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Heavy Metals Risk Assessment in the Vicinity of Battery Recycling Factory of Periurban Area in Dhaka, Bangladesh

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Abstract

The environment and human health are threatened by the effects of heavy metal contamination mostly on the soil profile and vegetation cover close to battery recycling facilities. The aim of the present study was to determine the extent of heavy metal contamination in the environment at the root level in the vicinity of battery recycling workshops to understand the soil and plants' heavy metal toxicity level. Lead concentrations differ substantially between places. It is challenging to pinpoint the particular aspects that might have attributed to this large variety because the factories are informally controlled and do not adhere to any sort of regulation. Soil and plant samples were collected and analyzed using Atomic Absorption Spectrometry (AAS). The leaf sample contained the highest amount of lead (0.3148 ppm), while the fruit sample contained the least amount (0.027 ppm). Highest concentration of cadmium was found for leaf in sample 02 (0.0156 ppm) and lowest concentration was found in the fruit sample (0.006 ppm). Copper levels in the leaf samples ranged from 0.9096 ppm at their highest to 0.5137 ppm at their lowest. The copper concentration in the root samples ranged from 0.1791 ppm to 0.2538 ppm. Nickel levels in the leaf samples ranged from 0.0053 ppm at the lowest to 0.0298 ppm at the highest. Maximum and minimum nickel concentrations in the soil samples were 0.0626 ppm and 0.0114 ppm, respectively. The identified heavy metals were concentrated in various plant sections as the following decreasing order: Root > Leaf > Fruit. The status of heavy metal contaminations determined from the study will help the government to regulate the informal recycling activities across the country. The magnitude of consequences at the ground level should be considered by policymakers in order to take actions to reduce exposure by stepping up monitoring efforts.

Keywords: *heavy metal, battery recycling, AAS, plant metals, soil metal accumulation*

Introduction

Global urbanization, industrialization and technological advancement have rapidly increased the demands and consumption of electronics. Battery production and consumption have also been proliferated, leading to huge amount of e-waste. The demand of lead acid battery is high due to cheaper price but it comprises about 85% utilization of lead worldwide (Akber et al., 2019). Besides this, due to recyclable properties, almost all the lead acid batteries (LAB) are sent for recycling in developing countries because of its lower cost which can have alarming impacts on both animal health and environment. In Bangladesh, the use of LAB is increasing day by day after the introduction of easy-bike and 97% of them are produced mostly by recycling discarded materials, and batteries (Ahmad et al., 2014). Bangladesh produces about 2.98 tons of e-waste annually, of which about 20–30% is recycled and the remainder is just discharged into the environment without any treatment (Alam and Bahauddind, 2015).

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Recycled batteries are one of the main anthropogenic sources of lead (Pb) (Chen et al., 2012). Lead mining, smelting and battery treatment are the major sources of lead (Pb) in the environment. Consequently, it appears on the North American National Priority List (Rampley and Ogden, 1998) as well as the European Black List II (EEC, 1976) (Palacios et al., 2002). Islam et al. (2015) evaluated the presence of six toxic metals (Cr, Ni, Cu, As, Cd, and Pb) in diverse urban land-use soils where they showed that tannery waste, electronic waste and metal workshops were significantly contaminated with these metals (Islam et al., 2015). Small battery repair shops are also responsible for the high lead-poisoning risk in adjacent inhabitants (Matte et al., 1989). There are many point and non-point sources of heavy metals responsible for soil contamination. Major point-sources include metalliferous mining, smelting and industrial activities which results in the atmospheric deposition of heavy metals in nearby topsoil and vegetation cover (Naser et al., 2009). Due to cheap labor and lax environmental law enforcement, developed nations are shipping millions of tons of electronic waste to developing regions (India, China, Bangladesh, and Pakistan) under the pretense of recycling (Agoramoorthy, 2006). In these developing nations' small workshops, e-waste is processed using extremely active methods like manual dismantling, digestion in strong acids, and open burning (Pradhan et al., 2014). In underdeveloped and low-income nations globally, batteries are recycled and reconditioned to a degree of about 97% (Van Der Kujip et al., 2013). Ultimately, Informal recycling of e-waste are mainly responsible for this growing heavy metal contamination, especially in the developing countries like Bangladesh.

Heavy metals are mainly toxic, non-degradable and bioaccumulative and that's why they are serious matter of concern for health as well as environment (Liu et al., 2014). Excess amount of heavy metals can change the properties of soil and have impacts on soil biology and functions which can ultimately impose potential risk and hazardous impacts on environment as well as health (Islam et al., 2015). Lead (Pb) toxicity is one of the main global burden of diseases in the developing regions where informal recycling can led to higher exposure of lead (Pb) via inhalation, ingestion, or dermal contact (Haefliger et al., 2009). These metals may enter into the food chain from the soil and accumulated in the plant and animals which have detrimental effects on health. Although heavy metal accumulation depends on plant species types and soil properties (Naser et al., 2009), they may transfer through food chain and result in biomagnification. Groundwater can be contaminated by an excessive amount of these priority pollutants. Heavy metal contamination in soil and vegetation (aquatic macrophytes, grass, rice, and arum) from ceramic, textile dying, tannery and sulphuric acid producing industries of Bangladesh were collected and assessed by Kashem and Singh (1998) and showed that heavy metals were mainly released by industrial solid wastes, effluents and emission of gas in urban and semi urban area of Dhaka, Bangladesh (Kashem and Singh, 1998). Majority of metals have no useful physiological functions in animal health and pose serious toxicity at a higher rate such as Cd may led to kidney, bone and pulmonary damage and Pd can affect the nervous system by mimicking calcium ions, blood system, kidneys and can cause gastrointestinal disorder (Liu et al., 2014; Van Der Kujip et al., 2013). Even a significant exposure of these metals may lead to death. Recycling of used lead acid batteries (ULAB) may release Arsenic which can have health impacts like skin lesions, lung, liver, bladder, skin and renal cancer, gangrene in leg etc. (Akber et al., 2019; Anawar et al., 2002; Islam et al., 2018).

Investigating the impact of heavy metal contamination on the soil, water, and plants close to battery recycling facilities at the root level is probably inevitable to understand the extent of exposure to these metals in the environment and predict the future health aspects and pollution scenario which will also help the government to take actions to protect the environment and animal health for a sustainable and safe future.

This study aimed to investigate the extent of heavy metal contamination in the environment at the root level near battery recycling workshops to understand the soil and plant heavy metal toxicity levels. More specifically, to assess the heavy metal contamination status near the recycling plant.

Methodology

Study Area and Sampling

Savar is one of the important peri-urban areas in Bangladesh, located around 24 km North-west direction from the capital city, Dhaka. Tannery Industries have recently relocated from Hazaribagh to Hemayetpur of Savar district. Some battery recycling factories are located at Hemayetpur of Tetuljhora union (Latitude- 23.7986° N, Longitude- 90.2680° E). This industrial zone is selected for study area due to the high level of pollutants released into the

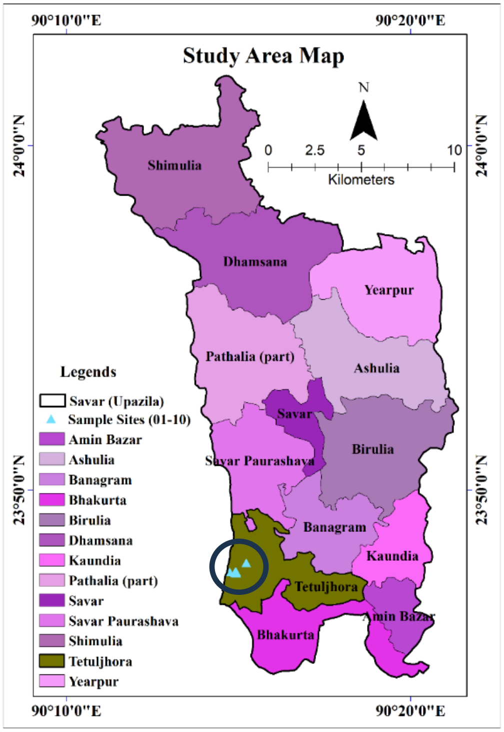

Figure 1: Study area and sampling locations

adjacent environment without any treatment after battery recycling activities. Karnatali River bounds Hemayetpur in the North, Buri River in the South and Dhaleshwari River in the west. One kilometer around the battery recycling plants was set as buffer zone. Plants and soil samples were collected from the 500 meters around the factory inside the buffer zone. Plant samples were separated in to root, leaf and fruit part. The sample location map produced using ArcGIS 10.7 software is demonstrated in Figure 1.

Materials

Laboratory Apparatus and Equipment

The laboratory apparatus for this study included Beakers, Conical Flasks, Measuring cylinders, Pipette, Reagent bottles, Glass rod, Crucible (50ml, 30ml), Funnels, Volumetric Flasks, Droppers, Ring stand, Rings and Clamps, Forceps, Bunsen burner, Whatman no. 42 filter paper, Gloves, Mask, Mortar and Pestle, Sample pot, Deionized water, Plastic bottle, Aluminum paper, Vortex mixer, etc. Moreover, the laboratory equipment included Weight Balance (FAWAGSA, JA2003); Oven (GALLENKAMP, Size 1); Atomic Absorption Spectrometry-7000 SHIMADZU (Japan); Fume hood ACCT-FH.O1; Hot plate with magnetic stirrer (Model –JSHS-180, South Korea); Multi parameter portable meter (Multi 3510 IDS).

Preparation of Reagents

Nitric acid was used as a reagent in this study. Three hundred ml of 1M nitric acid (HNO_3) solution was made by using the normality equation $V_1S_1=V_2S_2$.

Reference Standard for Heavy Metals

The reference standards for heavy metals detected in this study are given in Table 1.

Table 1. *Reference Standard for Heavy Metals*

Heavy Metal	Reference Standard
Lead (Pb)	Kanto Chemical CO.INC
Cadmium (Cd)	Kanto Chemical CO.INC
Copper (Cu)	Kanto Chemical CO.INC
Nickel (Ni)	Kanto Chemical CO.INC

Chemicals

The chemicals required in this study are as follows: HNO_3 (65% concentration, Damstadt, Germany), $HClO_4$ (70% concentration, Merk specialties Private limited, Mumbai), HCl (37% concentration, Damstadt, Germany).

Sample Collection

Collection of Soil Samples: One kilogram of soil samples were taken from ten locations along the Battery factory's core. To prevent contamination, samples were kept in sealed polythene bags. The samples had the appropriate labels. The samples were brought as rapidly as possible to the lab.

Collection of Plant Samples: Plant samples taken from the vicinity of the battery recycling factory was stored in polythene bags with proper labeling. The plant parts were dried at room temperature to remove soil moisture. Then the samples were transferred to the laboratory.

Sample Preparation Procedure

Preparation and Digestion of Soil Samples: After 48 hours of oven drying at 95 ° C, soil samples were finely pulverized using a pestle and mortar. Subsequently, 10g of powdered soil samples were collected and placed in a conical flask with 10ml of 1M HNO3. The solution was then given 20 ml of distilled water, and kept at rest for < 24 hours. Distilled water was added by weighting out 100 g after 24 hours. Whatman No. 42 filter paper was used to centrifuge and filter the samples. Finally, Atomic Absorption Spectrometry (AAS) was used to examine filters.

Preparation and Digestion of Plant Samples: Samples were initially cleaned with distilled water after collection. The components were then segregated (leaf, fruit and root). All cleaned samples were properly air dried before being divided into little pieces and dried for 24 hours at 950°C until they were completely dry. Dried samples were converted into powder form using a mortar and pestle for grinding and homogenization. The samples that had been pulverized were then kept dry by being stored in airtight containers. 1g of plant samples (root/ fruit/ leaf) were put into a crucible, and 10ml of acid with a purity level of 65% HNO3 were then added. After that, the combination was digested at 950°C until the solution started to semi-dry. Again, 10 ml of nitric acid (HNO3), 1 ml of hydrochloric acid (HCl), and 4 ml of perchloric acid (HClO4) were added, and the mixture was again kept on a hotplate for an hour. The samples were semi-dried, cooled, and filtered using Whatman no. 42 filter paper before being subjected to AAS analysis.

Heavy Metal Detection in Samples (Soil and Plant)

The identification of heavy metals was done using an Atomic Absorption Spectrometry (AAS)-7000 SHIMADZU (manufactured in Japan) instrument. A light beam from a lamp whose cathode is composed of the component being identified is transmitted through the flame to provide element-specific wavelengths. A tool like a photon multiplier may measure how much of the light's intensity is reduced as a result of the analyte's absorption, and this can be used to determine how much of the component is contained in the sample (Akteruzzaman et al., 2013). A highly popular method for finding metals in environment is atomic absorption. AAS is an analytical method for calculating elemental concentrations. Atomic Absorption Spectroscopy (AAS) is an analytical method for calculating elemental concentrations. The amount of electromagnetic radiation absorption by the ground state atoms of an element to transfer into a higher energy levels are used to calculate the analytical concentration of that element.

Calculation of Samples' Metal Amount and Statistical Analysis

The samples' metal content can be defined by following Equation 1:

$$Metal\ content\ of\ sample\ (in\ ppm)\ = \frac{Concentration\ of\ metal\ determined\ by\ AAS \times 1000}{10 \times sample\ weight} \qquad (1)$$

Concentration of heavy metals was analyzed using Microsoft Excel (2013).

Results and Discussion

Analysis of Heavy Metal Concentration

Plants and soil samples were collected from ten locations inside the 500 meters buffer zone around the factory. Plant samples were separated into root, leaf and fruit parts. Figure 2 displays the fruit samples randomly collected from one location among the sample collection sites.

Figure 2: Fruit samples

Concentration of Lead (ppm): Lead concentrations differed significantly between places. It was challenging to pinpoint the specific elements that might have attributed to this large variety because the factories are informally run and do not adhere to any type of rules. The quantity of lead in the soil and plant (leaf, root, and fruit) specimens that were collected is shown in Figure 4. The leaf sample contained the highest amount of lead (0.3148 ppm), while the fruit sample contained the least amount (0.027 ppm).

Concentration of Cadmium (ppm): Concentration of cadmium in the collected samples is shown in the Figure 5. The concentrations of cadmium were highly variable across the sites. Highest concentration was found for leaf in sample 02 (0.0156 ppm) and lowest concentration was found in the fruit sample (0.006 ppm).

Concentration of Copper (ppm): Concentration of copper of the collected samples is shown in the Figure 6. In the leaf, maximum concentration of copper was 0.9096 ppm and minimum was 0.5137 ppm. In the root sample, maximum concentration of copper was 0.2538 ppm and minimum was 0.1791 ppm.

Concentration of Nickel (ppm): Concentration of nickel of the collected samples is shown in the Figure 7. In the leaf, maximum concentration of nickel was 0.0298 ppm and minimum was 0.0053 ppm. In the soil sample, maximum concentration of nickel was 0.0626 ppm and minimum was 0.0114 ppm.

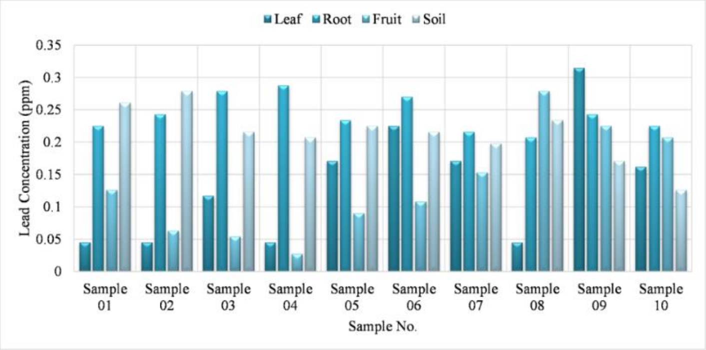

Figure 4: Concentration of Lead (Pb) in collected samples

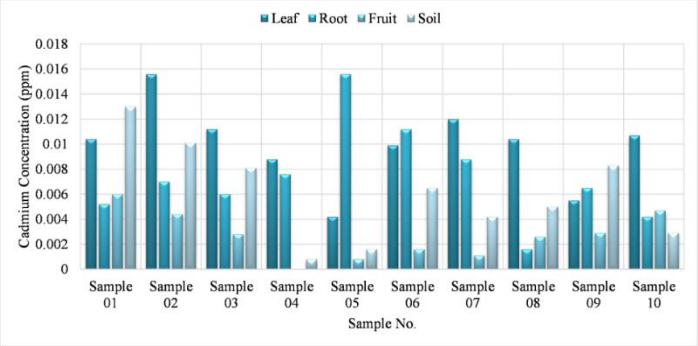

Figure 5: Concentration of Cadmium (Cd) in collected samples

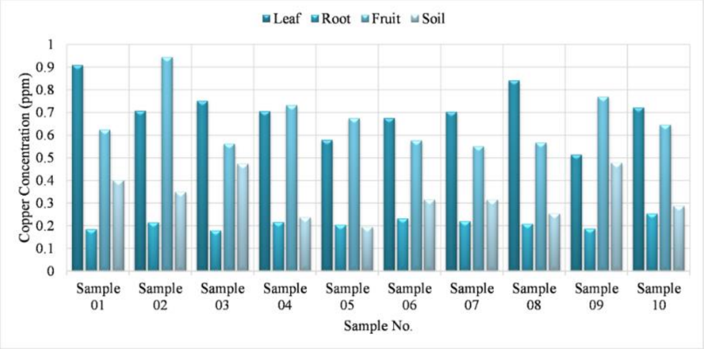

Figure 6: Concentration of Copper (Cu) in collected samples

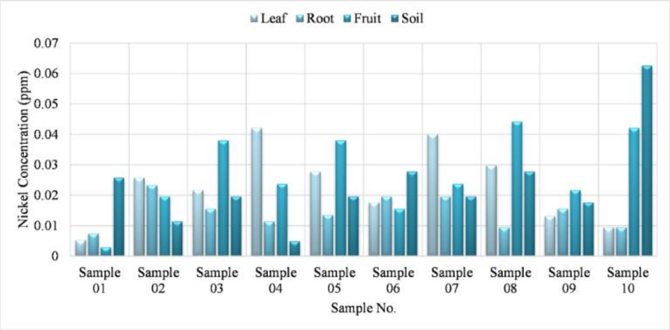

Figure 7: Concentration of Nickel (Ni) in collected samples

The maximum, minimum, and average value of heavy metals (Pb, Cd, Cu, Ni) in the collected soil and plant (leaf, root, and fruit) specimens nearby the battery recycling factories are given in Table 2. The observed heavy metal concentrations in various plant sections decreased in the following order: Root > Leaf > Fruit.

Table 2. *Maximum, Mean, and Minimum Value of Heavy Metals in Soil and Plant Samples*

		Leaf	Root	Fruit	Soil
Lead (Pb)	**Maximum**	0.3148	0.2878	0.2789	0.2789
	Mean	0.13403 ± 0.01	0.24289 ± 0.02	0.13315 ± 0.01	0.21321 ± 0.02
	Minimum	0.045	0.2069	0.027	0.126
Cadmium (Cd)	**Maximum**	0.0156	0.0156	0.006	0.013
	Mean	0.00987 ± 0.01	0.00737 ± 0.01	0.00269 ± 0.01	0.00605 ± 0.01
	Minimum	0.0055	0.0042	BDL	0.0008
Copper (Cu)	**Maximum**	0.9096	0.2538	0.9442	0.478
	Mean	0.71086 ± 0.02	0.20997 ± 0.01	0.66447 ± 0.01	0.33065 ± 0.02
	Minimum	0.5137	0.1791	0.5505	0.1947
Nickel (Ni)	**Maximum**	0.0298	0.0233	0.0442	0.0626
	Mean	0.02327 ± 0.02	0.0098 ± 0.02	0.02694 ± 0.02	0.02269 ± 0.02
	Minimum	0.0053	0.0074	0.0029	0.0114

Conclusion

Lead concentrations differed significantly between places. It is quite challenging to pinpoint the specific elements that might have attributed to this large variety because the factories are informally run and do not adhere to any regulation. The leaf sample contained the highest amount of lead (0.3148 ppm), while the fruit sample contained the least amount (0.027 ppm). Lead concentrations differ significantly among locations. The highest concentration was found for the leaf in sample 02 (0.0156 ppm), and the lowest concentration was found in the fruit sample (0.006 ppm). In the leaf, the maximum concentration of copper was 0.9096 ppm, and the minimum was 0.0053 ppm. In the root sample, the maximum concentration of copper was 0.2538 ppm, and the minimum was 0.1791 ppm. The leaf's maximum nickel concentration was 0.0298 ppm, and the minimum was 0.5137 ppm. In the soil sample, the maximum concentration of nickel was 0.0626 ppm, and the minimum was 0.0114 ppm. Heavy metal concentrations in various plant sections decreased in the following order: Root > Leaf > Fruit. The status of heavy metal contaminations determined from the study will help the government regulate informal recycling activities nationwide. The policymakers should consider the extent of impacts at the root level, which will help to minimize the exposure by increasing monitoring activities.

Acknowledgements

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