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A Comparative Study of Heavy Metal Concentration in Different Layers of Tannery Vicinity Soil and Near Agricultural Soil

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Abstract

This research was conducted to bring out the appropriate level of heavy metal contamination in soil at the site of Buriganga river bank near the Hazaribagh tannery area and the normal agricultural area to evaluate heavy metal contamination in soil due to untreated tannery effluents. AAS flame method was used to determine the concentration of Chromium (Cr), lead (Pb), Cadmium (Cd), Zinc (Zn) in several depths of the soil. Results showed that, the heavy metal concentration in soil at the site of Buriganga river bank in the tannery vicinity and normal agricultural area significantly varies, such as Cr varies (561.71 - 31.23) mg/kg, Zn varies (158.23 - 73.5), Pb varies (70.58 - 24) and Cd varies (2.25 - 0.71) mg/kg in the river bank as well as in the normal agricultural area Cr varies (27.869 - 24.5416) mg/kg, Zn varies (134.167 - 28), Pb varies (25.76 - 22.49) and Cd varies (1.30 - 0.64) mg/kg. The study indicated that heavy metals concentration was found to be significantly higher in river bank soils than in the normal agricultural area. This metal concentration in soil is responsible for the promotion of toxicity in agricultural products. Therefore, the human health and environment are affected by these areas.

Keywords

Heavy Metal, Soil, Contamination, Tannery Area, Agricultural Area

1. Introduction

In recent years, environment and health related problem by heavy metal has become a major concern [1]. As soil is a crucial component of rural and urban environments, the role of heavy metals in the soil system is increasingly becoming an issue of global concern [2]. The pollution of heavy metals in soil undesirably affects its physicochemical

criteria important to infertility and low yield of crops due to their toxicity [3]. Nowadays, with the development of the global economy, soil contamination by heavy metal has gradually increased, resulting in the deterioration of the environment [4]. This soil is tainted by heavy metals through the irrigation system; resulting toxicity is entering into the food chain which affects the food quality and safety [5]. Contamination of soil by heavy metal due to tannery waste becomes a worldwide problem [6]. Wastewater from tanneries, industries or other sources carries a large amount of toxic heavy metals such as Ca, Fe, Mg, Na, Ni, Cr, Cd, Pb, Zn etc. which are responsible for the contamination of agricultural soil [7].

In Bangladesh, Tannery is an important foreign currency sector. There are 214 tanneries in Bangladesh and among them, 200 are located in Hazaribagh near the bank of Buriganga river, covering an area of 25ha and the rest of them are located many other districts [8]. The tanneries in Hazaribagh are posing a grave threat to the environment. During tanning operation, many chemicals such as NaCl, H_2SO_4, $Ca(OH)_2$, $Cr(SO_4)_3$, dyes are extensively used in which the leather takes only 50% - 60% of the applied chemical and rest of them discharge as effluents [9]. Most of the tanneries in Hazaribagh do not have effluent treatment facilities. These tanneries dispose of their untreated effluent directly to open drain which finally connect to Buriganga River and discharge about 12,000 $m^3 \cdot d^{-1}$ untreated effluents [10]. Some researchers demonstrated that during peak period about 14,910 $m^3 \cdot d^{-1}$, off-peak period about 9100 $m^3 \cdot d^{-1}$ effluent discharge from tanneries [8]. Consequently, distribution of heavy metals has taken from the untreated effluent to rivers, soil, water and crops [11].

Heavy metal in soils may go into the body directly through ingestion, skin contact etc. Heavy Metals in agricultural soils are absorbed and accumulated by crops. Ingesting heavy metals by soil-crop system is a major way of damaging human health [12].

The aim of this research was the assessment of heavy metals (Cr, Pd, Zn, Cd) in tannery effluent-affected land and compared the results with the concentration of heavy metals in unaffected soil.

2. Materials and Methods

2.1. Study Area

The soil samples (**Figure 1**) were collected from five different points of different sites in the vicinity of Hazaribagh tannery on the bank of the river Buriganga and Karigang agricultural area, Dhaka. Hazaribagh is a densely populated area of Dhaka city where about more than 200 registered tanneries discharge their huge amount of untreated solid and liquid waste directly into the Buriganga River. Karigang is also located in Dhaka where there are no such harmful industries near this area. So this area was chosen as a study area to compare the level of heavy metals with Hazaribagh area. Five different points in the tannery vicinity were marked as Point-1 which is the dumping point itself, and Point-2, Point-3, Point-4, Point-5 which are located at 250 m, 500 m, 1000 m and 2000 m distance respectively from the dumping point. Karigang agricultural area was marked as Point-6.

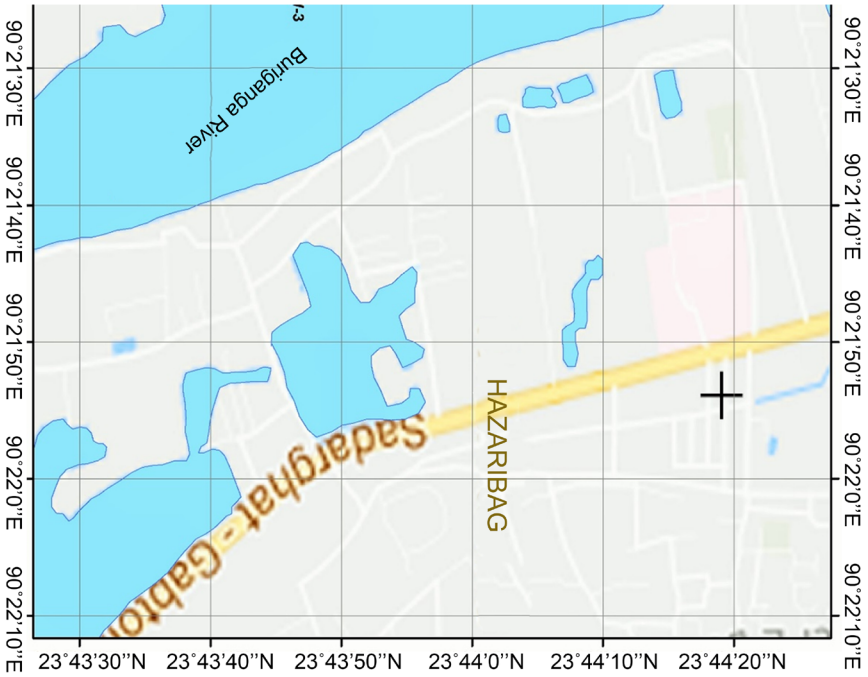

Figure 1. A real view of the sampling area with marked sample point.

2.2. Sampling

In the month of April 2016, the soil samples were collected from the sampling sites with the help of a stainless steel Ekman Grab Sampler and transferred to a pre-cleaned plastic container. The samples were collected from three different layers of different depth at each point. The first layer is the surface layer (0 - 15 cm) and the others are 15 - 30 cm and 30 - 45 cm below from the surface level. After collecting the soil samples were washed, weighed and dried in an oven at 105˚C until acquiring constant weight. After cooling in a desiccator all the samples were grounded and thoroughly homogenized by agate mortar and pastel. The powdered soil samples were finally stored in pre-cleaned dry glass bottles and preserved in a desiccator for further analysis.

2.3. Digestion of Soil Sample

For the quantitative analysis of Cr, Pb, Cd and Zn soil samples were digested following ISO 11466 thermal heating method. At the first 3 g of each grounded samples were weighed and taken into beakers. Then the weighed samples were moistened with 1 ml distilled water. After that 21 ml, HCl and 7 ml HNO_3 were added drop by drop and then 15 ml of dilute HNO_3 (0.5 M) was added to each beaker and the samples were allowed to stand at room temperature. Each mixture was then refluxed on a heating plate for two hours and was filtered through filter paper (Whitman no 40) after cooling and kept at room temperature for further determination

2.4. Total Heavy Metals Concentration Measurement

After digestion, the samples were taken to the Centre for Advanced Research and

Science (CARS), the University of Dhaka for the subsequent analysis for metals Cr, Pb, Cd and Zn with a Perkin-Elmer atomic absorption spectrometer (Model-An Analyst 800, USA). Cd (Wavelength 228.8 nm), Cr (Wavelength 357.9 nm), Pb (Wavelength 283.3 nm), and Zn (Wavelength 213.9 nm) specific hollow cathode lamp was used to analyze the samples. The instrument has a minimum detection limit of 0.01 mg/L for Cd, 0.10 mg/L for Cr, 0.20 mg/L for Pb and 0.01 mg/L for Zn in the flame method. Samples were aspirated through nebulizer and absorbance was measured with a blank as reference. Calibration curve was obtained using standard samples (containing 0.2, 0.4, 0.6, 0.8 and 1.0 mg/L for Cd; 0.2, 0.5, 1.0, 2.0 and 4.0 mg/L for Cr; 0.5, 1.0, 2.0, 4.0 and 8.0 mg/L for Pb and 0.2, 0.4, 0.6, 0.8, 1.0 and 2.0 mg/L for Zn). The correlation coefficient was found for Cd 0.999, Cr 0.994, Pb 0.999 and for Zn 0.999.

3. Result and Discussion

From the investigation, it was found that Cr concentrations of soils in the vicinity of Hazaribagh tannery are rather high and in the most cases, these exceeded the maximum permissible limits. The result recorded highest values of heavy metal content at the dumping point and lowest values in the soil of Agricultural area. The heavy metal content was found most abundantly in the surface layers and the values decreased with the increase of depth and distance except a few exceptions.

According to the (Figure 2) it is noticed that in the case of Tannery vicinity soil, Cr content was found most abundant (561.71 mg/kg) in the surface layer of point 1 (dumping point) and least abundant (31.23 mg/kg) in 30 - 45 cm depth of point 5. In surface layer, values for Cr content ranged from 561.71 to 170.83 mg/kg, in 15 - 30 cm depth, it ranged from 220.89 to 34.2 mg/kg and in 30 - 45 cm depth the range was from 90.09 to 28.72 mg/kg (Table 1). While in the case of Agricultural area soil, Cr content in surface layer, 15 - 30 cm and 30 - 45 cm depth is found 27.867, 26.0416 and 24.54166 mg/kg respectively (Table 2).

From the result, it is evident that Cr content in the Tannery vicinity of similar layer decreased with the increase of distant from the dumping point and also with the increase of depth at each point except few exceptions. In the surface layer, the rate of decreasing with distance was much higher than two other layers. In comparison with the

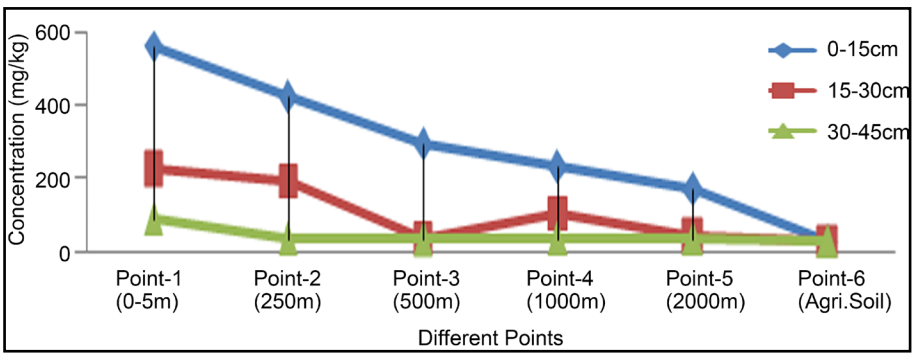

Figure 2. Concentration of Cr in Soil samples of different distance and depth.

Table 1. Heavy metal content in tannery area soil.

Sampling Points	Depth of layers from the surface level (cm)	Cr (mg/kg)	Pb (mg/kg)	Cd (mg/kg)	Zn (mg/kg)
Point-1	0 - 15	561.71	70.58	2.25	158.23
	15 - 30	220.89	42.95	1.28	118.52
	30 - 45	90.09	26.61	0.88	98.73
Point-2	0 - 15	423.43	65.21	2.01	137.31
	15 - 30	191.73	38.90	1.26	107.65
	30 - 45	33.25	26.29	0.98	101.48
Point-3	0 - 15	290.67	31.09	1.12	73.5
	15 - 30	34.20	26.31	0.898	121.33
	30 - 45	28.72	26.50	0.7660	107.33
Point-4	0 - 15	230.15	30.73	1.01	107.23
	15 - 30	98.88	27.29	0.97	115.66
	30 - 45	33.33	24.37	0.81	103.15
Point-5	0 - 15	170.83	27.97	0.93	123.72
	15 - 30	35.63	26.44	0.80	129.25
	30 - 45	31.23	28.29	0.71	115.88
Maximum permissible limit recommended by EC (1986) [13]		50 mg/kg	300 mg/kg	3 mg/kg	_

Table 2. Heavy metal content in agricultural area soil.

Sampling Points	Depth of layers from the surface level (cm)	Cr (mg/kg)	Pb (mg/kg)	Cd (mg/kg)	Zn (mg/kg)
Soil of agricultural area	0 - 15	27.867	23.60	0.64	28
	15 - 30	26.0416	25.76	0.82	134.167
	30 - 45	24.54166	22.49	1.30	80.5
Maximum permissible limit recommended by EC (1986) [13]		50 mg/kg	300 mg/kg	3 mg/kg	_

Agricultural area soil, in every case Cr concentration in the tannery vicinity soil is found higher than that of the agricultural area. In Tannery vicinity, in the surface layer of each point, the value of Cr content exceeded the permissible limit that is 50 mg/kg recommended by EC (1986) [13]. But Agricultural Area soil did not exceed that limit.

The high content of Cr in the surface layer of tannery vicinity soil may be due to pollution from various industrial wastes such as Cr pigment and untreated tannery wastes, electroplating sludge, leather manufacturing wastes, and municipal sewage sludge etc. [7].

Cr contamination in the soils could also be due to waste consisting of Pb-Cr batteries, colored polythene bags, discarded plastic materials and empty paint containers [14].

Cr is toxic and carcinogenic and long-term exposure to Cr can cause liver and kidney damage [15].

Cr can also alter genetic materials and cause cancer. Other health problems that area used by Cr are Skin rashes, Upset stomachs, and ulcers, Respiratory problems, weakened immune systems, Alteration of genetic material, Lung cancer and Death [16].

Pb is the second prevalent element in this study. In the case of Tannery vicinity, Pb content was found most abundant (70.58 mg/kg) in the surface layer of point 1 (dumping point) and least abundant (24.37 mg/kg) in 30 - 45 cm depth of point 4. In surface layer, values for Pb content ranged from 70.58 to 27.97 mg/kg, in 15 - 30 cm depth, it ranged from 42.95 to 26.31 mg/kg and in 30 - 45 cm depth the range was from 28.29 to 24.37 mg/kg. While in the case of Agricultural area soil, Pb content in the surface layer, 15 - 30 cm and 30 - 45 cm depth was found 27.87, 26.04 and 2 4.54 mg/kg respectively (**Figure 3**).

Also for Pb content in the Tannery vicinity soil of similar layer, the values decreased with the increase of distance from the dumping point and also with the increase of depth at each point except few exceptions. In the surface layer, the rate of decreasing with distance was much higher than two other layers. While it is compared with the Agricultural area soil, in every layer Pd concentration in the tannery vicinity soil is found higher than that of the agricultural area except 30 - 45 cm depth of point 4 which has value (24.37 mg/kg) higher than Agricultural Area soil (24.54 mg/kg) of the same layer. Neither Tannery vicinity soil nor Agricultural Area soil at any layer in this study exceeded the permissible limit for Pb that is 300 mg/kg recommended by EC (1986) [13].

The high content of Pb content near the dumping point may be due to the discharge of Pb-containing untreated tannery effluent.

The presence of Pb in soil may also due to the release of Pb by automobiles and other industries in the area. This Pb can be deposited on soil and water, thus reaching humans via the food chain [17].

Pb in the soils could also be from automobile exhaust fumes as well as dry cell batteries, sewage effluents, runoff of wastes and atmospheric depositions [18].

Pb exposure has effects like disruption of the biosynthesis of hemoglobin and anemia, increase in blood pressure, Kidney damage, Miscarriages and subtle abortions,

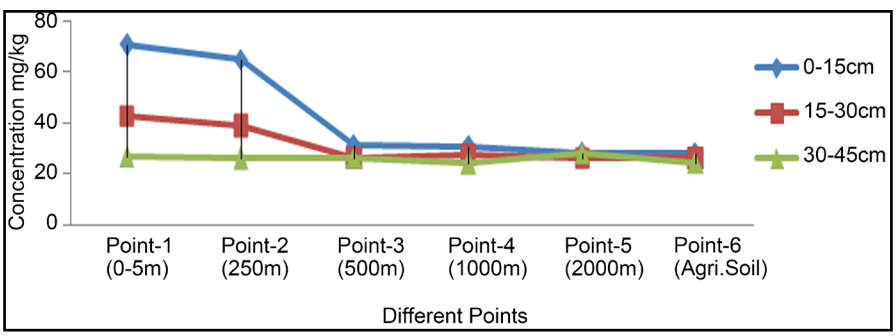

Figure 3. Concentration of Pb in soil samples of different distance and depth.

Disruption of nervous methods, Brain injury, Declined fertility of men through sperm harm, Reduced education abilities of children, Behavioral disruptions of children, such as aggression, imprudent behavior and hyperactivity [16].

When Cd was taken into consideration, the content was found most abundant (2.25 mg/kg) in the surface layer of point 1 (dumping point) and least abundant (0.71 mg/kg) in 30 - 45 cm depth of point 5 in case of Tannery vicinity. In surface layer, values for Cd content ranged from 2.25 to 0.93 mg/kg, in 15 - 30 cm depth it ranged from 1.28 to 0.8 mg/kg and in 30 - 45 cm depth the range was from 0.98 to 0.71 mg/kg. While in the case of Agricultural area soil, Cd content in surface layer, 15 - 30 cm and 30 - 45 cm depth is found 0.64, 0.82 and 1.3 mg/kg respectively (**Figure 4**).

At Point-3, Point-4 and Point-5, the concentration of Cd was more or less similar. In surface layer and 25 - 30 cm depth of tannery vicinity soil concentration of Cd decreased with the increase of distance from the dumping point. The result was not similar when 30 - 45 cm depth was considered as such regularity in the values was not found there. Like Cr and Pb, the concentration of Cd also decreased with the increase of depth at each point in the tannery vicinity. But this was not the case for Agricultural area soil as the result was opposite there.

For surface layer, Cd content in each point of the Tannery vicinity was found higher than that of Agricultural area. Same was the case for 15 - 30 cm depth except in Point-5 that has a value (0.80 mg/kg) than that of Agricultural area soil (0.82 mg/kg). But unlike Cr and Pb, Cd content in 30 - 45 cm depth of Agricultural area soil was found higher than that of each point in the Tannery vicinity soil.

At any layer of any point in both Tannery vicinity soil and Agricultural area soil, Cd content did not exceed the maximum permissible limit (3.0 mg/kg) recommended by EC (1986) [13].

The Cd is brought to soils with the application of phosphoric fertilizers. Application of a lot of phosphate fertilizers and compound fertilizers increases Cd in soils constantly [4].

Other sources of Cd could be paint, plastics, ceramics and glass manufacture industry [7].

The Cd is highly poisonous and even at very little concentrations, chronic exposure to this metal can prime to anemia, insomnia, cardiovascular diseases as well as hypertension [19].

Similarly for Zn, In the case of Tannery vicinity, the metal content was found most abundant (158.23 mg/kg) in the surface layer of point 1 (dumping point) and least abundant (73.5 mg/kg) in the surface layer of point 3. In surface layer, values of Zn content varied from 158.23 to 73.5 mg/kg, in 15 - 30 cm depth it varied from 129.25 to 107.65 mg/kg and in 30 - 45 cm depth the range was from 115.88 to 98.73 mg/kg. While in the case of Agricultural area soil, Zn content in the surface layer, 15 - 30 cm and 30 - 45 cm depth was found 28.0, 134.17 and 80.5 mg/kg respectively (**Figure 5**).

Like Cr and Pb, Zn does not show regularity in results. In point 4 and Point 5, no significant variations in values were noticed. In Tannery vicinity soil, Zn records lowest value (73.5 mg/kg) at Point 3 in the case of the surface layer and the value

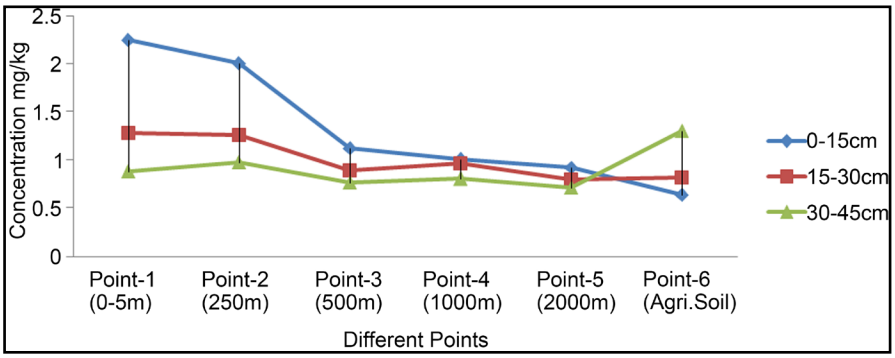

Figure 4. Concentration of Cd in Soil samples of different distance and depth.

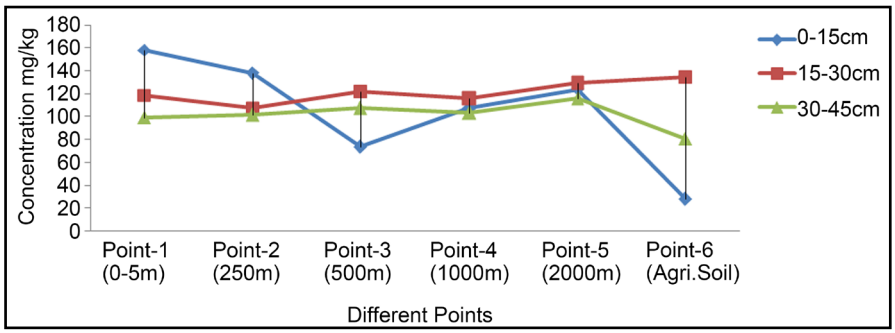

Figure 5. Concentration of Zn in Soil samples of different distance and Depth.

increases towards the dumping point as well as away from the dumping point. Whereas in 15 - 30 cm and 30 - 45 cm depth values of Cr content are irregular.

It is also noticed that in the case of the surface layer and 30 - 45 cm depth, Agricultural Area soil has lower Zn content Tannery vicinity soil at each point. But the result is opposite for 15 - 30 cm depth as Agricultural Area soil shows higher Zn content than that of Tannery vicinity soil.

The main sources of Zn contamination are industries as well as the use of liquid manure, composted materials and agrochemicals like fertilizers as well as pesticides in agriculture [6].

Zn is an essential trace element for the growth of humans, animals and plants but is potentially dangerous for the biosphere when present in high concentrations [18]. High doses of Zn show poisonous and carcinogenic effects and consequence in neurologic as well as hematological complications, hypertension, and kidney and liver function disorders [20].

4. Conclusion

Heavy Metal pollution in soil has now become a major concern. In a developing country like Bangladesh, the situation is worst due to lacking of technological advancement. From this study, it is clearly the evident that the soil in the tannery vicinity on the bank of river Buriganga is highly contaminated with Cr. This is due to being exposed to a huge amount of untreated tannery effluents and sludge from the nearby Hazaribagh

Tannery industries every day. A significant amount of Pb, Cd and Zn has also been found in the soil of this area. These heavy metals are deposited and accumulated in soil and uptake by vegetables and other foodstuffs grown in this area which ultimately get into human body through the food chain. This results in various adverse effect on human and animal health as Cr, Pb and Cd are highly toxic and carcinogenic in nature. So authority concerned should take immediate actions in this matter to prevent such pollution by heavy metals.

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