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TOXICITY ASSESSMENT FOR TANNERY SLUDGE CONTAMINATED SOIL, USING RED AMARANTH (AMARANTHUS CRUENTUS)

Farhat Tahsin Prattoyee*[1], Anjumand Ashraf[2] and Md. Delwar Hossain[3]

[1]Student, Department of Environmental, Water Resources and Coastal Engineering, MIST, Bangladesh, e-mail: prattoyee94@gmail.com
[2]Student, Department of Environmental, Water Resources and Coastal Engineering, MIST, Bangladesh, e-mail: rusabashraf@gmail.com
[3]Professor, Department of Civil Engineering, BUET, Bangladesh, e-mail: delwar@ce.buet.ac.bd

***Corresponding Author**

ABSTRACT

The presence of heavy metals in the atmosphere, soil, and water, even in traces can cause serious problems to all organisms. Heavy metal bioaccumulation in the food chain especially can be highly risky to human health. A study was conducted to assess the heavy metal contamination of soil and plants in the vicinity of tanneries in the Savar at Tannery Industrial Estate Dhaka (TIED). An analysis of concentrations of heavy metals (Fe, Zn, Mn, Cu, Cr, Pb) in soil and plant samples was done. Seed germination, seedling growth (root and shoot) and heavy metal accumulation were measured. The disposed tannery waste is polluting the soil of the dumping zone and the surrounding region. In most cases, plants growing in this region are containing heavy metals. These plants are coming to the market as vegetables and fruits which upon consumption are being included in our food chain. Out of these vegetables we have chosen the Red Amaranth (*Amaranthuscruentus)* plant to assess the contamination level of heavy metals in the soil and plants grown in the tannery waste contaminated area. In this study, we have tried to show the difference in the concentration level of heavy metals between tannery waste contaminated soil and normal soil. We have also studied the level of uptake in Red Amaranth plants grown in these two types of soil. Six pots were taken for the experiment in which three pots were filled with contaminated soil of Savar Tannery State and the other three were filled with normal soil. 100 seeds per pot were sowed in June 2019. The growth period of Red Amaranth was 40 days. The order of heavy metal level in tannery soil was Co<Cd<Pb<As<Ni<Cr and in the normal soil was Co<Cd<Pb<As<Ni<Cr, which matches with the former one. The level of heavy metal concentration is higher in soil samples than vegetable samples. The heavy metal accumulation in various plant components was found in this order: roots>leaf>stem. High concentrations of heavy metals were found in plant samples near the Tannery area, which in turn will affect the food chain. This may be considered as a major environmental concern.

Keywords: *Tannery sludge, Soil, Red Amaranth (Amaranthus cruentus), Concentration, Heavy metal.*

1. INTRODUCTION

Leather and leather products rank fourth in foreign exchange income for Bangladesh. The Statistics prepared by the Export Promotion Bureau of Bangladesh for the financial year 2011-2012 shows that the leather sector earned US$765 million for Bangladesh. However, pollutant discharges have severe impacts on the social and physical environment. The Department of Environment has categorized the tannery industry as one of the most polluting industries in Bangladesh. Most tannery industries use old and inferior leather-processing methods and thereby discharge wastes without treatment. This severely affects both the environment and human health (Ahmed, 2005).

During operations, a lot of organic and inorganic chemicals/compounds are used. Many of those are not fully consumed by the processed leather. Nearly 90% of all leather produced is tanned using chromium salts (Stein & Schwedt, 1994). Generally, 8% of the basic chromium sulfate salt is used for conventional tanning. It binds with the collagenous protein to convert to leather. About 60 to 70% chromium compound is consumed by hides and skins and the rest of the amount of chromium is discharged directly from the industry which pollutes the environment (Adeel et al., 2012). Other metal pollutants of concern within the tanning industry include cadmium, cobalt, copper, barium, arsenic, nickel, lead, mercury, iron, etc. (Mwinyihija, 2010).

In 2017, the tanneries of the Hazaribagh area of Dhaka have shifted to Savar on the banks of Dhalweswari River, as Hazaribagh became one of the most polluted areas in Dhaka city and Buriganga River has become highly polluted.

Vegetables, especially those of leafy vegetables grown in heavy metals contaminated soils, accumulate higher amounts of metals than those grown in uncontaminated soils (Jassir et al., 2005). In Bangladeshi context, some of the major known toxic bio-accumulative metal pollutants from industrial sectors, which are particularly dangerous are Hg, Pb, As, Cr, Ni, Cu, Zn and Cd (Faisal et al., 2004). Studies have shown that heavy metals are potentially toxic to crops, animals, and humans when contaminated soil is used for crop production because heavy metals easily accumulate in vital organs and threaten growing crops and human health (Sharma et al., 2009). The intake of heavy metals through the food chain by the human population has been widely reported throughout the world (Muchuweti et al., 2006). Due to their non-biodegradable and persistent natures, heavy metals are accumulated in vital organs in the human body such as the kidneys, bones and liver and are associated with numerous serious health disorders (Duruibe et al., 2007). But the uptake of heavy metal by plants or food crops from the soil to biota and its impacts on the human health in Bangladesh has been rarely reported up to now. Further, the consumption of rice crop and vegetables are very high in Bangladesh **(**Mahfuza et al., 2015).

Red amaranth (*Amaranthus cruentus*) is one of the commonly grown leafy vegetables in Bangladesh. It is fast-growing and cheap. Hence it was chosen for the research work. Vegetables cultivated in soils, polluted with toxic metals due to industrial activities, take up heavy metals and accumulate them in their edible and non-edible parts in quantities high enough to cause clinical problems both to animals and human beings consuming these metal-rich plants because there is no good mechanism for their elimination from the human body (Alam et al., 2003).

2. METHODOLOGY

2.1 Soil and plant sampling

This study was undertaken to find out the heavy metal contamination of soil beside the Central Effluent Treatment Plant (CETP) at Savar and the level of transmission of heavy metal from soil to red amaranth plants.

Six pots were taken for the experiment in which three pots were filled with contaminated soil of Savar Tannery State (23°46′32.34″N, 90°14′24.42″E) and the other three were filled with normal soil, collected from Bangladesh Agricultural Research Institute (BARI - 23°59′31.15″N, 90°24′50.95″E), experimental field, regarded as the low-level pollution area. A hundred seeds per pot were sowed in June 2019. The growth period of *Amaranthus cruentus* was 40 days. Then the plants were carefully removed from the pots. Soil clinging to the plant was removed by rinsing in deionized water. The plant samples represented different parts of the plant (root, stem, and leaf). The plant samples were kept in separate polythene bags and properly labeled. The soil samples were collected from the pots and kept in the polythene bags and labeled properly. The plant and soil samples were analyzed in the Soil Science Division laboratory of BARI.

2.2 Preparation and preservation

After the delivery to the laboratory, all vegetables were washed in fresh running water to eliminate dust and dirt, possible parasites or their eggs and were finally washed with deionized water. The clean vegetable samples were air-dried and placed in an electric oven at 65°C for 72-96 hours, depending on the sample size. The dry vegetable samples were homogenized by grinding using a ceramic coated grinder. All the soil samples were spread on plastic trays and allowed to dry at ambient temperature for 8 days. The dry soil samples were ground with a ceramic coated grinder and sieved through a nylon sieve. The final samples were kept in the labeled polypropylene containers at ambient temperature before the analysis.

2. 3 Digestion and determination

One gram dry plant or soil sample was weighed into a 50-ml volumetric flask, followed by the addition of a 10 ml mixture of analytical grade acids HNO_3 : $HClO_4$ in the ratio of 5:1. The digestion was performed at a temperature of about 190 ºC for 1.5 hours. After cooling, the solution was made up to a final volume with distilled water. The metal concentrations were determined by atomic absorption spectrometry using a VARIAN model AA2407 (USA) Atomic Absorption Spectrophotometer(AAS).

3. ILLUSTRATIONS

3.1 Soil Characteristics

The absorption of heavy metal is controlled by soil characteristics. The pH of the tannery soil and normal soil was found 8.26 and 6.87, respectively. The organic matter concentration was 4.07% in the tannery soil and in the normal soil, it was 1.03%. The concentration of nutrients in both types of soil are shown in Table 1.

Table 1: Physical and Chemical properties of the soil.

Soil properties	**Nutrient status**	
	Tannery soil	**Normal soil**
pH	8.26	6.87
OM (%)	4.07	1.03
Total N (%)	0.115	0.085
Exchangeable Ca (meq/100 g soil)	7.4	0.65
Exchangeable Mg (meq/100 g soil)	2.5	2.3
Exchangeable K (meq/100 g soil)	0.3	0.25
Available P (mg kg^{-1})	10	13.1
Available S (mg kg^{-1})	11	12
Available Cu (mg kg^{-1})	1.3	2.0
Available Fe (mg kg^{-1})	45	57
Available Mn (mg kg^{-1})	8.1	9.6
Available Zn (mg kg^{-1})	2.56	2.89

Soil properties	Nutrient status	
	Tannery soil	**Normal soil**
Available B (mg kg^{-1})	1.9	2.0
Available Pb (mg kg^{-1})	12.7	5.66
Available Cd (mg kg^{-1})	2.12	1.14
Available Cr (mg kg^{-1})	6946	324
Available Ni (mg kg^{-1}	355.5	112
Available Co (mg kg^{-1})	8.02	5.08
Available As (mg kg^{-1})	15.13	9.08

The concentrations of all six of the heavy metals examined in this study were found to be higher in the tannery soil (Table. 2).
The Pb concentration in the tannery soil was 4.78 times higher than the normal soil. In the case of Cr, the concentration was 4.95 times higher in the tannery soil than the normal soil. Similarly, for Cd the concentration was 1.62 times higher, for Ni, the concentration was 3.87 times higher, for Co the concentration was 1.74 times higher and for As it was found that the concentration was 3 times higher in the tannery soil than the normal soil.

Table 2: Heavy metal concentration of the soil.

Heavy Metal	Tannery Soil (mg kg^{-1})	Normal Soil (mg kg^{-1})
Pb	12.8	5.7
Cd	12.7	5.66
Cr	6946	324
Ni	356	112
Co	8.02	5.08
As	15.13	9

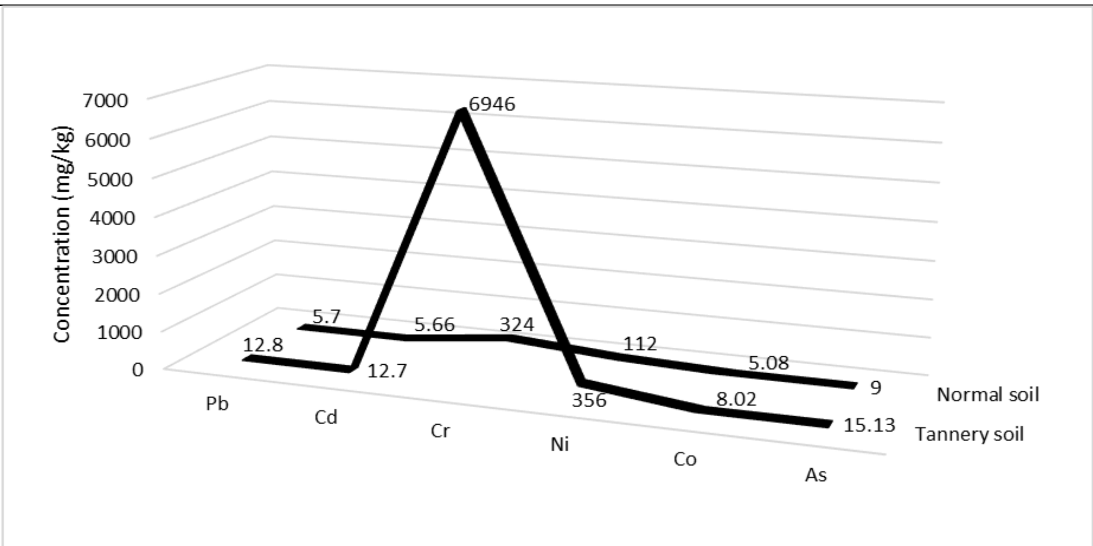

Figure 1: Heavy metal concentration of tannery soil and normal soil.

3.2 Plant Growth

For the germination test, 50 seeds/petri dishes were taken. Out of them 39 germinated in the Savar soil and 21 germinated in normal soil. 100 seeds/pot were sowed. The average No. of plant/pot for the tannery soil was 21 and for the normal soil, it was 41. The length of root shoot and fresh weight, dry weight information are shown in Table 3.

Table 3: Growth attributes of red amaranth grown in the tannery soil and in the normal soil.

Treatment	No. of Plant/ pot	Shoot Length (cm)	Root length (cm)	Fresh wt. (g/10 plant)			Dry wt. (g/10 plant)		
				Shoot	Root	Leaf	Shoot	Root	Leaf
T_1: Tannery soil	21	14.47	5.67	12.12	1.21	11.62	1.23	0.13	1.21
T_2: Normal soil	41	23.67	7.53	60.21	6.11	59.31	6.05	0.62	6.00

3.3 Accumulation of Heavy Metal into Plant Tissue

For all heavy metals, the concentrations were found higher in the roots. Roots are the point of entry into the plant, so it can be the possible reason. The level of heavy metal concentration is higher in the soil samples than the vegetable samples. The level of heavy metals in the vegetable is generally lower than the soil samples (Demirezen & Aksoy, 2006). Such results might be attributed due to root activity, which seems to act as a barrier for the translocation of metals (Davies & White, 1981; Yusuf et al., 2003).

The levels of uptake of heavy metals in samples from the tannery soil were higher than those from the low-level polluted (BARI) area. Several studies have indicated that vegetables grown in the heavy metals contaminated soils have higher concentrations of heavy metals than those grown in the uncontaminated soils (Jassir et al., 2005).

The low concentration of Cd in plant tissues is probably because of the presence of the low Cd concentration in the soil (Table. 2). On the other hand, the high concentration of Cr in the plant tissues is maybe due to the fact that Cr concentration in the soil was the highest among these metals. The mean concentrations of Pb, Cd, Cr, Ni, Co, and As in the whole plant (roots, stem, and leaf) are shown in Table 4.

Table 4: Heavy metal concentration (Pb, Cd, Cr, Ni, Co, and As) in plant components (mg kg^{-1} of dry wt.) of red amaranth.

Treatment	Heavy Metal	Soil (mg kg^{-1})	Plant parts (mg kg^{-1} of dry wt.)			
			Root	Stem	Leaf	Total plant
T_1: Ternary soil	Pb	12.8	6.03	2.21	4.39	4.21
T_2: Normal soil		5.7	1.90	0.49	1.23	1.21
T_1: Ternary soil	Cd	12.7	0.51	0.28	0.38	0.39
T_2: Normal soil		5.66	0.37	0.10	0.25	0.24
T_1: Ternary soil	Cr	6946	1839	1057	1469	1455
T_2: Normal soil		324	385	212	285	294
T_1: Ternary soil	Ni	356	245.3	89.1	160	164.8
T_2: Normal soil		112	62.5	20.9	44.1	42.5
T_1: Ternary soil	Co	8.02	2.29	1.42	1.72	1.83
T_2: Normal soil		5.08	1.39	0.69	1.07	1.05
T_1: Ternary soil	As	15.13	0.87	0.28	0.51	0.54
T_2: Normal soil		9.08	0.27	0.18	0.17	0.18

For all the metals, the uptake into the plant roots was highest. The uptake of heavy metals was the lowest in the leaf parts. The heavy metal accumulation in various plant components was found in this order: roots > leaf > stem.

In this study, the heavy metal accumulation concentration of Cr was very high in the plant than the permissible limit set by WHO/FAO (Figure.2). The concentration of Ni was found higher in the plant grown in tannery soil. The concentration of other heavy metals, Pb, Cd, As was found a bit higher than the permissible level. The accumulation concentration of Co was lower than the maximum permissible level.

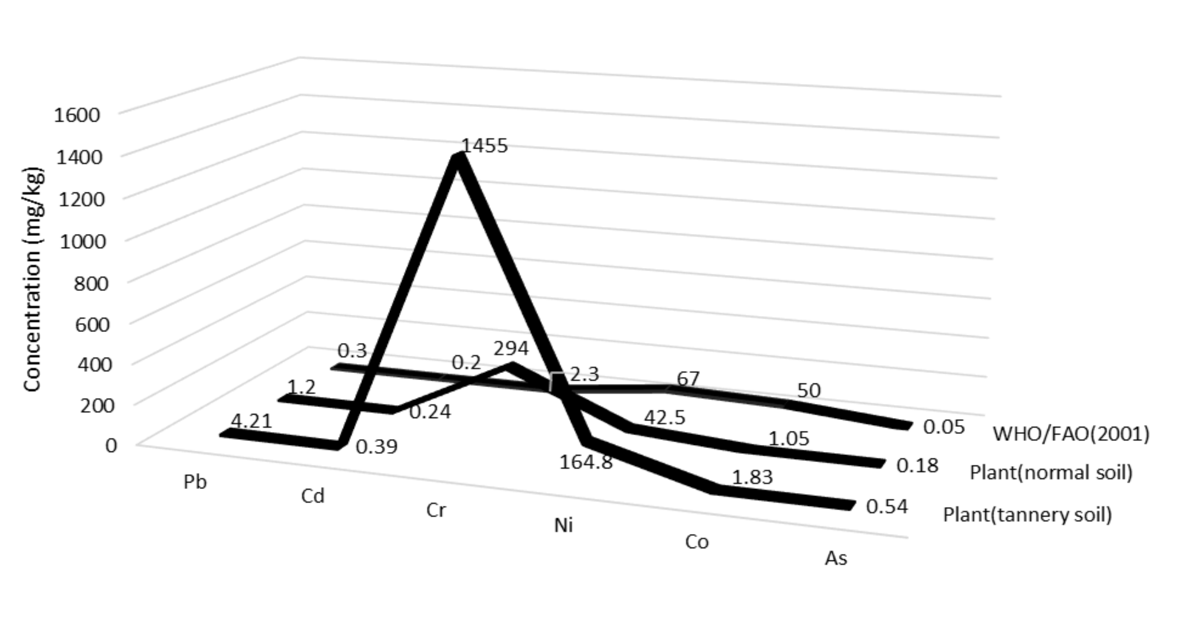

Figure 2: Total concentrations of heavy metal in the vegetables and maximum allowable limits.

4. CONCLUSIONS

From the test results, it is clear that red amaranth plants accumulated heavy metals from soil and the concentration varied among different parts of plants (root, stem, and leaf). The heavy metal accumulation was highest in the roots of the plant, lower in the leaf and lowest in the stem of the plant. In both tannery soil and normal soil, the concentration of Cr was found highest. And the order of heavy metal level of both soil was found to show a similar trend. The order was: Co<Cd<Pb<As<Ni<Cr. Further research can be conducted to prove the level of heavy metal accumulation in different species of plants and their impact on the food chain.

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