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URBAN SOLID WASTE MANAGEMENT: HEAVY METAL ACCUMULATION IN SOIL AND PLANTS FROM WASTES GENERATED AT DIFFERENT SOCIO-ECONOMIC NICHES OF DHAKA CITY

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Abstract

With a view to assess the prospect of solid waste management in Dhaka, a pot experiment was conducted with four different types of solid domestic wastes collected from three socio-economic niches (*viz.* Gulshan where high income group of people live, Mirpur where very low and medium income group of people live and Rayerbazar where all types of wastes were dumped) to study the effect of waste on the growth performance of plant (*Ipomea aquatica*) as well as the build up of heavy metals in soil and their subsequent transfer to plant, hence to the food chain. For almost all the cases, heavy metals built up in the soil and were subsequently transferred to plants. However, the growth of plants was not found to be affected. The plants were observed to be very fresh, strong and leafy. Besides improving the organic matter status of the treated soils, the Cd, Fe, Mn and Zn contents of the soils showed an increasing trend. The contribution of solid wastes to the soil and plant has been found to be source and dose dependent.

Key words: solid waste, heavy metals, plant growth

Introduction

The increasing quantity of solid wastes is a growing environmental problem in developing countries like Bangladesh. Compared to cities and towns of developed countries, developing countries generate less solid wastes per capita (Enayetullah 1995). In developing countries, people have less purchasing power and therefore, consume less. There is less industrial activity but there is a very high rate of reuse of solid wastes by the poorer sections of the community (Cairncross and Feachem 1993). Despite this, large volumes of solid wastes are produced every day. Dhaka, the capital and the biggest city of Bangladesh, generates about 3000 metric tons of municipal solid waste per day (Enayetullah 1995). The City Corporation is responsible for the management of this enormous quantity of solid waste, but only 42% of this waste is being collected everyday.

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The rest lies on roadsides, open drains and low lying areas, thus contributing to the deteriorating quality of the city's environment (Enayetullah 1995).

Source of solid wastes may be agricultural, industrial, municipal and domestic in nature. The agricultural and domestic wastes in rural areas are the major sources of nutrients to be returned to the soil. But in urban area, industrial and municipal wastes are considered as the main source of solid wastes. Household wastes are also other main important wastes in urban areas and these are the main concerns to us. Solid wastes and refuse, particularly in urban areas contribute to the soil pollution. This refuse contains garbage and rubbish materials like plastics, metallic cans, fibers, paper, rubbles, street sweepings, fuel residues, leaves, containers, abandoned vehicles and other discarded manufactured products (Sharma 2000). Other items like paints and varnishes, which we use to add color to everyday life, also add poison to the urban wastes that are posing soil pollution problems. The leachates from dumping sites and disposal tanks of sewage mixed with industrial effluents and wastes are extremely harmful and toxic (Sharma 2000). Solid waste disposal on water or land may cause a direct public health hazard, external ground water pollution, accumulation in the soil or water of hazardous substances that can enter into the food chain. Some organic wastes are difficult to deal with because of their diffuse or non point nature, such as manure deposited at random by live stock, which may be washed into nearby streams and degrade the environmental quality (Troeh *et al.* 1980). Bangladesh soils are basically very low in organic matter. As a result, the use of fertilizers has become indispensable for increasing crop yield. Continuous use of chemical fertilizers is likely to be detrimental to soil health; the status of soil organic matter content has been decreasing day by day. Untreated organic wastes are being indiscriminately used in the agriculture for the purpose of increasing nutrient content in soil and for better yield of crops as well. But the detrimental effect of these untreated wastes has not yet been investigated properly in soil and plants as these organic wastes may contain toxic heavy metals along with other harmful substances, which may pollute soil and enter into the growing plants (Molla and Imamul Huq 2004, Sikder *et al.* 2007). The principal objectives of the solid waste management are to control, collect, treat, utilize and dispose off the solid wastes in an economical manner consistent with the protection of public health, land, plant and environmental deterioration. With these views in mind, the present work was aimed at evaluating the quality of solid wastes produced in the Dhaka city in various socio-economic classes and their effect on soil and plant with the ultimate objective of finding a better way of urban solid waste management.

Material and methods

The experiment was conducted at the Department of Soil, Water and Environment, University of Dhaka. All the subsequent research works were done in the "Bangladesh-

Australia Centre for Environmental Research (BACER-DU) Laboratory", University of Dhaka.

Sample collection

Four different types of wastes were used in the present work and the wastes were collected from different areas of Dhaka city having different socio economic conditions: (i) from low socio-economic groups, where slum people dwell; (ii) from medium socio-economic group where middle class people live; these two types of wastes represented samples of Mirpur area; (iii) wastes from high socio economic groups representing Gulshan area and (iv) was mixed wastes, which were collected from Rayerbazar dumping site where all kinds of wastes are dumped as mixed wastes. Soil sample belonging to the Dhamrai series from Joypura of Savar thana was collected from a depth of 0-15 cm from the surface by composite soil sampling method as suggested by the Soil Survey Staff of the USDA (USDA 1951).

Sample preparation

After collection, the soil sample was prepared to bring the soil to a favorable condition for crop growth. The soil was air-dried, the larger aggregates were gently broken and passed through a 2 mm sieve and then mixed thoroughly. A portion of the soil was further ground to pass through 0.5 mm sieve; this portion of soil was used for various laboratory analyses. The wastes from various sources were also air-dried and were separated from the unwanted debris. Then those were processed into fine-grained samples by using grinder and passed through a 0.2 mm sieve for further analyses.

Experiment with plant (Ipomea aquatica)

The experiment was carried out with *Ipomea aquatica*. In the experiment, two different treatments were used for each waste. There was a control and three individual replications. The wastes are denoted as: W_1 = wastes from low socio-economic groups, where slum people dwell; W_2 = waste from medium socio-economic group where middle class people live; W_3 = waste from high socio economic groups; W_4 = mixed wastes where all kinds of wastes are dumped.

Pot preparation

For the growth of *Ipomea aquatica*, four kg soil (previously prepared) was put in each four liter sized earthen pots having no holes at the bottom. All the wastes were applied at two different rates (5 t/ha and 10 t/ha) and mixed properly with soil for the respective pots. Control pots did not receive any wastes. Tap water was added to bring the soil at field moisture condition.

Seed sowing

The seeds of *Ipomea aquatica* were collected from a local seed market and were sown directly in the pots. Seed germination started after 3 days of sowing. Proper watering was done with tap water at least once daily in the afternoon. Positions of the pots were changed every alternate day to allow equal exposure of each of the pots to sunlight. After few days thinning was done keeping 30 plants per pot. Adequate plant protection measures were taken during the growth period. Plants were harvested manually by uprooting the plants after 45 days from seed sowing. The plant roots were washed first with tap water then with distilled water for dislodging the debris. The aerial parts of the plants were also washed.

Sample preparation after harvesting

The plants were separated into shoot and root after harvest at 45 days after germination. The plant samples were air dried for a day and then oven dried at 70 ± 5^0 C for 48 hours. The oven-dried samples were ground and passed through a 0.2 mm sieve for subsequent analysis. Soil samples from each pot were also collected after plant harvest and prepared for analysis as mentioned above.

The various properties of the soil, wastes and plants were determined following the procedures described in Imamul Huq and Alam (2005). Soil, wastes and plants were analyzed for total Pb, Cd, Zn, Fe and Mn by atomic absorption spectrometer (AAS). The plant samples were extracted with HNO_3 and the soil and wastes were extracted with aqua-regia solution (Portman and Riley 1964). Certified reference materials (CRMs) were used through the digestion and analyzed as part of the quality assurance/quality control protocol. Each batch of 20 samples was accompanied with reference standard samples to ensure strict QA/QC procedures.

Results and Discussion

The selected soil and raw wastes were analyzed to know the nutrient status as well as other elements present in them. The results are presented in Table 1.

Table 1. Analytical results of the soil and wastes.

Soil/ Wastes	pH	Moisture	OM	N	P	K	Fe	Zn	Mn	Pb	Cd
		(%)						(mg/kg)			
Soil	7.10	3.4	0.91	0.12	0.02	0.27	0.15	2.12	0.06	18.10	0.03
W_1	5.90	53.7	4.65	3.30	1.91	0.90	17.37	233.33	519.03	120.50	2.00
W_2	5.88	30.7	3.00	2.90	1.14	1.87	25.05	326.67	333.62	54.71	0.83
W_3	5.92	75.1	1.86	1.51	0.27	0.57	3.78	260.00	356.45	49.17	3.66
W_4	5.91	58.3	2.48	1.76	0.30	0.75	26.46	346.67	318.67	85.17	0.33

W_1 = wastes from low socio-economic groups, where slum people dwell; W_2 = waste from medium socio-economic group where middle class people live; W_3 = waste from high socio economic groups; W_4 = mixed wastes where all kinds of wastes are dumped.

Changes in various soil parameters

Changes in various soil parameters due to the application of wastes or not are presented in Table 2. Soil pH decreased in every case and the decreases were high in treatments receiving higher rates of solid waste application. This might be due to the decomposition of high amount of organic matter present in the wastes that produced different types of organic acids. Organic matter content of the soil was increased in all the cases except in the application of waste collected from high socio-economic condition (Table 2). This reason is obvious as high content of organic matter was present in different types of wastes except the one collected from high socio-economic situation. The total nitrogen content was not found to be changed (Table 2). Soil phosphorous was found to have increased compared to that of either control treatment or as it was before the experiment was set up (Table 2). The initial total K content in the experimental soil was 0.27%. After harvest of the plants, K content was decreased and it was about 0.11% in the control treatment. This might be due to the uptake of K by plant shoots and roots. On the other hand, due to application of wastes at different rates, the soil analysis showed that total K content increased from control as well as its initial content but in case of mixed waste it did not exceed the initial value (Table 2).

Table 2. Changes in soil due to application of wastes.

Treatment	pH	OM	N	P	K	Fe	Zn	Mn	Pb	Cd
		(%)				(mg/kg)				
Background level	7.10	0.91	0.12	0.020	0.27	0.15	2.12	0.06	18.10	0.03
Control	7.06	0.68	0.10	0.040	0.11	9.05	85	985	11.00	0.02
W_1@5t/ha	5.85	1.85	0.12	0.067	0.34	18.43	116	1485	23.33	0.30
W_1@10t/ha	5.80	1.93	0.12	0.069	0.36	29.30	108	1401	22.13	0.20
W_2@5t/ha	5.92	2.01	0.13	0.068	0.33	26.50	123	1625	22.40	0.05
W_2@10t/ha	5.89	1.99	0.12	0.069	0.31	23.08	115	1315	20.80	0.17
W_3@5t/ha	6.02	0.87	0.11	0.074	0.34	35.03	116	1523	20.53	0.13
W_3@10t/ha	5.99	0.82	0.10	0.066	0.28	32.03	112	1245	18.20	0.20
W_4@5t/ha	6.00	0.99	0.11	0.058	0.18	29.32	116	1124	20.47	0.02
W_4@10t/ha	5.96	1.15	0.09	0.068	0.27	42.87	111	1143	19.40	0.18

W_1 = wastes from low socio-economic groups, where slum people dwell; W_2 = waste from medium socio-economic group where middle class people live; W_3 = waste from high socio economic groups; W_4 = mixed wastes where all kinds of wastes are dumped.

Heavy metal build- up in soil

The concentration of Fe, Zn, Mn, Pb and Cd were determined in the soils after plant harvest. The average values for the build-up of different heavy metals in soil after harvest are also presented in Table 2. The Fe concentrations in the soil for the control treatments were 9.05 mg/kg where the initial soil Fe was 0.15 mg/kg. Soil Fe was increased in all the were 9.05 mg/kg where the initial soil Fe was 0.15 mg/kg. Soil Fe was increased in all the cases. In soil, almost all of the treatments released Fe where the highest concentration of Fe (42.87mg/kg) was found in W_4@10t/ha (Table 2). Such a big increase in the Fe concentration could be explained from the fact that this treatment contained mixed wastes that included both organic and inorganic sources and the wastes from these sources also contained the maximum Fe among all the wastes used in this experiment. Zinc concentration in soil was found to be 85.00 mg/kg for the control treatment (Table 2). Zinc was also found to have been released almost at the same trend for all the sources of wastes irrespective of the initial concentration in different wastes (Table 2). The control soil contained 985.33 mg/kg of Mn (Table 2). Treatments with wastes at the rate of 5 t/ha, released more Mn and the highest amount of Mn was found for the treatment with W_2@5t/ha. Wastes with low Mn content (W4) also released less Mn in the soil. It was observed that the wastes contributed higher amount of Mn in soil. These happened for both the rates of application. It was also noticed that the wastes collected from the areas of medium socio-economic niche contributed comparatively higher amount of Mn in soil. The lead concentration in soil was also increased in all the cases and it was high in soil where waste from low socio-economic niche were applied; it was because it contained high amount of Pb (Table 2).

The initial soil Pb concentration was 18.1 mg/kg while it was decreased to 11 mg/kg after harvest (control) but in the cases of waste treatment the soil Pb concentration exceeded the initial soil Pb value and it was for all the treatments indicating that the waste contributed to build-up of Pb in soil. The initial soil Cd concentration was quite low and after harvest cadmium levels in soil for control treatment was also low but the waste treated soils showed higher values in most cases (Table 2) which could have been released from the applied wastes and it was increased with increasing rate of application except W_1. The Cd build-up in soil was relatively small. That wastes might change the availability of heavy metals in soil has also been reported by Molla and Imamul Huq (2004). This possibility mainly depends on the chemical composition of wastes and characteristics of the soil.

Accumulation in plants

Plants (*Ipomea aquatica*) grown in soil treated with different types and rates of wastes were harvested after 45 days from seed sowing. Different nutrient elements as well as heavy metals in plant roots and shoots were analyzed and the analytical results are shown in the Table 3.

Table 3. Concentration of different nutrient elements as well as heavy metals accumulated in plants.

Treatments	N		P		K		Fe		Zn		Mn		Pb		Cd	
	(%)						(mg/kg)									
	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot
Control	0.05	0.07	0.01	0.02	0.35	0.65	2.15	0.04	23.00	40.00	17.45	28.21	0.16	0.25	0.001	0.01
W_1@5t/ha	1.57	3.44	0.11	0.28	1.40	2.36	43.82	0.13	46.67	53.33	108.90	41.17	0.42	1.677	0.300	0.54
W_1@10t/ha	1.48	3.25	0.09	0.31	1.28	2.15	9.48	0.15	20.00	86.67	38.30	54.93	0.30	2.50	0.700	0.29
W_2@5t/ha	1.29	3.25	0.10	0.24	1.24	2.48	40.35	0.16	40.00	106.67	88.83	68.13	0.17	4.58	0.170	0.06
W_2@10t/ha	1.68	2.85	0.12	0.33	1.46	3.01	38.68	0.20	40.00	100.00	67.27	64.57	0.67	3.08	0.020	0.02
W_3@5t/ha	3.02	3.12	0.17	0.16	2.96	4.74	1.85	0.19	166.67	166.67	255.70	168.47	2.00	9.17	0.670	1.76
W_3@10t/ha	2.70	3.21	0.20	0.25	2.07	3.16	44.32	0.21	160.00	193.33	203.50	157.63	6.50	8.17	0.880	1.22
W_4@5t/ha	2.07	3.06	0.13	0.18	1.89	4.38	32.56	0.26	140.00	160.00	235.27	198.00	0.17	0.50	1.160	0.58
W_4@10t/ha	2.14	2.81	0.12	0.20	1.21	3.30	32.71	0.27	66.67	120.00	118.23	133.00	0.08	19.40	0.720	1.27

W_1=wastes from low socio-economic groups, where slum people dwell; W_2 = waste from medium socio-ecomic grop where middle class pepole live; W_3 = wast from low socio-economic groups, W_4 = mixed wastes where all kinds of wastes are dumped.

Nitrogen accumulation in different parts of plant was different for different waste applications. It was clear that plant shoots accumulated higher amount of N than roots in all the treatments. The maximum amount of N (3.44%) in plant shoot was found for the treatment of the raw wastes from low socio-economic level (W_1@5t/ha) whereas the control plant shoots was found to contain 0.07% N (Table 3). This might be due to the fact that the wastes from low socio-economic niche contained high amount of nitrogen. Between the two plant parts, P content was higher in shoot than in root and the maximum amount was found for the treatment of waste from low socio-economic niche. Almost similar effect was observed for the treatment of the waste from medium socio-economic niche. So, it was clear that the P concentration in waste played a vital role in this regard. In case of plant shoots, the highest amount of P was found in the treatment with W_2 at the rate of 10 t/ha and the least amount was found with W_3 treatment at the rate of 5 t/ha. The highest amount of K found in shoot was 4.47% with W_3 at the rate of 5 t/ha.

Accumulation of heavy metals

The concentration of Fe, Zn, Mn, Pb and Cd were also analyzed in the plant parts. The average values of different heavy metals accumulated in plant parts are presented in Table 3. The Fe concentrations in the plant shoots and roots for the control treatments were 0.04 and 2.15 mg/kg respectively. The concentration of iron changed due to the application of wastes. In all the cases, the Fe concentration was found to be higher in plant roots than in shoots. In plant roots, the amounts of Fe found were 43.82, 40.35 and 32.56 mg/kg respectively for the treatments of W_1@5t/ha, W_2@5t/ha and W_3@5t/ha; whereas very little amounts were found (1.85mg/kg) for W_4@5t/ha (Table 3). In shoots, the higher amounts of Fe were found in W_4@10t/ha, W_3@10t/ha and W_2@10t/ha treatments. The treatment of W_1@10t/ha contributed to more Fe accumulation. For every cases of plant growth, at the rates of both 5 t/ha and 10 t/ha of wastes application, Fe was found to be released in soil and taken up by plant roots where a very little of it was transferred to the plant shoots.

The Zn concentrations in plant shoots and roots were found to be 40.00 mg/kg and 23.00 mg/kg respectively for the control treatment. The accumulation, however, differed in plants with the sources of wastes. The highest amount of Zn was found to have accumulated by plant parts from W_2. Application of wastes at 10t/ha rate, resulted in practically similar Zn release to the soil for all sources. However, the plant Zn concentration was found to be different. Plant shoot accumulated the highest amount (193.33 mg/kg) of Zn from the W_3@10t/ha treatment where plant root also accumulated significant amount of Zn. For all other treatments, plant Zn concentration was found to be lesser in the plant root than that in the shoot. With the wastes W_1 and W_2 a similar tendency was observed as to their contribution to the Zn accumulation in plant. The highest amount of Zn was contributed by W_3 compared to the rest of the treatments.

The plant shoot and root contained 28.2 mg/kg and 17.45 mg/kg Mn respectively. Plant shoot and root took up very little amount of Mn for all the treatments applied at the rate of 5 t/ha. For all the cases, plant shoot and root have the similar tendency to accumulate very little amount of Mn at both rates of waste application.

For the control treatment, the Pb concentrations in plant shoot and root were 0.25 mg/kg and 0.18 mg/kg respectively. In root, only W_3@5t/ha treatment contributed to a substantial amount of Pb where W_2@5t/ha contributed the amount was almost similar to the control treatment. For the waste treatment at the rate of 10 t/ha, the Pb concentration was observed higher in plants shoot. Lead uptake by root and shoot was quite high for the treatment W_3@10t/ha. The rest of the treatments contributed very little amount of Pb to the root compared to the shoot.

Plant shoot accumulated the highest amount (1.76 mg/kg) of Cd from the W_3@5t/ha treatment while plant root accumulated almost half the amount of Cd from the same treatment and same rate of application. The plant shoot and root accumulated almost similar amount of Cd from the W_1@5t/ha treatments whereas W_4@5t/ha treatment contributed to almost the double amount of Cd in plant root than that in plant shoot. Plant accumulated quite high amount of Cd in shoots from W_4@10t/ha treatment where very little amount of Cd was accumulated from the W_1 and W_2 at the same rate of application. In plant roots, Cd was found to be exceptionally very high with the treatment of W_3 @10t/ha and W_4@ both 5 &10t/ha.

From above results and considering the plant growth with the application of wastes, it was observed that the wastes contributed higher amount of Pb only to soil but lesser amount in plant shoots and roots; Cd only in plant shoots and roots; Zn in soil and plants; Fe only in soil and plant roots and Mn only in soil. These occurred for both 5 t/ha and 10 t/ha rates of application. It was also noticed that the wastes collected from high socio-economic niche contributed comparatively higher amounts of Pb, Cd, Zn, Fe and Mn at both 5 t/ha and 10 t/ha rates of application. However, the source of the wastes has a bearing on this – wastes from high socio-economic niche contain higher amounts of the heavy metals. The source of consumption could be a valid reason for this. The present study gives a good indication as to the strategy of urban solid waste management. The solid wastes generated in the urban area needs to be segregated according to their source and added to soil. The direct incorporation of the solid wastes could also be a good strategy for a carbon trade policy as this is likely to reduce carbon emission to the atmosphere.

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