compared to population explosion and urbanization. Moreover, rapid development and changing lifestyle in growing cities have also changed waste composition from mainly organic to mainly plastic, paper and packaging material that are complex in nature [2]. With the rapidly increasing waste generation rate, there is need to tackle this issue because if the waste is handled improperly it will be a source of land, air, surface water and groundwater pollution. Uncontrolled dumping can cause health problems like skin infections, gastrointestinal, respiratory tract infections and environmental problems such as pollution of surface and groundwater from leachate production. Therefore, in present scenario, proper collection, characterization, treatment and disposal of waste is the utmost need for the well-being of life on earth [3].

On the other side with the onset of the industrial revolution and increasing energy demands Pakistan is facing serious energy crisis. Former fossils driven energy resources such as petroleum, coal and natural gas are nonrenewable resources and are projected to be exhausted in the near future due to over extraction and utilization [4]. Therefore, due to escalating demands for energy there is an urgency to develop efficient bioenergy conversion processes i.e biochar in order to meet energy challenges of the millennium [5].

Biochar, replacement of coal, is a charred by-product produced by the thermochemical pyrolysis of biomass in a low or zero oxygen environments, at quite low temperatures i.e. less than 700°C [6]. In these conditions, thermal scission of bonds and poly condensation reactions occur that ultimately convert biomass into biochar However, the feedstock which can be used for biochar production includes numerous sorts of biomass such as wood waste, agricultural residues, forestry residues, organic waste. Among the Municipal Solid Waste (MSW), organic potion contribute a major share of 50%, which are considered as waste, but in actual these are natural and valuable resources and can act as precursor for biochar which is an alternative renewable energy resources [7]. Furthermore pyrolysis of biomass generates gas, liquids and solid products. The gas can be used to provide energy to power the pyrolysis process itself, whereas bio-oil can be used as a replacement for numerous applications where fuel oil is used, as well as a feedstock for chemical production. On the other hand bio-oil can also be gasified to produce clean ash free syngas [8].

The present study was thus conducted by keeping in view the importance of solid waste characterization and quantification as a prerequisite for any solid waste management plan along with the aim to assess the potential of the organic portion of solid waste of Haripur city production of Biochar through Pyrolysis technology. This pyrolysis of organic waste will not only reduce the problem of solid waste, but also diminish the dependence on non-renewable petroleum based energy resources by serving as a sustainable energy resource for the future and will be a role model for other cities of Pakistan.

2. MATERIAL AND METHODS

1.1. Study area

District Haripur, comprises an area of about 1725 km^2, is located in Khyber Pakhtoon Khawa (KPK) province. According to a 2005 statistic, district Haripur have a population of almost 10,53,307 residing in its 44 union councils [9]. However, for particular study purpose, among 44 union councils only 4 Union councils named as UC Central, UC Sikandarpur, UC North and UC South were selected which lies in municipality jurisdiction.

1.2. Collection and preparation of sample

The solid waste samples were collected from selected 4 Union councils at household level, by following stratified random technique, on a daily basis for upto 8 days consecutively. Plastic bags were used for collection of waste which were ultimately transferred to the selected southing side where they weighed by using collaborated weighing balance.

Afterwards the waste collected from each Union council was mixed in a uniform way and the waste pile was further divided into four portions by using rope. One portion was selected and that representative portion was further divided into 11 categories of waste. Only the organic portion of the waste was then transferred to sterile plastic bags and transported to laboratory as in accordance with the standard methods where they were subjected for various experimental trials.

1.3. Proximate analysis of Organic waste

Proximate analysis was done to determine the organic waste composition in terms of moisture, ash and energy content.

1.3.1. Moisture Content (DIN-EN 14346)

In order to measure the moisture content of organic waste samples firstly weighed the empty tray and tray with almost 1kg of sample which were then placed in an electrical furnace at temperature of 105°C for 2hrs. However, the percentage moisture content was calculated by employing following formula [10]:

$$\mathrm{M.C}\ (\%) = \frac{\mathrm{W1} - \mathrm{W2}}{\mathrm{W1}} \times 100$$

Whereas;

M.C = Moisture Content (%).

W1 = Weight of the sample before oven drying (g)

W2 = Weight of the sample after oven drying (g)

1.3.2. Ash Content (DIN CEN/TS 16023)

To determine the ash content, firstly weighed the dried organic waste sample obtained after the calculation of moisture content and then placed the dried sample in blast furnace at a temperature of 600 °C for upto1 hour for combustion. After the completion of combustion process the sample was reweighed and the ash content was calculated by the following formula [11] & [12]:

$$\%\ Ash\ (dry\ basis) = \frac{Mass\ of\ Ash}{Mass\ of\ Dry\ sample} \times 100$$

1.3.3. Energy content (DIN SPEC 1954)

Energy content of organic waste samples was determined by using bomb calorimeter. First the samples were dried and excised into smaller pieces which were then sieved and compressed to form pellets. On the other hand the bomb was filled with pressurized oxygen upto 30 bars and the sufficient water was adjusted in calorimeter vessel to submerge the bomb completely. Afterwards the firing circuit was tested and the temperature was noted. Then prepared pallet was placed in a container and the bomb was fired then the temperature difference was recorded. However the calorific value was calculated by employing following formula [11] & [13]:

$$HHV = \frac{\Delta T Cp}{m_g}$$

Whereas;

HHV = Total energy content (MJ/Kg)

ΔT = change in temperature (K)

Cp = heat capacity in MJ/kg

m_g= mass of sample in Kg

1.4. Production of biochar from organic waste

Biochar was produced from organic waste by following Slow pyrolysis process. First the organic waste was dried in air and then excised into smaller pieces, approximately 4-5cm in size. Afterwards the prepared sample was inserted into pyrolyzer designed by the Carbon Terra GmbH Germany. The sample was charred for 4hrs at the average temperature of 500-600 °C with heating rate of 10°Cm^{-1}. The yield of biochar was calculated by employing following formula [14]:

$$Biochar\ Yield = \frac{Weight\ of\ Biochar}{Weight\ of\ sample} \times 100$$

3. RESULTS AND DISCUSSION

1.5. Scenario of solid waste generation in study area

Figure 3.1 shows the amount of waste generated among selected four union council of District Haripur. However the results revealed that the highest per capital waste generation was of UC Sikandarpur i.e 0.42/kg/capita/day and the lowest per capita waste generation was of UC south i.e 0.34/kg/capita/day. The variation in per capita generation of waste among four union councils was due to the varying living style, consumption patterns and economic status of residents [7]. However the results also revealed that the average per capita waste generation in study area was 0.39/kg/capita/day. According to JICA and world Bank studies [15] in Pakistan per capita waste generation ranges between 0.283/kg/capita/day to 0.613/kg/capita/day depending upon the cities and income level of the residents. Thus the results obtained within the ranges exist in literature.

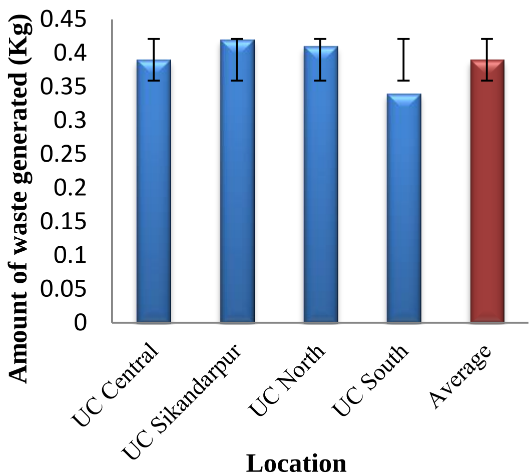

Fig 3.1 Average per capita waste generation among selected four union council of District Haripur

1.6. Characterization of solid waste

Characterization of solid waste is one the most effective step of solid waste management. It enables the managing authorities to assess the quality, quantity of solid waste generated and evaluate its suitability for various waste treatment processes like composting, biogas, refuse-derived fuel, landfilling etc [16]. In the present study the solid waste was characterized into 11 different categories named as Kitchen waste, Yard trimmings (Grass & wood etc.), Paper, Diapers, Textile, Plastic, Leather and rubber, Metal, Bottle and glass, Miscellaneous (Ceramic, stone and soil etc) and Domestic hazardous wastes. Figure. 3.2 represents the average percentage distribution of different waste categories in representative samples of UC Central, Sikandarpur, North and South. However the results revealed that on average basis among all UC levels the kitchen waste was in the highest proportion (i.e. 58 %).The other prominent waste categories among all residential groups were Plastic (14 %), Paper and Diapers (7%). Similar study was conducted in Gujranwala in which they concluded that most of the solid waste originated from household was organic including peelings from fruit and vegetables, food remnants, leaves and yard trims [17].

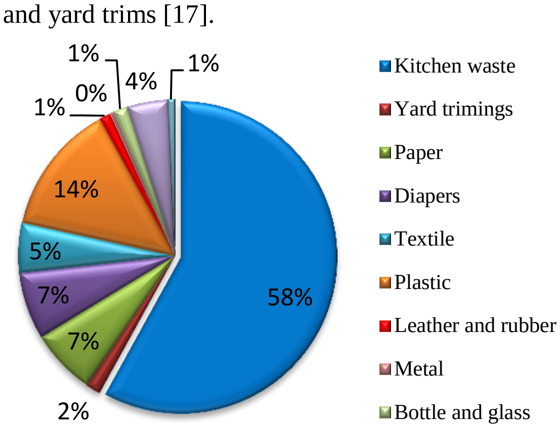

Fig 3.2 average percentage distribution of different waste categories in representative samples of UC Central, Sikandarpur, North and South.

1.7. Potential of biochar

After the characterization of solid waste the second and important step was to find out the potential of Biochar from the solid waste being generated in the Haripur city, in order to achieve the overall purpose of the study. As previously discussed among all 11 categories of solid waste highest proportion was of organic waste that includes kitchen waste i.e 58%, paper waste 7% and yard trimmings 1%. On cumulative basis organic waste accounted for 66% and was suitable for conversion into biochar through environment friendly process. Moreover other categories of waste included Diapers, Plastics, textile and leather & rubber collectively made 27% of the total municipal solid waste that can be easily converted into Refuse Derived Fuel (RDF) that have many applications in cement industries. Table 3.1 is the tabular representation of the categories of solid waste stream in Haripur along with their suitability. Due to high proportion of organic waste collected from study area further study was conducted in this regard only.

1.8. Proximate analysis of organic waste

The proximate analysis of organic waste was done in order to determine the potential of organic waste to convert into biochar and have been reported in Table 3.2.

The results revealed that kitchen waste had maximum moisture content i.e 95.4% whereas paper had lowest moisture content i.e 9.3%. This variation in moisture content was due to different source and composition of organic waste.

Ash content basically indicates the residue left after the complete combustion of given waste sample as a percentage of the original mass of sample [13]. However the results revealed that the maximum ash content was of yard trimmings i.e 19% whereas minimum ash content was of kitchen waste i.e, 16%. This is due to the reason that ash content depends upon the moisture content. Inverse relationship exists between these factors as moisture content increases ash content decreases and vice versa. Kitchen waste has the highest moisture content of 95.4% therefore the ash content of kitchen waste was low as compared to other samples [18].

Energy content is one of the main attribute in order to determine the potential of waste to convert into energy resource [19]. Therefore energy content was measured and the results showed that energy content of yard trimming were highest upto 18 MJ/Kg whereas the lowest energy content was of kitchen waste i.e 15MJ/Kg. The actual amount of energy content recovers from solid waste vary with the technologies used for evaluation of energy content. Moreover moisture content is one of the most important parameter it reduces the energy content of sample. As the moisture content of kitchen waste was highest i.e 95.4% therefore the energy content of kitchen waste was low as compared to other samples [20].

1.9. Production of Biochar from organic waste

Slow pyrolysis process was used for the conversion of organic waste in to biochar at lab scale level. From the 5 kg of organic solid waste sample 0.459kg of biochar with 20.4% yield was produced. Figure 3.3 shows the biochar produced

Table 3.1 Categories of solid waste stream in Haripur along with their resource recovery options

	Categories	Central	Sikandarpur	North	South	Average %	Average % according to suitability
Suitable for Biochar	Kitchen waste	62.24	53.13	62.69	54.00	58.01	66.30
	Yard trimmings	0.32	0.66	0.48	4.55	1.50	
	Paper	4.91	8.28	6.19	7.72	6.78	
Suitable for RDF	Diapers	9.62	8.45	3.87	5.91	6.96	26.92
	Textile	5.11	5.57	4.54	5.50	5.18	
	Plastic	14.83	11.60	14.07	14.01	13.63	
Suitable for Recycle	Leather and rubber	0.60	1.50	1.68	0.82	1.15	1.89
	Metal	0.22	0.53	0.12	0.70	0.39	
	Bottle and glass	1.21	1.39	3.36	0.02	1.49	
Suitable for Reuse	Miscellaneous (Ceramic, stone and soil etc)	0.45	7.96	2.29	6.13	4.21	5.15
Suitable for incineration	Domestic hazardous wastes	0.47	0.94	0.71	0.64	0.69	0.74

Table 3.2 Comparison of minimum and maximum mean values between different physical properties of kitchen waste, yard trimmings and paper waste

Proximate analysis	**Kitchen waste**		**Yard trimming**		**Papers**	
	Min	Max	Min	Max	Min	Max
Moisture Content (%)	-	95.4	-	60.3	-	9.3
Ash Content (%)	0.7	16	7.4	19	15	17
Energy content (MJ/Kg)	< 0.2	15	5.5	18	14	16

from organic waste of study area. A similar study conducted in Balgium which revealed that the %yield of biochar by following slow pyrolysis was 35% which was far high than the %yield of present study. The reason for the low biochar yield in this study could be the moisture content for instance moisture content of waste calculated in present study was 55% as compared to 30% of calculated moisture content of waste in European nations which could yield upto 30 to 40% of biochar. Moreover seasonal variations also affect the %yield of biochar among different countries [21] & [22]. Thus Biochar produced from organic waste offers a simple sustainable tool for managing solid waste of District Haripur and can serve as an alternative sustainable energy resource.

Fig 3.3 End product Biochar produced from organic waste of Haripur

CONCLUSION

A total of 480 samples from 60 sources were analyzed, approximately 1354 kg waste in total was taken in the field investigations conducted consecutively for 8 days. Average per capita waste generation in study area was 0.39/kg/capita/day. The study showed that in Municipal solid waste stream, 66% of waste is feasible for the Biochar and Refuse Derived Fuel (RDF) has the 26% potential. Biochar yield are 20.4% with 55% water content. Yield can be increased by reducing the water content. For this solar dehydrator can be used. Overall in Haripur city 17 tons/day Biochar can be produced from organic portion of municipal solid waste stream with 80% plant efficiency and 40% collection efficiency.

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