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Evaluating key parameters for developing a sustainable solid waste management plan in Lahore-China scheme

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A B S T R A C T

This study focuses on evaluating the primary parameters of municipal solid waste (MSW) in the "China scheme" region of Lahore to create a solid waste management plan. The China scheme was divided into six hypothetical zones, and the results indicated that the average MSW generation rate in storage bins was 0.555 Kg/person/day. The MSW composition analysis showed that food waste (putrescible) was the dominant waste type, accounting for 82.424%, while glass had the smallest share of 0.396%. The laboratory analysis revealed that the average values of moisture content, ash, volatile matter, fixed carbon, and organic matter were 77.487%, 6.624%, 14.386%, 1.492%, and 93.369%, respectively. While the calorific value of dried MSW, carbon content, nitrogen content, and C/N ratio was 6759.879 BTU/lb, 50.972%, 1.020%, and 50.265 correspondingly. Composting was suggested as a feasible solid waste management (SWM) option because of the higher moisture content and biodegradable organic matter in the MSW of China Scheme. Laboratory findings supported that the dried MSW could be utilized for energy generation by forming biogas, running steam boilers, or utilizing its quantity to make Refuse-derived fuel pellets.

Capsule Summary: The municipal solid waste (MSW) in the Lahore, Pakistan was evaluated to manage a solid waste management plan. Based on moisture content, ash, volatile matter, fixed carbon, and organic matter, the values were beyond the limit and by managing this waste, the MSW could be utilized for energy generation.

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INTRODUCTION

With the worldwide development of the economy, urbanization, and population, municipal solid waste, or MSW is becoming a crucial environmental element to consider (Ding et al., 2021). Improper management of municipal solid waste (MSW) is hazardous to inhabitants and this can easily be seen in the area of China Scheme, Lahore, where unaccounted rubbish disposal and poor MSW management practices are common (Sharholy et al., 2008). The present study focuses on the average MSW generation of the China Scheme, its percentage composition, and MSW characterization for giving suitable options in the development of a municipal solid waste management plan. In heavily populated urban areas, appropriate and safe MSW management is of utmost importance to create a healthy environment for the people (Mosler et al., 2006).

Municipal solid waste (MSW) has the potential for sustainable development and it is directly related to the increase in population. With population increase and urbanization, the rate of municipal solid waste generation has also up surged which has caused severe environmental and health effects. Local governments are unable to manage the upsurge of MSW (Aleluia and Ferrão, 2016). Although it has a latent risk for environment and human, still it can be considered as the major renewable resource to convert in material, energy (Triyono et al., 2019), byproducts and fuel (Białowiec et al., 2018).

In MSW management, waste characterization is vital as it results in smoother pathways for specific waste to be utilized according to its composition which in return saves time and resources. All the MSW management elements namely, waste collection, transportation, storage, conversion, energy generation, and disposal, can be successful through waste characterization (Ugwu et al., 2020). Proper implementation of waste characterization results in a positive contribution to gross domestic product (GDP) and mitigating greenhouse gasses (GHG) emissions (Wang and You, 2021).

The composition and grade of MSW differ depending on different regions due to contrast in socioeconomic factors, and native environmental regulations (Azam et al., 2020; Khan et al., 2016). Thus, it required different waste recycling and recovery methods concerning seasons, urban regions, and socioeconomic class (Ali et al., 2019).

To harness the energy potential along with the recycling potential of municipal solid waste proper management is necessary (Rong et al., 2017). Waste recovery and recycling are effective techniques to utilize that potential because GHG emissions are directly linked to the open disposal of MSW (Magazzino et al., 2020). The biochemical potential of MSW is enough to eradicate GHG emissions due to the open disposal of MSW. This potential will generate revenue and contribute to developing countries' economies (Sohoo et al., 2021). Optimum MSW recycling methods can be sufficient to cover electricity demand in certain areas of the world if replaced with fossil fuels to generate electricity (Salem et al., 2018). In short, MSW management can be done properly by utilizing available resources efficiently which results in effective sustainable development (Yousafzai et al., 2020).

The main objectives of the present study are to Identify the issues related to municipal waste management in China scheme and determine whether the social class of a household influences the type of waste generated. Characterize the Municipal Solid waste of China Scheme to find out the best treatment technique for MSW and Develop the MSWM plan for the area of China scheme.

MATERIAL AND METHODS

Description of study area

A sampling of solid waste was done at the China scheme (31’36N and 74’21E), near Bhagat Pura, Lahore. Its total area was 4900 canals. For collecting solid waste samples, the China schemes area was divided into 6 zones, which were given hypothetical names C1, C2, C3, C4, C5 and C6, respectively.

Sampling procedure

The sampling method was based on ASTM standard D5231-vol 11.04. Sampling was done twice a week (Thursday and Sunday). For single-day sampling, 6 grab samples were collected randomly from 6 hypothetical zones by using a fixed small-sized bucket to form a composite sample of that day. The per capita generation of MSW was Determined using Eq. 1.

$$\text{PCG} = \frac{\textit{Waste generated / day}}{\textit{Population}} \text{ (Kg/day/person)} \quad (1)$$

Determination of MSW composition

Determination of the composition of solid waste samples of the china scheme was done according to the ASTM standard D5231-vol 11.04. Manual sorting was done to separate plastic items, paper, cloth pieces, cardboard, metal, and kitchen waste (vegetables and fruit peels).

$$\text{MSW composition (\%)} = \frac{\textit{MSW weight}}{\textit{Total weight of MSW}} \times 100 \quad (2)$$

Sample preparation and storage

The representative samples of MSW were made by coning and quartering techniques. Shredding of the representative sample was done and finally, one composite sample was prepared. The same method was applied to the rest of the samples. It was based on ASTM standard D5231-vol 11.04. Samples were stored in small-sized sealed plastic bags and were placed in a dry place at room temperature.

Moisture content

For determining the moisture content in the MSW sample, the empty clean, and dry crucible was taken and its weight was noted on a scientific weighing balance then approximately 1g of sample. After cooling down its weight was noted. Residual or Inherent moisture was determined according to the ASTM standard E790-87 (vol: 11.04) (Eq. 1, Where S= g of analysis sample used. B= g of the sample after heating).

$$\text{Moisture content \%=}R\ \% = \left\{\frac{S-B\ \times 100}{S}\right\} \quad (3)$$

Ash content

Figure 1: Location of China scheme area in Lahore, Pakistan

To determine ash content, approximately 1g sample was taken in a dry crucible. The sample was placed in a furnace and the temperature was set at 575±25Ċ for 4 hours. It was calculated according to the ASTM method E830-87 (2004) vol: 11.04 (Eq. 4).

$$\text{Ash as determined } \% = \left(\frac{A-B}{C} \times 100\right) \tag{4}$$

A= weight of crucible and ash residue, B= weight of empty crucible g, C= weight of ash analysis sample g.

Organic matter

Organic matter was calculated from ash value by using the following formula described in ASTM D2974-07. vol: 11.04 Organic matter (O.M) % = 100 Ash% (Eq. 5)

$$\text{Carbon\%} = \frac{\text{Organic mater \%}}{1.83} \tag{5}$$

Volatile matter

To determine Volatile Matter approximately 1g sample was taken with a spatula in a weighted crucible, the crucible was covered, and its weight was noted. Covered crucibles containing 1g sample were placed into a preheated furnace at a temperature of 950±20Ċ for approximately 7 minutes. After cooling its weight was noted. The volatile matter was determined according to the ASTM method E-897-88(2004) vol: 11.04 (Eq. 6).

$$V_{ad}\,\% = \left[\frac{A-B}{A} \times 100\right] - \text{Mad} \tag{6}$$

Where, A=Weight of sample used g, B= weight of sample after heating g, Mad = Moisture (as determined) %. Fixed carbon was calculated by using Eq. 7.

$$\text{F.C } \% = 100 - [\text{V. M } \% + \text{ Ash } \% + \text{Moisture } \%] \tag{7}$$

The calorific value

Calorific value was determined according to the ASTM method D5468-02(2007) vol: 11.04. To determine the calorific value of MSW samples, PARR 6200 Bomb calorimeter was used.

Nitrogen percentage

To determine the nitrogen % of MSW samples, approximately 1g sample was taken into the digestion flask and a pinch of digestion mixture was added. Then 20 ml of concentrated sulphuric acid was added to the digestion flask. The digestion flask was kept on a burner for approximately 2-3 hours until the color of the solution became clear (transparent). When the digestion of the sample was completed then its volume was made up to 100ml by using distilled water. Then 10ml of digested diluted sample was taken into the kjeldhal flask and was attached to the kjeldhal apparatus. Then 5ml of boric acid was taken in a beaker (100ml), a few drops of methyl red were added, and it was kept at the lower end of the condenser of the Kjeldahl apparatus. Then 12-15ml of 40% sodium hydroxide was added from the upper of the Kjeldahl apparatus into the sample flask. When the volume of boric acid became 50ml and the color changed from pink to yellow the beaker was removed. And was titrated against 0.014N of HCl. Titration was completed when its color changed from yellow to pink and a volume of 0.014N of HCl used was noted. Nitrogen percentage was determined according to the ASTM method E778-87(2004) (Eq. 8).

Volume of 0.014N HCl = x 1/5 (Where, x = y)

$$\text{Nitrogen } \% = \frac{y \times 100 \times 100}{10(\text{sample ml}) \times \text{wt of sample taken} \times 1000} \tag{8}$$

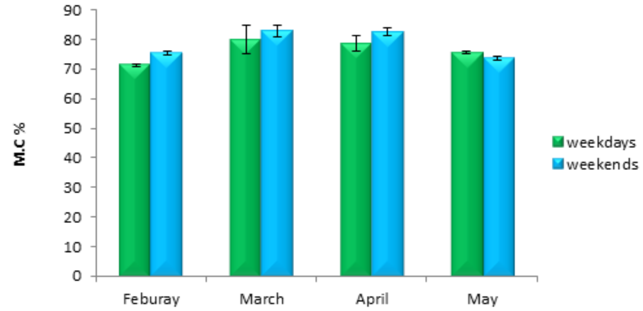

Fig. 2: Average percentage of moisture content of municipal solid waste samples of China scheme, Lahore

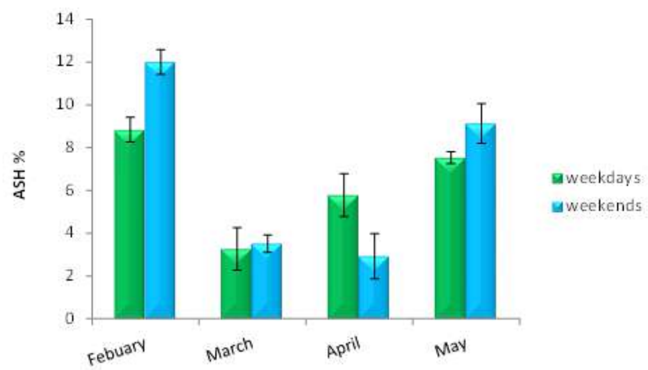

Fig. 3: Average percentage of ash content in the municipal solid waste samples of China scheme, Lahore

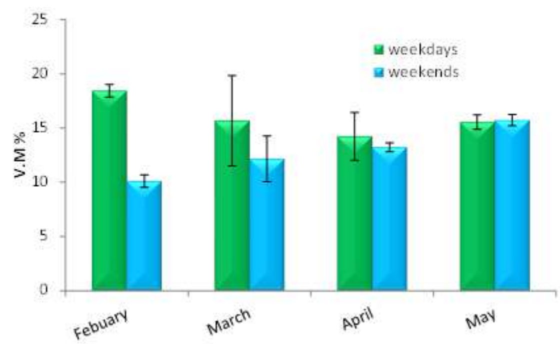

Fig. 4: Average percentage of volatile matter in the municipal solid waste samples of China scheme, Lahore

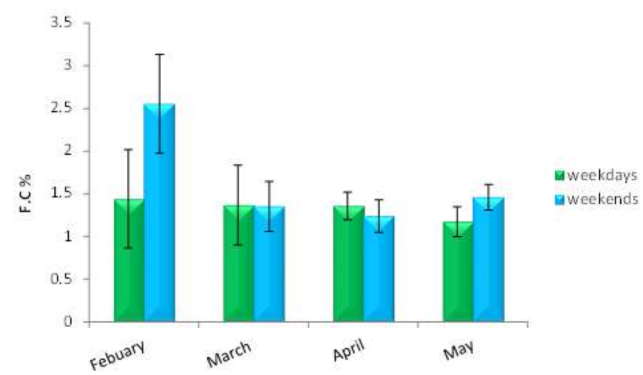

Fig. 5: Average percentage of fixed carbon in the municipal solid waste samples of China scheme, Lahore

RESULTS AND DISCUSSION

The percentage composition, of MSW considered in this study to develop the MSW management plan for the China Scheme, was characterized by Proximate analysis (moisture content, ash content, volatile matter, fixed carbon), ultimate analysis (C and N content) and energy content (gross calorific values) were measured. The physio-chemical analysis of these elements provides us with quantitative and qualitative parameters essential in determining the specific waste recovery or recycling technique or methodology to be applied to get feasible result efficiency and one step closer to sustainable energy generation (Patel et al., 2023).

The MSW generation rate of the China Scheme was determined by using the generation rate formula. It was found by using the per capita generation formula that the average value of per capita municipal solid waste generation of China Scheme was 0.555 kg/person/day. A similar result of generation rate was found in the research findings of MSW of Aziz Bhatti Town (ABT) in Lahore which was 0.57 kg/person/day (Hussain et al., 2014). It was found that the highest percentage was of food waste (putrescible) during weekdays and weekends in February, March, April, and May, that range from 86.158% to 71.361%. Moreover, glass was the least in percentage during all studied months from February to May, that range from 0.136% to 0.438%. Similar results can be observed in the result reported by (Palanivel and Sulaiman, 2014). The higher food and vegetable waste may be because the people of the municipality consume and dispose of fewer inorganic food materials (Ansah, 2014).

It was observed during the field visit that the China Scheme area was the area having residents ranging from middle to low socio-economic status and scavenger activities for picking recyclable items from MSW were common in China Scheme, Lahore. It was another reason for explaining the least percentage of recyclables in MSW composition. Moisture content is a key factor that decides what waste-to-energy methodology will be feasible (Patel et al., 2023). The moisture content is found to be higher in Asian regions in contrast to developed regions due to the various social and cultural aspects like cooking methodology, use of whole organic products, and sorting and storage methods (Karmakar et al., 2023; Kumar and Samadder, 2017). The moisture content is measured with the amount of water lost from materials upon drying to a constant weight. Usually expressed as the weight of moisture per unit weight of wet material. It is directly affected by the physical and chemical properties of the material which enable it to absorb the existing water in the environment (Kalanatarifard and Yang, 2012). As can be seen in figure 2, the average moisture content percentage, from February to March, ranged from 71.28%±0.577 to 82.97%±2.034, where 79.878%±4.783 and 71.28 %±0.577 were maximum and minimum values observed in March and February, respectively, during weekdays.

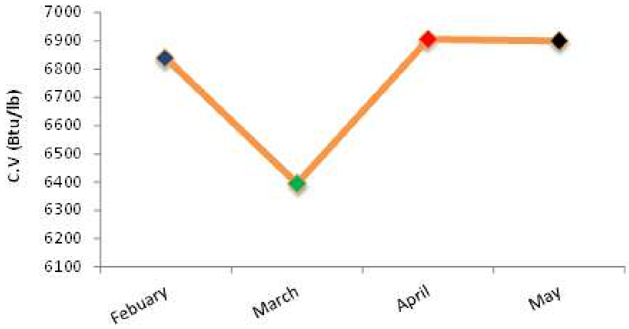

Fig. 6: Calorific value of the Municipal Solid Waste samples of China Scheme, Lahore

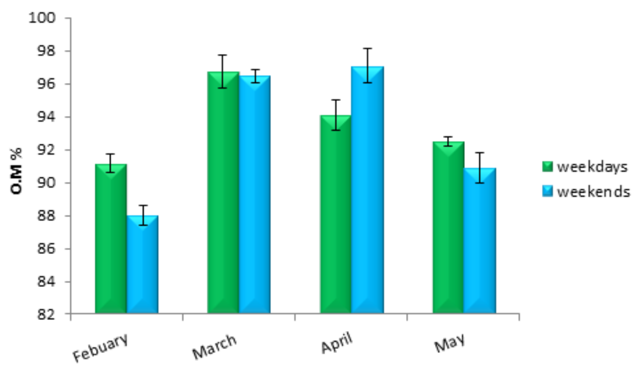

Fig. 7: Average percentage of organic matter in the municipal solid waste samples of China scheme, Lahore

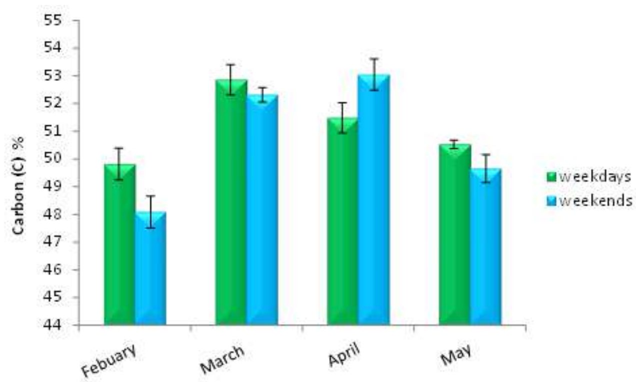

Fig. 8: Average percentage of carbon in the municipal solid waste samples of China scheme, Lahore

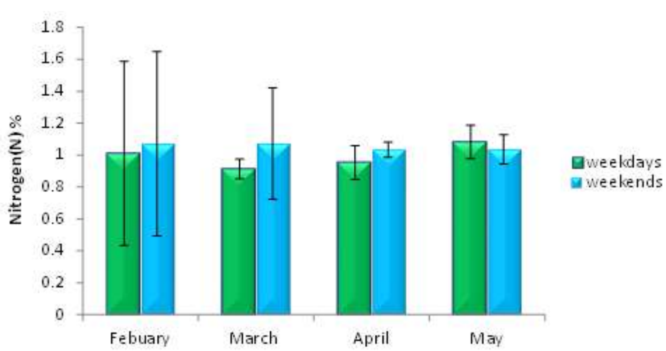

Fig. 1: Average percentage of nitrogen in the municipal solid waste samples of China scheme, Lahore

During the weekends the maximum value of moisture content percentage during the weekends was 82.97%±2.034 in March and the minimum value was 73.692 %±0.516 in May. Although the data range with respect to month and type of weekday, there is a slight increase in moisture content of weekday MSW than weekends, in May. High moisture content poses problems in implementing waste recovery due to calorific value.

The percentage ash content has some nonlinear trend throughout the study period which can be seen in Figure 3. The ash content ranged from 2.929% ±1.055 to 12% ±0.577, in which the maximum ash content of 8.84% ±0.577 was found in February during weekends alongside the minimum value was 3.271% ±0.994, in March weekdays. Another notable observation is the lowest ash percentage of 2.929% ±1 on weekends in April.

The results of ash percent were slightly higher because of the presence of inert material especially due to dust and soil. The inert materials mostly consisted of dust, sand, and soil and existed in a large fraction of MSW due to the presence of largely unpaved areas (Katiyar et al., 2013). China scheme area was not very well-developed area, there were many unpaved locations, open vacant plots having dumps of MSW, and dust bins were fewer and were not properly placed also littering of MSW was common.

Figure 4 illustrates the trend of Volatile matter percentage in MSW samples, ranging from 10.096% ±0.577 to 18.44% ±0.577, with the maximum percentage of 18.44% ±0.577 and minimum percentage of 14.231% ±2.218 on weekdays of February and April, respectively. In the case of weekends, the maximum and minimum percentage of 15.718% ±0.527 and 10.096% ±0.577 was observed in May and February, respectively. A trend of increasing volatile matter on weekdays and decreasing volatile matter on weekends, from February to May, can be seen. Relative to the other Lahore case studies by (Hussain et al., 2014; Oumarou et al., 2012), the percentage of V.M was less in the collected MSW samples from the China scheme because of the presence of more dust and other inorganic portion in MSW samples.

Fixed carbon is the carbon remaining on the surface as charcoal and it was reported by (Kalanatarifard and Yang, 2012) that food waste has low fixed carbon content. As in the collected MSW samples of the China scheme large fraction was based on food waste. In Figure 5 the data range of fixed carbon percentage can be seen ranging from 1.174% ±0.176 to 2.554% ±0.577. The fixed carbon % is very consistent on weekdays throughout the sampling period, with a maximum of 1.44% ±0.577 in February and a minimum of 1.174% ±0.176 in May. In the case of weekends, the maximum and minimum percentage of 2.554% ±0.577 and 1.239% ±0.19 was observed in February and April, respectively.

Calorific values of MSW samples are shown in Figure 6. The maximum calorific value was 6905.533 Btu/lb. in April and the minimum value was 6395.11 Btu/lb.in March, which is in comparison with the mean calorific value of Aziz Bhati Town, Lahore was 5566 J/g equal to 2392.954 Btu/lb8. The difference in the caloric value occurred because moisture affects the calorific value of MSW. With the increase of moisture content in MSW its calorific values decrease (Komilis et al., 2012).

According to the World Bank report published in 1999 that the average calorific value of MSW should not be less than 7100 kJ/kg (3052.451 BTU/lb.),24 to render their incineration viable (Azam et al., 2020). Due to high moisture content, it will be complex to implement waste recovery due to calorific value. The average Organic Matter % in MSW samples was ranging between 88% ±0.577 to 97.07% ±1.045 as displayed in Figure 7. The relative percentage of organic waste in MSW is generally increasing with the decreasing socio-economic status (Sharholy et al., 2008). The organic matter percentage was more due to the high percentage composition of biodegradable materials. It was reported that the organic fraction of waste is suitable for composting process (Hussain et al., 2014; Jilani, 2007; Policastro et al., 2023).

Figure 8 is showing the Average Percentage of Carbon in MSW samples of China Scheme, Lahore for the 4 months, of 2019. Its range was 48.087% ±0.577 to 53.043% ±0.571, in which the maximum value of carbon content on the weekdays was 52.856% ±0.5435 which was found during March 2019 and the minimum value was 49.814% ±0.577 which was found during February 2019. Whereas the maximum value of carbon content on weekends was 53.043% ±0.571 in April and the minimum value of carbon content was 48.087% ±0.577 which was found during February. Figure 9 is showing the average percentage of nitrogen in the MSW samples of China Scheme, Lahore for the 4 months. Its range was 0.912% ±0.062 to 1.082% ±0.349, in which the maximum was found in May and the minimum value of nitrogen content was found in March.

Figure 10 shows the average values of C/N ratios of MSW samples of the China scheme, Lahore during the studied months from February to May 2019. Its range was 36.7% to 68%. The maximum value of the C/N ratio, 53.348% was found in April and the minimum value 46.941% occurred in February. The carbon to nitrogen ratio of the present study inclined towards the higher values meaning that to make good quality compost; it may need supplements to increase its nitrogen value. However, the C/N ratio of the MSW waste can be adjusted to an optimum level by adding cow manure, poultry manure, and garden waste (Jilani, 2007). Results showed that organic components holding a maximum share in MSW would be suitable for compost and or animal feed or energy generation and more beneficial for developing regions. Since leachate from municipalities' landfills represents a potential health risk to both surrounding ecosystems and human populations. Re-using organic waste in any of the transformed states described above would reduce the waste to open dumping sites (Salem et al., 2018).

It is well-known that MSW can be used to generate electricity. Research published highlighted the use of the biodegradable component in MSW to generate electricity through biogas (Amponsem et al., 2023; Tshemese et al., 2023). The advantage of utilizing the biological component of MSW is that it provides us an opportunity to employ waste recovery and energy generation methods like composting and RDF which demand less space than landfill sites which is an influential disadvantage for landfill sites (Eriksson et al., 2007; Huai et al., 2008; Sarquah et al., 2023).

Solid waste disposal remains one of the biggest environmental concerns worldwide, but by introducing an appropriate policy framework, ensuring their implementation with local government support, and educating community people towards integrated waste management approach the present condition could improve much.

Table 1: Average generation rate of MSW in China scheme, Lahore

Population of China scheme	55808
Total waste generation per day	31 ton
Per capita MSW generation	0.555Kg/capita/day

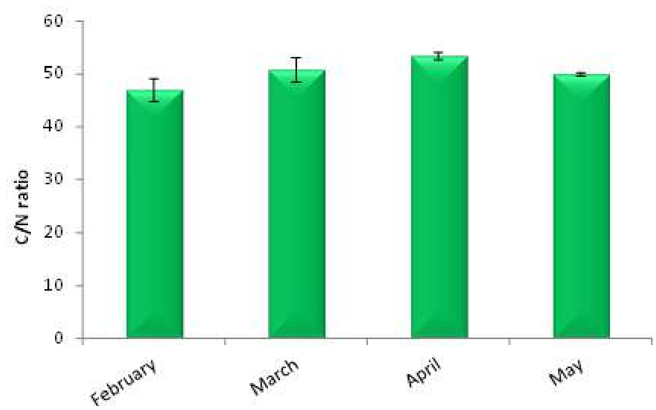

Fig. 2: Carbon to nitrogen ratio of the Municipal Solid Waste samples of China Scheme, Lahore

CONCLUSIONS

According to the present study of solid waste in China Scheme area is of biodegradable, recyclable, and textile origins and is dominated by food waste (82.424%), plastics (10.284%), paper (4.167%), cloth pieces (2.752%), metals (0.612%) and glass (0.3%). The multi-class nature of waste generated in the China scheme necessitates the use of an integrated approach to managing solid waste in the area. Laboratory analysis showed that the MSW of China scheme has substantially high percentages of moisture content 77.487%. So, composting could be the feasible treatment option for the management of biodegradable MSW. Moreover, it is also concluded that the calorific value of dried MSW 6759.879BTU/lb. was good enough for energy generation purposes to reduce the current energy crisis present in our country. This would minimize the menace caused by solid waste and enhance the economic value of compost and recyclable solid wastes in the area and in doing so, promote public health and the benefits of the various practices (including compost formation and recycling) could be maximized

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