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Heavy Metal Contents of Different Wastes Used for Compost

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Abstract

A study was conducted to assess the heavy metal (As, Pb, Cd, Cr, Cu, Zn and Hg) contents of different sources of wastes generated in Dhaka city which was further used for a compost plant. The study consisted of both field survey and laboratory analyses. Relevant primary and secondary sources of data were collected to identify the source and nature of wastes generated near the compost plant. A total of eight households, ten officers and ten waste collectors were surveyed for data collection. For laboratory analyses, wastes from various socio-economic niches (lower, lower middle, middle and high) were collected. The result showed that wastes generated in the lower income niche contained the minimum contents of heavy metals compared to middle and high niches. The increasing trend of heavy metal contents of the wastes from lower to high income groups has been found to be linked to the life style, attitude, profession, culture and food habit. Most of the heavy metals did not meet the standard level for almost all the niches. Most of the correlations were found to be insignificant between the contents of nutrient element (C, N and P) and heavy metals (As, Pb, Cd, Cr, Cu, Zn and Hg).

Keywords

Heavy Metal, Compost, Primary Data, Secondary Data, Correlation

1. Introduction

Waste is an unavoidable by-product of human activities due to economic development, rapid population growth, urbanization as well as improved living standards. All of these factors lead to increased quantity and complexity

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of generated waste which degrades the urban environment and poses serious stress on natural resources. Improper and inefficient management of waste is one of the main causes of environmental pollution and degradation in many cities throughout the world. Improper waste management not only leads to environmental degradation, but also hampers development activities and poses great risks to public health [1]. Waste disposal leads to land pollution if openly dumped, causes water pollution if dumped in low lands, and air pollution if burnt. Therefore, there is a need to work towards a sustainable waste management system, which ultimately leads to environmental, ecological, financial, economic and social sustainability [2].

According to [3], Bangladesh is the ninth most populous country in the world with an urban population growth rate of 2.06%. Current waste generation in Bangladesh is around 22.4 million tonnes per year. With this population growth, there is an increasing problem of waste management in Bangladesh particularly in the larger cities. The Waste Generation Rate (kg/cap/day) is expected to increase to 0.6% in 2025. Dhaka, the capital of Bangladesh, has an annual average growth rate of 6.6%. The six million residents of Dhaka City generate about 3000 - 3500 metric tons of solid waste per day. The total amount of land required for the disposal of solid waste in Dhaka is estimated to 110 ha per year. Though the Dhaka City Corporation (DCC) is responsible for management of the enormous amount of waste produced, only 42% is collected by it every day. The rest lies on road sides, open drains and low-lying areas which deteriorate quality of our surrounding environment [4].

Rapid growth of industries, lack of financial resources, inadequate trained manpower, inappropriate technology and lack of awareness of the community are the major constraints of waste management. There are some approaches of solid waste management and the most suitable and convenient process is composting. Composting process recycles different types of wastes into organic, nutrient rich compost that can be used as fertilizer and/or soil amendment [5]. However, the composition of wastes and subsequently the composts generated might affect soil quality through contaminants. It helps to reduce harmful emission of green house gases along with decreased pollution of air and water. The composition of mixed solid waste generated in Dhaka City shows an average of 70% by weight consisting of food and vegetable waste. This amounts to a total of 2100 - 2450 tons of easily biodegradable organic waste which potentially can be removed from the waste stream by composting [6].

In Bangladesh, composting is not a new practice. Traditional rural techniques are not suitable for big megacities like Dhaka, where large amount of wastes are generated daily. Thus, less capital intensive and environmental friendly compost plant has been developed which is well suited to Dhaka's waste stream, climate and socio-economic condition [7].

The present study focuses on the heavy metal contents of the household wastes generated in Dhaka City which are likely to be used for composting.

2. Materials and Methods

2.1. Sampling Site

The present study was carried out to study the metal contents more particularly the heavy metals (As, Pb, Cd, Cr, Cu, Zn, Hg) of the wastes used for compost preparation. The plant is situated near Dhaka Metropolitan City. The topography is flat with mild slope from west to east. The geo-location of the study area is 23˚37.817'N and 90˚28.649'E (**Figure 1**). The compost plant has a total area of 4640.26 square meters with a capacity to produce 18.75 tons of compost per day.

2.2. Primary and Secondary Data Collection

The methods used for the study are a combination of field survey and laboratory analysis. Both primary and secondary sources of data were collected. Primary data were collected by field investigations through institutional survey, Focus Group Discussion (FGD) and Key Informant Interview (KII) following the procedures as described in [8]. At first, the field survey was conducted to identify the source and nature of diverse waste generated by different socio-economic groups living near the compost plant. These socio-economic groups included: (a) Low income group—Up to Tk. 4000, (b) Lower middle income group—Tk. 4001 - 8000, (c) Middle income group—Tk. 8001 - 30,000 and (d) High income group—Tk. above 30,000 [9]. In the second phase of the study, undecomposed/uncomposted solid waste materials were collected for laboratory analysis. Two households from each category were randomly selected and thus a total of eight households were studied. Besides, 10 waste collectors and 10 officers were surveyed for data collection. Finally, data entry was done and database was developed using Microsoft Excel.

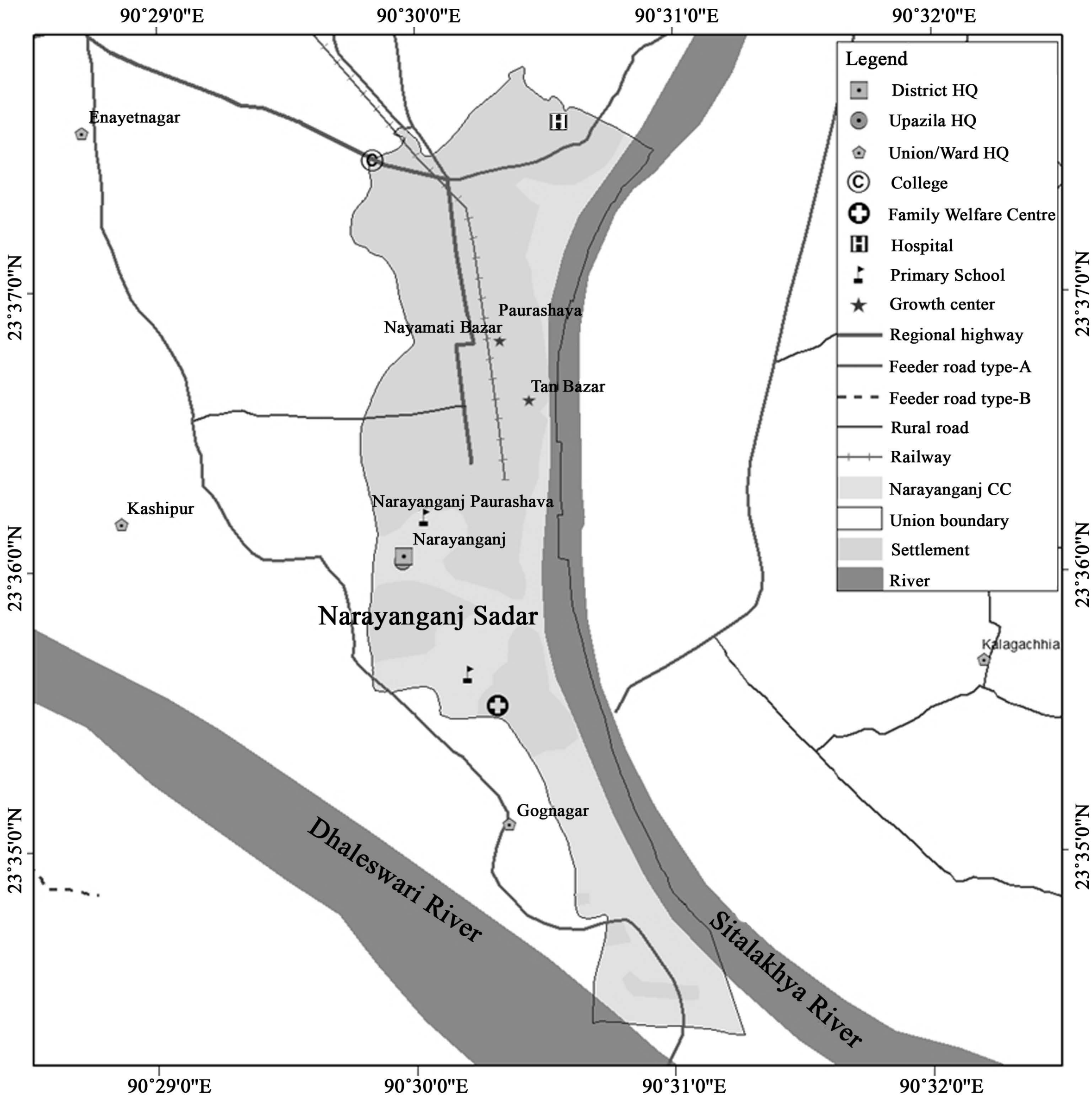

Figure 1. Location of sampling site.

2.3. Processing and Analysis of Waste

At first, the solid waste samples were air dried. Then they were ground and sieved through a 0.2 mm sieve. Various physical, chemical and physico-chemical properties of these samples were analyzed to assess the nutritional and heavy metal status of household wastes generated in Dhaka City. pH was determined immediately after transportation of the waste samples into the laboratory and was measured electrochemically by using a glass-electrode pH meter. The moisture content of the sample was determined by using an electric oven at 105˚C for 24 hours until the constant weight was obtained. The moisture percentage was calculated from the loss of moisture from the sample as described in [10].

Content of organic carbon was obtained by wet oxidation method of Walkley and Black. Total nitrogen was determined by steam distillation of the Kjeldahl digest after digesting with concentrated sulfuric acid (H_2SO_4) [11]. Total potassium content was extracted by digesting the samples with nitric acid (HNO_3) and perchloric ($HClO_4$) acid following the procedures as described in [10]. Then the extract was analyzed for total K by a flame analyzer**.** Total Arsenic (As), Lead (Pb), Cadmium (Cd), Cromium (Cr), Copper (Cu), Zinc (Zn) and Mercury

(Hg) were determined by Atomic Absorption Spectrophotometer (AAS) after extracting with the aqua-regia digest (concentrated HCl:concentrated HNO_3 = 3:1). At first, the waste sample was digested with aqua-regia on a hot plate until the content became white. Then it was cooled down, diluted with water and filtered into a volumetric flask. This extract was used to determine total heavy metals in the waste sample.

Certified reference materials were carried through the digestion and analyzed as part of the quality assurance/quality control protocol. Reagent blanks and internal standards were used where appropriate to ensure the accuracy and precision of the analysis. Each batch of ten samples was accompanied with reference standard samples to ensure strict QA/QC procedures.

2.4. Statistical Analysis

The experimental data were statically analyzed by using the Microsoft Excel. Correlation study was done to know whether or not there is a significant difference between the nutrient elements (C, N, P) and heavy metals (As, Pb, Cd, Cr, Cu, Zn and Hg).

3. Results and Discussions

3.1. Results from Field Survey

It is revealed from the field survey that the physical composition of wastes varies with the different income groups. The percentages of different types of wastes in the study area in the year 2013 are presented in **Figure 2**. It is evident that the food wastes constitute the highest percentage of total waste generated per day for all income groups. The rate of plastic and paper waste generation are in the second position (about 8%). The waste generation from the metal and wood is negligible. It is observed that the percentage of food waste generated daily is higher for middle and high income groups compared to that of the lower and lower middle groups. On the other hand, wastes of plastic, electronics, paper and fiber show almost parallel trend.

The quantity of solid waste generation and the socio-economic condition of the local people were found to be highly correlated. This finding corroborate with the work of [12] and [13].

It was observed that the people of the lower income group produce waste at a rate of 0.42 kg/capita/day whereas the lower middle, middle and high income groups produce waste at a rate of 0.29, 0.25 and 0.32 kg/capita/day respectively. This rate of waste generation is uneven with high per capita waste generation rate. Of the four income classes, the lower middle class generates the highest amount of solid waste (32.0 M. ton/day). The middle and high class produce almost the same amount of waste per day (**Figure 3**). However, only 8.3 M. ton of waste is produced daily by the low income group. According to [14], composition of household solid waste depends upon socioeconomic status, food habits and cultural traditions. [15] observed that the waste generation rate shows a positive correlation with the socioeconomic groups.

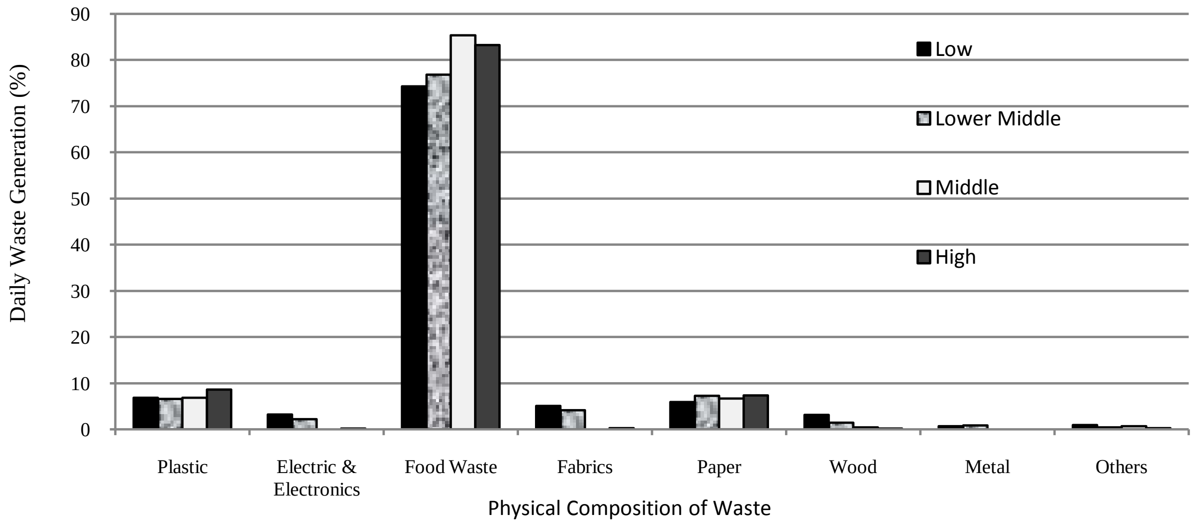

Figure 2. Physical composition of waste considering different income groups.

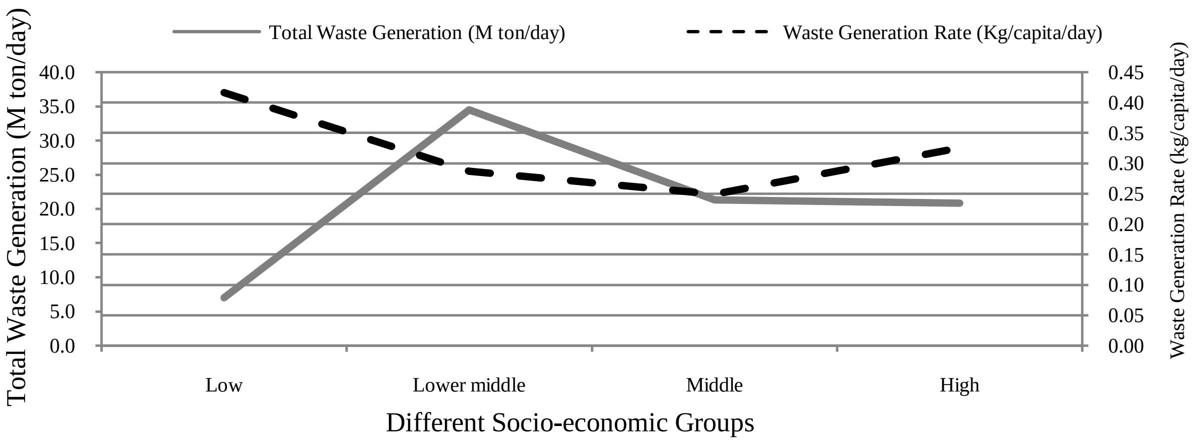

Figure 3. Daily waste generation (Mton/day) and per capita waste generation rate (kg/capita/day) by different income groups of the study area.

Table 1 shows the relative difference of compostable and non-compostable household waste produced by different income groups. The maximum compostable waste generation (per day) was found for the lower income group (92%) followed by the lower middle group (87%). This was found to be minimum (57%) for high income group. On the other hand, maximum amount of non-compostable waste generation (43%) was found to be produced by the high income group followed by the middle income group (21%). This value reached a minimum (8%) in case of lower income group.

Correlation analysis revealed that the generation of household solid waste was positively correlated with family size (r = 0.8483) at 1% significant level indicating the fact that families with more individuals generate larger quantity of solid waste per day. Also, a positive correlation was found between the income (r = 0.8735) and waste generation at 1% significant level. Waste generation was found to be increasing gradually with the increase of income per month by different socio-economic groups. This increasing trend was also found in the work of [13].

3.2. Laboratory Analysis of Solid Waste

The results of physical, chemical and physico-chemical properties of the solid waste are presented in **Table 2**. These wastes were collected from various socio-economic groups living near the compost plant of the study area.

The pH was found above 7.0 for all the income groups ranging from 8.08 to 9.21. It is apparent from the present study that the contents of organic carbon and nitrogen were higher in low income groups compared to that of middle and high income groups. The reason could be that the people from the higher income category are used to consume relatively more non-grains and animal products than that of the lower income category. [16] mentioned that the people of lower income groups are bound to consume more organic food and leafy vegetables. However, potassium content was found to be higher in low and lower middle income groups than in middle and high income groups.

Mean concentration of organic carbon was found to be 22.94%, 15.66%, 10.22% and 8.95% in low, lower middle, middle and high income groups respectively. All these values were far greater than the standard value (2.0%) as described in [10]. The mean content of total nitrogen in low, lower middle, middle and high income groups was 7.25%, 5.68%, 4.89% and 2.76% respectively. It is observed that the contents of nitrogen were higher than the standard values. According to [10], the standard range for nitrogen is 0.2%. The mean concentration of total potassium was found 4.54%, 6.26%, 1.03% and 0.82% in low, lower middle, middle and high income groups respectively. Thus, potassium content of the waste generated from middle and high income groups was found within the acceptable limit (1.8%) whereas waste from the lower and lower middle groups was below that limit.

3.3. Heavy Metals in Solid Waste

The contents of heavy metals (As, Pb, Cd, Cr, Cu, Zn and Hg) found in the solid waste is presented in **Table 3**.

Table 1. Compostable and non-compostable waste generated (per day) by different income groups.

Income Group	Waste category								
	Non-compostable (%)						Compostable (%)		
	Paper	Electronics	Can	Plastic	Glass	Rocks	Textile	Vegetable	Wood
Lower	3	1	0	2	1	1	2	89	1
Lower middle	4	2	2	3	1	1	3	81	3
Middle	5	4	3	3	4	2	3	74	2
Higher	9	13	11	3	4	3	2	53	2

Table 2. Physical, chemical and physico-chemical properties of the solid waste.

Income Group	Sample No.	Moisture (%)	pH	Organic C (%)	Total N (%)	Total K (%)
Lower	1	59.82	9.21	21.98	7.38	5.97
	2	62.67	8.64	23.90	7.12	3.21
Lower middle	1	45.50	8.65	14.92	5.38	5.89
	2	55.90	8.21	16.39	5.98	6.64
Middle	1	71.42	8.79	10.87	4.56	1.97
	2	65.89	8.98	9.56	5.23	0.08
High	1	72.89	8.23	9.23	3.33	0.97
	2	78.24	8.08	8.67	2.19	0.67

Table 3. Contents of heavy metals in solid waste.

Income Group	Sample No.	Heavy metal (mg·kg^{-1})						
		As	Pb	Cd	Cr	Cu	Zn	Hg
Lower	1	0.09	4.58	0.03	1.91	0.004	15.90	0.12
	2	1.17	7.90	0.09	2.98	0.001	21.23	0.14
Lower middle	1	1.98	11.09	0.04	4.78	0.004	32.90	0.21
	2	4.58	16.73	0.93	15.98	0.007	34.85	0.92
Middle	1	8.90	16.73	3.23	56.83	0.007	43.11	0.12
	2	11.46	14.79	2.62	54.71	0.02	51.11	0.13
High	1	16.78	16.77	3.33	61.67	0.06	67.55	0.22
	2	21.34	15.96	4.24	74.19	0.09	65.46	0.01

According to Imamul Huq and Alam (2005), the mean concentration of As was found within the acceptable limit (<8.0 mg·kg^{-1}) for both lower and lower middle income groups while it exceeded the safe limit for middle and high income groups. The mean content of As in waste generated by lower, lower middle, middle and high income group was 0.63, 3.28, 10.18 and 19.06 mg·kg^{-1} respectively. Thus, As concentration in the wastes followed the order as: high > middle > lower middle > lower. This trend was also noticed in case of the mean content of Pb, Cd, Cr and Cu. Mean contents of Pb were found within the acceptable limit (<32 mg·kg^{-1}) for all waste samples. The mean content of Pb was found to be 6.24, 13.91, 15.76 and 16.37 mg·kg^{-1} for the waste of lower, lower middle, middle and high income group respectively. The mean concentration of Cd in waste was found within the standard value (<1 mg·kg^{-1}) for only the lower and lower middle groups. The mean content of

Cd in waste was found to be 0.06, 0.49, 2.93 and 3.79 mg·kg^{-1} for lower, lower middle, middle and high income group respectively. The mean Cr concentration was found within safe limit (<65 mg·kg^{-1}) for all wastes except for high income group. The Cr concentration was 2.45, 10.38, 55.77 and 67.91 mg·kg^{-1} in the waste of lower, lower middle, middle and high income group. The increasing trend of the heavy metal content of the waste from lower to high income group might be due to the difference in life style, attitude, profession, culture as well as characteristics, composition and quantity of waste produced.

Except for high income group, the Zn content of the wastes was found below the acceptable limit (<64 mg·kg^{-1}). However, content of Hg in all wastes exceeded the threshold level (0.00 mg·kg^{-1}). The mean content of Zn and Hg in lower, lower middle, middle and high group was 18.57, 13.88, 47.11, 66.51 and 0.11, 0.57, 0.13, 0.12 mg·kg^{-1} respectively. Thus no specific trend was observed for the content of Zn and Hg in the waste samples. Ali *et al.* (2009) also observed this type of finding when working with the urban waste of Dhaka City.

3.4. Correlation between the Nutrient Element and Heavy Metal Contents for Different Socio-Economic Groups

Both positive and negative relationships were found between the contents of nutrient elements (C, N and P) and heavy metals (As, Pb, Cd, Cr, Cu, Zn and Hg) for individual socio-economic group (**Tables 4-6**).

Table 4-6 show that most of the correlations were insignificant. Cu content in the waste of middle and high socio-economic groups showed highly significant (p = 0.001) relation with the C content. In case of the correlations between N and heavy metal contents, only Cr and Cu showed significant relation. Cr content of high socio-economic group and Cu content of middle group were found to have significant relation with the content of N. On the other hand, K contents in the waste showed significant (p = 0.1) negative correlation with As and Pb

Table 4. Correlations between the carbon and heavy metal contents.

C	As	Pb	Cd	Cr	Cu	Zn	Hg
Lower	+0.862	−0.670	+0.508	−0.862	+0.492	+0.998*	+0.862
Lower middle	+0.793	+0.366	+0.149	−0.953	+0.149	+0.827	−0.149
Middle	+0.101	+0.164	+0.619	+0.084	+1*	+0.187	−0.5
High	−0.904	−0.908	−0.188	+0.757	−1*	+0.674	−0.866

* denotes significance.

Table 5. Correlations between the nitrogen and heavy metal contents.

N	As	Pb	Cd	Cr	Cu	Zn	Hg
Lower	+0.5	−0.736	−0.866	−0.5	+0.866	−0.075	+0.5
Lower middle	+0.970	+0.956	−0.681	−0.831	−0.681	+0.955	+0.681
Middle	+0.101	+0.164	+0.619	+0.084	+1*	+0.187	−0.5
High	+0.404	+0.414	+0.784	−1*	+0.757	−0.027	+0.328

* denotes significance.

Table 6. Correlations between the potassium and heavy metal contents.

K	As	Pb	Cd	Cr	Cu	Zn	Hg
Lower	−0.839	+0.637	−0.544	+0.839	−0.454	−0.999*	−0.839
Lower middle	−0.018	+0.5	−0.866	+0.356	−0.866	−0.075	+0.866
Middle	−0.811	−0.772	−0.370	−0.820	+0.5	−0.757	−1*
High	−0.994*	−0.993*	+0.356	+0.300	−0.851	0.962	−0.999*

* denotes significance.

for high groups. K contents in the waste showed significant ($p = 0.02$) negative correlation with Zn for lower group; and with Hg for both middle and high groups ($p = 0.001$ and $p = 0.02$).

4. Conclusion

Nowadays waste management is one of the burning and alarming issues throughout the country. There is an urgent need for turning the waste into resource in order to achieve sustainable economic growth. It is high time to identify the threats and explore the potentiality for waste management in Dhaka. Depending on the economic niche, the present work provided a precise idea about heavy metal contents of different sources of wastes generated in Dhaka City which can be further used for composting. The results confirmed that heavy metal contents of the wastes produced by different socio-economic groups showed an increasing trend from lower to higher income groups. The quantity of the waste produced and socio-economic condition of the local people were found to be highly correlated. The heavy metals in wastes and composts ultimately entered into the soil that might end up in the food chain and food web. Thus, it is pertinent to assess the composition of wastes and composts where these are applied to soil as ameliorates. Future research is needed regarding the type and magnitude of the treatments for these waste materials. Successful waste management will depend on proper developmental policy from the Government as well as awareness of local authorities.

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