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Heavy metal determination of brinjal cultivated in Soil with wastes

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Abstract

An experiment was conducted to determine the heavy metal status in fruits and roots of brinjal plant cultivated in soil mixed with wastes at Environmental Science Field Laboratory, Bangladesh Agriculture University, Mymensingh. Two brinajl varieties of BARI namely BARI–1 and BARI–4 and three treatments *viz.* T_0: control soil, T_1: Municipal waste and T_2: Industrial wastes were used for the present study. The data were collected on Cu, Zn, Pb and Fe of both fruits and roots of the brinjal plants. The data were analyzed by Atomic Absorption Spectrophotometer (AAS). The two factors experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Results revealed that the initial contents of Cu, Zn, Pb and Fe were higher in industrial waste mixed soil as compared to municipal waste and control soil. In contrast, the incidence of heavy metals in fruits and roots were tolerable range in normal and municipal waste mixed soil while industrial waste mixed soil showed highest values. This study also showed that the industrial waste treated plants of BARI–1 uptaked the more Cu and Zn content (16.12 and 21.39 mg/kg, respectively) in roots while plants of BARI–4 gave the more Pb and Fe content (0.363 and 365.70 mg/kg, respectively) in roots compared other interaction treatments. However, without waste treated or normal soil showed lowest effect on the incidence of heavy metal but municipal waste obtained the moderate effect. This result revealed that the both control and municipal waste treated soil may be acceptable for the cultivation of BARI brinjal in Bangladesh condition. This study also suggested that the industrial waste treated soil may not suitable for the vegetable cultivation might be due to the higher incidence of heavy metal in fruits and roots.

Key words: Heavy metals, brinjal, waste incorporated soil

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Introduction

Heavy metals have a great concern for contamination of soil and water because they are persistent and may affect vegetables, plant and human health. The term “heavy metals” refers to any metallic element that has a relatively high density and is toxic or poisonous even at low concentration (Lenntech, 2004). The term heavy metals are also known as trace elements, micronutrients, microelements, minor elements and trace inorganic. Some heavy metals are essential in trace amounts, namely Cobalt (Co), Copper (Cu), Iron (Fe), Manganese (Mn), Molybdenum (Mo) and Zinc (Zn) for plants and in addition, Chromium (Cr), Nickel (Ni) and Sn for animals whereas Arsenic (As), Cadmium (Cd), Mercury (Hg) and Lead (Pb) have not been shown to be essential for either plants or animals. The concentrations of heavy metals in soils do not normally exceed 1000 mg/kg (0.1%), in fact most have average concentrations of less than 100 mg/kg (Mitchell and Bear, 1964). Heavy metals mostly found specific adsorption sites in the soil where they are retained very strongly either on the inorganic organic colloids.

The heavy metals are widely distributed in environment, in soil, in plants and animal tissues. Industrial discharge, fertilizers, manure, pesticides, fossil fuels, municipal wastes, sewage–sludge, mining wastes, animal wastes, contaminated water etc. might be some of the major sources of heavy metal contamination in soil (Khairiah *et al.*, 2004). Heavy metals can be found generally at trace levels in soil and vegetation, and living organisms. However, these have a toxic effect on organisms at high concentrations. Heavy metal toxicity has an inhibitory effect on plant growth, enzymatic activity, stoma function, photosynthesis activity and accumulation of other nutrient elements, and also damages the root system (Gune *et al*., 2004).

The introduction of industrial and municipal solid waste into our environment has contributed greatly to the increase in levels of heavy metals in soil and vegetation grown in dumpsites. The soil and plants on these dumpsites will constitute a serious threat to the health of people living around such areas (Adefemi and Awokunmi, 2009). Industrial effluent discharged from textiles and tannery contains a higher amount of metals especially chromium, copper and cadmium, zinc, lead (Deepali and Gangwar, 2010).

Heavy metal pollution of agricultural soil and vegetables is one of the most severe ecological problems on a world scale and also in Bangladesh. The food chain contamination is the major pathway of heavy metal exposure for humans (Khan *et al*., 2008). The consumption of vegetables is one of the most important pathways for trace metals that harm human health (Sipter *et al.,* 2008). Some trace elements are essential in plant nutrition, but plants growing in the nearby zone of industrial areas display increased concentration of heavy metals serving in many cases as bio monitors of pollution loads (Mingorance *et al*., 2007). It has also been reported that crops have different abilities to absorb and accumulate metals in their different parts and that there is a wide variation in metal uptake and translocation between plant species and even between cultivars of the same species (Yu *et al*., 2006).

Plant grown on a land pollutant with municipal, domestic or a land polluted with Municipal domestic or industrial wastes can absorb heavy metals in form of mobile ions present in the soil through their roots or through foliar absorption. These absorbed metals get bio accumulated in the roots, stem and leaves of plants (Fatoki, 2000). Vegetables are exposed to the heavy metals contamination because one of the reason identified is the polluted agricultural soil has been used to cultivate the plants. Heavy metals that are attached with soil water and soil particles will be absorbed by plant roots and accumulated in vegetables (Aweng *et al*., 2011)

The contamination of vegetables with heavy metals poses a threat to its quality and safety because the excessive content of heavy metals in vegetables and fruits is associated with etiology of a number of diseases, especially cardiovascular, kidney, nervous system and bone diseases. During the last decade, the increasing demand of food safety has stimulated research regarding the risk associated with consumption of foodstuffs contaminated by heavy metals. Therefore the present study was determined to know the incidence of heavy metal in vegetable by affecting different types of waste into soil while we can easily consume our selective vegetable for our health safety. The study was conducted to investigate the concentration of heavy metals in soil, wastes and brinjal and to compare the concentration of heavy metals accumulation among varieties of brinjal.

Materials and Methods

The experiment was carried out in the Environmental Science Field Lab. Department of Environmental Science, Bangladesh Agricultural University, Mymensingh during the period of November 2015 to March 2016 to find out heavy metal determination in brinjal. Details materials used and methodologies followed in conducting the experiment have been presented in this chapter under the following headlines:

Experiment site: Geographically the experimental area is situated at 24.75^{0}N latitude and 90.5^{0}E longitude and elevation is about 18 cm above sea level. It belongs to the old Brahmaputra floodplain, Agro–ecological Zone (AEZ–9) having non calcareous Dark Gray Plain soil (FAO, 2010).

***Climate of the experimental site*:** The experiment plot was medium high land. The experimental area under subtropical climate characterized by moderately high temperature humidity and heavy rainfall with occasional gusty winds during Kharif season (March to September) and scanty rainfall associated with moderately low temperature during Rabi season (October to February). Details of the meteorological data during the study period have been presented in Table 1.

Table 1. Meteorological data from November 2015–March 2016

Month	Temperature (^{0}C)			Humidity (%)			Rainfall (mm)	Sunshine (hrs)	Evapotransp– iration (mm)
	Max	Min	Avg	Max	Min	Avg			
November 2015	27.90	18.00	23.20	90.90	54.20	82.20	00	200	76.09
December 2015	25.10	13.60	19.20	97.80	53.06	83.40	00	117.9	50.01
January 2016	23.90	12.01	17.30	104.0	56.90	84.60	00	82.7	49.8
February 2016	26.70	16.80	22.30	96.60	52.86	80.13	8.4	137.8	74.03
March 2016	31.05	20.16	24.80	97.60	52.35	75.90	104.8	190.2	110.05

Source: Weather Yard, Dept. of Irrigation and Water Management, BAU, Mymensingh

Experimental design and layout: The experiment was laid out in a randomized completed block design (RCBD). The size of the unit plot was 2m × 2m. Distance between block to block and plot to plot 0.5m in the experimental field. Two varieties were used for this study. Each treatment on replicated in thrice in the experimental field.

Treatments:

Factor A. Variety as planting materials (2): Two varieties were used as planting materials for the present study. They are as follows: V_1= BARI–1 brinjal, V_2=BARI–4 brinjal.

Factor B. Treatment (3): Different types of waste were incorporated with soil as treatments of the study. They are as follows: T_o= Control soil, T_1= Municipal waste, T_2= Industrial waste.

***Collection of wastes sample*:** Two types of wastes were used such as industrial waste and municipal waste. Normal soil was also used as control. Municipal waste was collected from waste dumping site near to Shombugong bridge area of Mymensingh sadar, Mymensingh. Industrial waste was collected from GMS composite knitting industries Ltd. at Sultan market in Kashimpur, Gazipur.

***Land preparation*:** The land was first opened with power tiller then it was ploughed and cross ploughed as many as five times followed by laddering at suitable intervals to prepare well pulverized plot. Farmyard manure or compost was incorporated into the soil during 1st ploughing. During land preparation weed and other stubbles of the previous crops were collected and removed from the land. These operations were done to bring the land under a good faith.

***Manures and fertilizer application*:** Manures and fertilizers were applied equally in the experimental plot according to the recommended dose of BARI (2012). Organic manures were applied just after opening the land preparation. The Bangladesh Agricultural Research Institute has recommend 15–20 tons organic manures, 375 kg urea, 150 kg TSP and 250 kg MOP for brinjal cultivation (Rashid and Singh, 2010). The amount of fertilizer required for each plot was calculated based on the area of each plot. The amount of fertilizer for each plot (2m×2m) is given in Table 2. Full amount of manure and fertilizer mentioned in the above table were applied in to the field during land preparation. Urea was applied per plot 50 gm in three times at 15 days, 45 days, and 65 days respectively after planting.

Table 2. Manure and fertilizer application rate for each plot in experimental field

Fertilizer	Amount per plot
Farmyard manure	2kg
Urea	150gm
TSP	50gm
MOP	50gm

***Collected wastes sample mixing*:** The collected soil samples were mixed according to the treatment. There were six plots that were mixing with municipal waste and six plots were mixing with industrial waste. About 12 kg wastes were used for each plot. Remaining six plots were used as control. Collected sample were mixed 15 days before planting.

***Source of seedling collection*:** About 32 days old seedlings were used as planting material. The two varies of brinjal were selected for experiment e.g. BARI–1 and BARI–4. There were 9 plots which were used for BARI –1 variety and remaining 9 plot used for BARI–4 variety in plots.

***Planting*:** Seedlings were collected from the field laboratory of the department of horticulture, Bangladesh Agricultural University, Mymensingh. Seedlings were planted after 7 days of final land preparation. Transplanting was done by 25 November 2015. It was done at afternoon to avoid sunlight. Seedlings were irrigated immediately after transplanting. Some extra seedlings were planted near the experimental plot for gap filling. Shadings were provided by pieces of banana leaf sheath for three days to protect the seedling from the direct sun just after planting. Irrigation, weeding and pesticides application were done properly according to crop production guidelines.

***Harvesting*:** Fruits were started to harvest when it became slightly violet color. First harvest was done on 24^{th} March. Harvesting was continued from March to early May. Fruits were collected separately for further research activities.

***Data collection*:** Data were collected on initial content of Cu, Zn, Pb and Fe from the three type's *viz.* normal, municipal waste and industrial waste mixed soil of the study. Thereafter, those heavy metals contents were also recorded on fruits and roots sample from the harvested brinjal plant at harvest.

***Sample preparation*:** Some healthy and fresh fruits were selected at first then these were air dried. Then these were grounded and preserved into paper made packed for heavy metal analysis.

Appearance: Color, size and freshness of fruits were observed.

***Waste sample preparation for analysis*:** After collecting of waste sample the unwanted material such as stubbles, stones, gravels, weeds etc were removed. Then samples were air dried, grounded and sieved through 2mm sieve. These samples were stored in a clean plastic bag for heavy metal analysis.

***Determination of heavy metal in waste and soil samples*:** Pb, Zn, Cu, Fe were analyzed from the wastes and soil sample. Analyses were done at the soil science division laboratory, Bangladesh Institute of Nuclear Agricultural (BINA), Mymensingh. For the determination of total metal concentration exactly 1 gm of powered waste sample was digested with aquaregia

(HNO_3: HCl =1:3). Then the content was evaporated to dry and again 5 mL of aquaregia was added. This process was repeated 2–3 times for efficient extraction of metals. Then the digest was filtered through a filter paper (Whatman no. 42) and the filted volume was made 25 mL with HNO_3. The determination of different heavy metals from waste samples was done by atomic Absorption Spectrophotometer (AAS) (PG990, England). Mono element Hollow Cathode lamp (HCl) was employed for the determination of each heavy metal. At first the AAS was calibrated followed by the manufacture's recommendation. Then the sample was diluted and directly run in AAS for the determination of heavy metal in sample. A standard curve was prepared by plotting the absorbance reading on. Y–axis versus the concentration of each standard solution of metal on X–axis. Then the concentration of metals was calculated in the sample by plotting the AAS reading on the standard curve.

Determination of heavy metal in vegetable: Pb, Zn, Cu, Fe were analyzed from the fruit samples. Analyses were done at the soil science division laboratory, Bangladesh Institute of Nuclear Agricultural (BINA), Mymensingh. For the determination of a sample weighing 0.5g was transferred into a dry clean digestion vessel. Nitric acid of 5ml was added to the sample and was allowed to stand overnight under fume hood. On the following day the vessels were placed on a heating block and heated at a temperature slowly raised to 120^0 C for two hours. After cooling 2ml of hydrogen per oxide (H_2O_2) was added and kept for few minutes. Again the vessel was heated at 120^0 C. Heating was momentarily stopped when the dense with white fumes occurred after which the volume was reduced to 3–4 ml. The digested was cooled. Diluted to 50ml with deionized water and filtered through Whitman no.42 filter paper into plastic bottle. The determination of different heavy metals from fruit and root samples were done by atomic Absorption Spectrophotometer (AAS) (PG990, England).The above method was followed.

Data processing and analysis: All the ends of data collection were compiled, tabulated and analyzed. Statistical analysis of the data generated out of the chemical analysis of water samples were done with the help of scientific calculator. The collected data were tabulated and coded. The data on various parameters under study were statistically analyzed according to the principles of experimental design to find out the variation resulting from experimental treatments. Analysis of variance was done following the Randomized Complete Block Design (RCBD) with the help of MSTAT–C package programme developed by Russel (1986). The mean of all the studied parameters were adjudged by Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984)

Results and Discussion

Initial heavy metal contents of studied soils

***Cupper (Cu)*:** Table 3 indicated initial contents of Cu in studied soil which had significant influenced due to the types of studied soil. The three types of soils were used for the present study where obtained result showed that the industrial waste content highest content of Cu (67.65 mg/kg) followed by municipal waste (46.33 mg/kg). As well as the control soil content the lowest content of cu (25.65 mg/kg) (Table 3).

***Zinc (Zn)*:** The initial contents of Zn of the studied different types of soil showed significant variation where it was significantly varied from 74.86 to 178.30 mg/kg (Table 3). From the above variation it was found that the industrial waste content more Zn as compared municipal waste (132.00 mg/kg) while control soil recorded the lowest initial content of Zn (Table 3).

***Lead (Pb)*:** Initial Pb content of different studied soil also showed significant variation where Industrial waste soil showed more Pb content (76.22 mg/kg) followed by municipal waste (51.48 mg/kg) while control soil content lowest Pb (15.79 mg/kg) (Table 3).

Iron (Fe): Initial Iron content varied significantly from 1950.0 to 3380.0 mg/kg where industrial waste soil showed more content and control soil recorded lowest content of Iron (Table 3).

Table 3: Initial heavy metal contents in waste mixed soil

Types of soil	Cu (mg/kg)	Zn (mg/kg)	Pb (mg/kg)	Fe (mg/kg)
Control soil	25.65 c	74.86 c	15.79 c	1950.0 c
Municipal waste	46.33 b	132.00 b	51.48 b	2710.0 b
Industrial waste	67.65 a	178.30 a	76.22 a	3380.0 a
Average	**46.54**	**128.39**	**47.82**	**2680.00**
SD (±)	**21.00**	**51.81**	**30.37**	**715.47**
$LSD_{(0.05)}$	**1.66**	**2.692**	**2.398**	**33.73**
Level of sig.	**	**	**	**
CV (%)	**1.57**	**0.92**	**2.21**	**0.56**

In a column figures having similar and no letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per Duncan's Multiple Range Test (DMRT) at same level; SD= Standard deviation; LSD= Least significant difference, CV = Co–efficient of variation; **= Significant at 1% level of probability

Heavy metal accumulation in fruits of BARI brinjal

***Cupper (cu) content due to effect of varieties*:** Both the varieties did not vary significant effect on the content of Cu in fruits. However, the fruits of BARI–1 showed more Cu content (12.21 mg/kg) than that of BARI–4 (11.27 mg/kg) in this study. The average Cu content of both fruits was 11.74 mg/ka with the standard deviation of 0.66.

***Cu content due to effect of treatments*:** Treatments significantly influenced on Cu content of BARI brinjal fruits. Among the treatments, industrial waste soil showed significantly high Cu content (15.32 mg/kg) followed by municipal waste soil (11.89 mg/kg) while control soil showed the lowest content of Cu (8.017 mg/kg) in this study. The average content of Cu was 11.74 mg/kg while SD value was 3.66 (Table 4).

***Interaction effect of varieties and treatments on Cu content*:** A significant variation for Cu content was observed due to the interaction of BARI brinjal varieties and different types of soil. Among the interaction treatments, the fruits of the variety BARI–1 treated by industrial waste showed the highest Cu content (16.12 mg/kg) which was statistically identical to the fruits of the variety BARI–4 treated by same soil (14.53 mg/kg). On the other hand, without treated fruits of BARI–4 showed the lowest Cu content (7.58 mg/kg) followed by the without treated fruits of BARI–1 (8.45 mg/kg). The average mean of Cu content of the whole treatments was 11.74 with the SD value of 3.32 (Table 5).

***Zinc (Zn) content due to effect of varieties*:** A non significant variation was found on Zn content in fruits due to the effect of BARI brinjal varieties. However, the variation in Zn content was 16.54 (BARI–1) to 16.16 mg/kg (BARI–4) with the average mean of 16.35 and SD value of 0.27 in this study.

***Zn content due to effect of treatments*:** Zn content varied significantly from 11.11 to 20.99 mg/kg where industrial soil recorded the highest and control soil obtained the lowest Zn content in this study. The average mean Zn content value was 16.35 mg/kg due to treatments while the SD value was 4.97 (Table 4).

***Interaction effect of varieties and treatments on Zn content*:** Zn content due to the interaction of BARI brinjal varieties and its cultivated soil showed significant variation and ranged from 10.70 to 21.39 mg/kg (Table 5). From the Table 5, it was found that the fruits of the variety BARI–1 treated by industrial waste recorded the highest Zn content while the fruits of BARI–4 treated by same soil also showed statistically identical Zn content (20.59 mg/kg). Similarly, the lowest Zn content was found in without treated fruits of BARI–1. The average mean of Zn was 16.35 mg/kg among the different treatments of interaction while SD value was 4.47 (Table 5).

Table 4: Effect of wastes on heavy metal contents of brinjal fruits at harvest

Treatments	Cu (mg/kg)	Zn (mg/kg)	Pb (mg/kg)	Fe (mg/kg)
T_0	8.017c	11.11c	0.097c	225.5c
T_1	11.89b	16.94b	0.257b	284.0b
T_2	15.32a	20.99a	0.357a	346.1a
Average	**11.74**	**16.35**	**0.24**	**285.20**
SD (±)	**3.66**	**4.97**	**0.13**	**60.31**
$LSD_{(0.05)}$	**1.525**	**0.750**	**0.041**	**18.65**
Level of sig.	**	**	**	**
CV (%)	**10.10**	**3.57**	**9.64**	**5.08**

In a column figures having similar and no letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per Duncan's Multiple Range Test (DMRT) at same level; SD= Standard deviation; LSD= Least significant difference, CV = Co–efficient of variation; **= Significant at 1% level of probability; T_0= Control soil; T_1= Municipal waste and T_2= Industrial waste.

***Lead (Pb) content due to effect of varieties*:** The Pb content showed significant variation between the varieties. The fruits of BARI–4 recorded significantly the more Pb content (0.26 mg/kg) compared the fruits of BARI–1 (0.21 mg/kg) with the average Pb content of 0.24 mg/kg. The standard deviation value was 0.03 for this character.

***Lead (Pb) content due to effect of treatments*:** The content of PB in different soil at harvest varied significantly from 0.097 to 0.357 mg/kg in this study (Table 4). Table 4 revealed that the industrial waste soil showed the highest and control soil recorded the lowest Pb content while municipal waste soil showed moderate Pb content (0.257 mg/kg) in this study. The average mean value of Pb content of the different soil was 0.24 mg/kg while SD value for the Pb was 0.13 (Table 4).

***Interaction effect of varieties and treatments on Pb content*:** Results indicated significant difference on Pb content due to the interaction effect. The highest Pb content (0.363 mg/kg) was found in fruits of BARI–4 brinjal while it was grown under industrial waste.

Table 5. Interaction effect of variety and waste on heavy metal contents in fruits of brinjal at harvest

Variety	Treatments	Cu (mg/kg)	Zn (mg/kg)	Pb (mg/kg)	Fe (mg/kg)
BARI–1	T_0	8.45c	10.70d	0.067e	229.50d
	T_1	12.07b	17.53b	0.227c	295.30c
	T_2	16.12a	21.39a	0.350a	326.50b
BARI–4	T_0	7.58c	11.52d	0.127d	221.50d
	T_1	11.70b	16.35c	0.287b	272.60c
	T_2	14.53a	20.59a	0.363a	365.70a
Average		**11.74**	**16.35**	**0.24**	**285.18**
SD (±)		**3.32**	**4.47**	**0.12**	**55.87**
$LSD_{(0.05)}$		**2.157**	**1.061**	**0.05753**	**26.38**
Level of sig.		*	*	*	**
CV (%)		**10.10**	**3.57**	**9.64**	**5.08**

In a column figures having similar and no letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per Duncan's Multiple Range Test (DMRT) at same level; SD= Standard deviation; LSD= Least significant difference, CV = Co–efficient of variation; *= Significant at 5% level of probability and **= Significant at 1% level of probability; T_0= Control soil; T_1= Municipal waste and T_2= Industrial waste

The fruits collected from the same treated plants of BARI–1 also recorded the statistically identical highest content of Pb (0.350 mg/kg) in this study while the fruits of same variety grown under control condition showed the lowest Pb content (0.067 mg/kg) in this study (Table 5). The average mean of PB content was 0.24 mg/kg while the SD value was 0.12 (Table 5).

***Iron (Fe) content due to effect of varieties*:** However, the Fe content of 286.60 mg/kg was recorded from the fruits of BARI–4 while the fruits of BARI–1 showed of

283.80 mg/kg Fe content but both the variety were statistically identical due to non significant variation (Figure 4).

***Iron (Fe) content due to effect of treatments*:** The different types of soil had also significant influenced on Fe content at harvest where industrial waste treated soil showed the highest Fe content (346.10 mg/kg) followed by municipal waste treated soil (284.0) (Table 4). On the other hand, control soil obtained the lowest content of Fe (225.50 mg/kg) in this study. The average mean value was 285.20 mg/kg while SD value was 60.31 (Table 4).

***Interaction effect of varieties and treatments on Fe content*:** There was a significant variation for Fe content in fruits of BARI brinjal due to the effect of interaction where it was significantly varied from 221.50 to 365.70 mg/kg in this study (Table 5). From the above variation in Fe content, it was found that the highest content of Fe was obtained from the fruits of BARI–4 while it was grown under industrial waste followed by the fruits of BARI–1 grown under same soil (326.50 mg/kg). On the other hand, the collected fruits from the plants of BARI–1 grown under control condition showed the lowest Fe content. The average mean Fe content of the study was 285.18 mg/kg while SD value was 55.87 (Table 5).

***Heavy metal accumulation in roots of BARI brinjal*:**

***Cupper (Cu) content due to effect of varieties*:** The variation of Cu content in roots of BARI brinjal varieties was statistically significant where BARI–1 showed more Cu content (23.77 mg/kg) than that of BARI–4 (21.91 mg/kg) (Table 6). The mean content of Cu of both varieties was 22.84 mg/kg while SD value was 1.32 (Table 6).

Table 6. Effect of waste on heavy metal contents in roots of brinjal at harvest

Treatment	Cu (mg/kg)	Zn (mg/kg)	Pb (mg/kg)	Fe (mg/kg)
T_0	16.94 c	24.50 c	1.722 b	310.5 c
T_1	23.58 b	39.19 b	3.158 a	388.6 b
T_2	28.00 a	46.05 a	3.492 a	440.2 a
Average	**22.84**	**36.58**	**2.79**	**379.77**
SD (±)	**5.57**	**11.01**	**0.94**	**65.30**
$LSD_{(0.05)}$	**0.795**	**0.788**	**0.460**	**21.5**
Level of sig.	**	**	**	**
CV (%)	**3.36**	**1.67**	**12.81**	**4.40**

In a column figures having similar and no letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per Duncan's Multiple Range Test (DMRT) at same level; SD= Standard deviation; LSD= Least significant difference, CV = Co–efficient of variation; **= Significant at 1% level of probability; T_0= Control soil; T_1= Municipal waste and T_2= Industrial waste.

***Cupper (Cu) content due to effect of treatments*:** The different treated soil showed significant response on the content of Cu where industrial waste treated soil showed the more Cu content (28.00 mg/kg) while control soil showed the lowest Cu content (16.94 mg/kg) in roots of BARI brinjal plants (Appendix III and Table 4). The mean of Cu was 22.84 due to treatments while SD value was for the character was 5.57 (Table 6).

***Interaction effect of varieties and treatments on Cu content*:** Effect of interaction between the varieties and treatments showed significant variation in respect of Cu content where it was ranged from 16.56 to 29.42 mg/kg (Table 7). The highest Cu content was found from the roots of the plants of BARI–1 grown under industrial waste treated soil followed by the plants of BARI–4 grown under same treated soil (26.58 mg/kg). On the other hand, the roots of the plant of BARI–1 grown under condition showed the lowest Cu content in this study. The average mean Cu content of the treatments was 22.84 while SD value was 5.10.

***Zinc (Zn) content due to Effect of varieties*:** Between the varieties Zn content varied from 36.53 (BARI–4) to 36.63 mg/kg (BARI–1) but they were statistically identical due to non significant variation. The mean Zn content of 36.58 mg/kg was for both varieties while they showed of 0.07 SD value (Table 6).

***Zinc (Zn) content due to effect of treatments*:** Zn content also varied significantly from 24.50 to 46.05 mg/kg where industrial waste treated plant recorded the highest Zn content in roots followed by municipal waste treated soil (39.19 mg/kg) while without treated or control soil took the lowest Zn content. The average mean Zn content was 36.58 mg/kg for the treatments with the SD value of 11.01 in this study (Table 6).

***Interaction effect of varieties and treatments on Zn content*:** Zn content in roots of brinjal plant significantly varied from 23.46 to 46.67 mg/kg where the highest Zn content was found from the plants of BARI–4 grown under industrial waste treated soil followed by the same treated plant of BARI–1 (45.42 mg/kg). Similarly, without treated plant of BARI–4 recorded the lowest Zn content while the average mean of Zn content was 36.58 with the SD value of 9.87 (Table 7).

Table 7. Interaction effect of variety and waste on heavy metal contents in roots of brinjal at harvest

Variety	Treatment	Cu (mg/kg)	Zn (mg/kg)	Pb (mg/kg)	Fe (mg/kg)
BARI–1	T_0	17.32 e	25.55 d	1.527 c	314.80 d
	T_1	24.56 c	38.92 c	3.417 ab	376.10 c
	T_2	29.42 a	45.42 b	3.753 a	430.10 ab
BARI–4	T_0	16.56 e	23.46 e	1.917 c	306.20 d
	T_1	22.60 d	39.46 c	2.900 b	401.00 bc
	T_2	26.58 b	46.67 a	3.230 ab	450.20 a
Average		**22.84**	**36.58**	**3.04**	**379.73**
SD (±)		**5.10**	**9.87**	**0.70**	**59.31**
$LSD_{(0.05)}$		**0.9831**	**1.113**	**0.651**	**30.41**
Level of sig.		*	**	*	*
CV (%)		**3.36**	**1.67**	**12.81**	**4.40**

In a column figures having similar and no letter(s) do not differ significantly at 5% level whereas figures with dissimilar letter(s) differ significantly as per Duncan's Multiple Range Test (DMRT) at same level; SD= Standard deviation; LSD= Least significant difference, CV = Co–efficient of variation; *= Significant at 5% level of probability and **= Significant at 1% level of probability; T_0= Control soil; T_1= Municipal waste and T_2= Industrial waste

***Lead (Pb) content due to effect of varieties*:** Between the varieties, the Pb content in roots of the plant of BARI–1 was 2.90 mg/kg and BARI–4 was 2.68 mg/kg where both are statistically identical due to non significant variation. The average mean of Pb content was 2.79 while SD value was 0.15.

***Lead (Pb) content due to effect of treatments*:** The Pb content in roots of brinjal plant varied significantly from 1.722 to 3.493 mg/kg due to the effect of treatments where industrial waste treated soil showed more Pb content and without treated soil recorded the lowest Pb content in this study. The average mean of Pb content was 2.79 mg/kg while SD value was 0.94 (Table 6).

***Interaction effect of varieties and treatments on Pb content*:** The variation in content of Pb in roots of brinjal plant was statistically significant and varied from 1.71 to 3.75 mg/kg (Table 7). The highest Pb content was found from the plant of BARI–1 grown under industrial waste treated soil while the plants of BARI–4 grown under same treated soil also showed statistically highest Pb content (3.230 mg/kg) in this study. On the other hand, the lowest Pb content was found in BARI–1 brinjal plants grown under control condition. The average value of the pb was 3.04 mg/kg among the interaction treatments where SD value was 0.70 (Table 7).

***Iron (Fe) content due to effect of varieties*:** Both the variety did not vary significant effect on Fe content in roots of Brinjal plant where Pb content varied from 373.60 (BARI–1) to 385.80 mg/kg (BARI–4) with an average mean of 379.70 and SD of 8.63 (Table 6.

***Iron (Fe) content due to effect of treatments*:** Among the different treatments, the soil treated by industrial waste showed significantly the highest Fe content (440.20 mg/kg) in roots of brinjal plants compared to the treated soil of municipal waste (388.60 mg/kg) and without treated soil (310.50 mg/kg). The mean of total Fe content was 379.77 and SD) value was 65.30 (Table 6).

***Interaction effect of varieties and treatments on Fe content*:** A significant variation on Fe content was also found due to the effect of interaction where the highest Fe content (450.20 mg/kg) was found from the plants of BARI–4 grown under industrial waste treated soil closely followed by the same treated plants of BARI–1 (430.10 mg/kg). Similarly, without treated plants of BARI–4 recorded the lowest Fe content (306.20 mg/kg) in this study. The average mean Fe content was 379.73 mg/kg while SD value was 59.31 (Table 7).

***Heavy metal accumulation in soil*:** From the result of the present study, it was found that the Cu content was much higher in industrial waste whereas Cu content is lower in control soil. However, Cu content in municipal waste is lower than industrial waste but it was higher than normal soil in this study which might be due to the municipal wastes contain in waste such as batteries, plastic containers, cosmetics and some medicinal and electrical materials. Such the same observations were also obtained in CCME (1999) also reported that the maximum permissible concentrations of Cu in soil 63 mg/kg. Similar findings with the present study was also reported by Islam *et al.* (2009) who also reported that the average concentration of Cu was found 1347.5 mg/kg in the sludge samples, which was higher than those of permissible levels. Weldemariam (2014) and Enyinna and Nte (2013) also supported the present findings of the present study. Similarly, CCME (1999) reported that the maximum permissible concentrations of Zn in soil 200 mg/kg while maximum permissible concentrations of Pb in soil 70 mg/kg. This permissible concentrations suggested that the municipal or industrial waste mixed soil may be acceptable for the vegetable cultivation in our country which might be due to the Zn level of industrial waste were in acceptable range according to CCME (1999). Such the same findings was also reported by Islam *et al.* (2009); Bahadir *et al.* (2007); Enyinna and Nte (2013) and more other scientists of the home and abroad. Anake *et al*. (2009) reported that the ranges of Pb levels for all the dumpsites were 42.6–9662 mg/kg while Enyinna and Nte (2013) state that the concentration of Pb in municipal dumpsite was above the international limits with the highest concentration 862.6 mg/kg. Besides, the range of iron of the present study had also acceptable range in both municipal and industrial waste mixed soil according to WHO/FAO (2007) who reported that the permissible limit of Fe in soil is 50000 ppm. Weldemariam (2014) reported that the mean concentration of Fe in sludge sample was 16827 mg/kg. Chowdhury (2003) reported total concentrations Fe in surface soils of ranged between 2066–3951 mg/kg. Hoque (2003) carried out an experiment to determine the status of Fe waste areas of Chapai Nawabganj. He reported that the mean concentration of Fe in soils were 40.30 µg/g.

***Heavy metal accumulation in fruits of brinjal*:** The ranges of Cu in fruit sample for BARI verities were 7.58 to 16.12 mg/l while Zn, Pb and Fe contents in brinjal fruits were 10.70 to 21.39, 0.067 to 0.363 and 221.50 to 365.70 mg/kg, respectively. However, higher contents were obtained in industrial waste mixed soil and lower in normal soil but the ranges were acceptable for Cu and Fe but Zn and Pb were not in range according to WHO/FAO (2007) who reported that the acceptable ranges of Cu, Pb, Zn and Fe in fruits were 15, 0.30, 20.0 and 425 mg/kg, respectively. From the above ranges of WHO/FAO (2007), it was found that the heavy metal contents in fruits of brinjal due to the effect of different waste mixed soil were acceptable range in normal and municipal waste mixed soil but not in industrial soil. This result reported that the normal or municipal waste mixed soil may be used for the brinjal cultivation in Bangladesh but industrial waste mixed soil inappropriate in Bangladesh condition. Similarly Islam and Hoque (2014) also reported that the concentration of Cu in brinjal range from 13.57–19.90 mg/kg while Zhu *et al.* (2011) reported that the concentrations of copper 0.214–0.875 (μg/g) in brinjal. In another observation of Islam and Hoque (2014) also found that the concentration of Pb in brinjal range from 0.06–3.5 mg/kg while Alamgir and Chakarabarty (2000) also showed the range of Pb 10.04 mg/kg for the vegetable cultivation in Bangladesh condition. Those findings also reported that the municipal waste may be accepted for vegetable cultivation but industrial waste mixed soil did not appropriate for vegetable cultivation in Bangladesh due to higher incidence of heavy metal in fruits according the above indicating all scientists. Similarly, Islam and Hoque (2014) further observed that the concentration of Zn in brinjal range from 16.29–21.50 mg/kg while Oluyemi and Eyitayo (2013) reported that Concentration of Zn range from 7.54–91.10 mg/kg in eggplant. However, the range of Zn of industrial waste mixed soil did not appropriate according to Islam and Hoque (2014) but it was optimum according to Oluyemi and Eyitayo (2013). In another observation, Oluyemi and Eyitayo (2013) reported that concentration of Fe range from 200.01–655.90 mg/kg in fruits of eggplant which indicated that the heavy metal incidence in fruits of the present study may be accepted due to all types of waste mixed soil. However, industrial soil may be inappropriate according to Islam and Hoque (2014) in Bangladesh condition. From the above findings of the present study it was found that municipal wastes mixed soil may be acceptable but industrial waste mixed soil may not appropriate for the brinjal cultivation in Bangladesh acceding to the maximum scientists of the home and abroad.

***Heavy metal accumulation in root of brinjal*:** The heavy metal concentration in roots of the brinjal plant were determined in respect of Cu, Zn, Pb and Fe where it was found that it was ranged from 16.56 to 29.42, 23.46 to 46.67, 1.527 to 3.753 and 306.20 to 450.0 mg/kg. WHO/ FAO (2007) reported that the normal range of 20–100, 0.50–30.0 and 400–500 mg/kg for Zn, Pb and Fe, respectively in vegetable plant were acceptable which indicated that the brinjal plant of the present study were in acceptable range at any waste mixed soil. However, Kebir and Bouhadjera (2011) showed that the ranges of Zn in sludge dosed plants were 155.79–282.35 ppm while Sekabira *et al.* (2011) showed that the heavy metal concentration of Pb and Fe were 1.67 and 1104.66 mg/kg, respectively in roots of *C. bengalensis* species where they reported that Pb was acceptable and Fe were not acceptable. Therefore, the ranges of Zn, Pb and Fe in roots of the present study reported that municipal waste may be suitable among different waste used in the present study for vegetable cultivation according to the above and other scientists namely Zhu *et al.* (2011).

Conclusion

From the obtained results it may be concluded that the both brinjal variety showed optimum values as per FAO and WHO for the heavy metal contents in both fruits and roots in different types of soil which indicated that both BARI–1 and BARI–4 brinjal variety may be acceptable for the cultivation in different soil types of the Bangladesh. Besides, both control and municipal waste treated soils also showed acceptable range of heavy metal for the cultivation of BARI brinjal in Bangladesh condition which also indicated that municipal waste may will be used for the cultivation of brinjal which will ensure the sustainable agriculture and safer for our environment . This study showed that the roots contain more heavy metals than fruits of brinjal. This study showed that Cu, Zn contents were higher in BARI-1 and Pb, Fe were higher in BaRI-4 varieties brinjal. This study suggested that the industrial waste treated soil may not suitable for the vegetable cultivation might be due to the over range of heavy metal as recommended by FAO and WHO.

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