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A Study of Lead (Pb) Pollution Near Lead-Acid Battery Recycling Industries in Khulna

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ABSTRACT
Lead (Pb) toxicity is a great threat to humankind and the environment. As Pb-related activities such as Pb-acid battery recycling have grown in popularity, Pb toxicity has been swiftly disseminated across Bangladesh. The primary objective of this research is to examine Pb contamination in the soil of the Pb smelting facilities in the Khulna region. A variety of soil samples were collected (near Pb acid battery recycling industries) and analyzed to determine their Pb content. Dry ashing, extraction, digestion, and atomic absorption spectroscopy (AAS) were used to analyze the soil samples. Pb was detected in varying concentrations at different distances from the Pb acid battery recycling industry's location. The soil samples were found to contain excessive amounts of Pb compared to the background concentration. Pb concentrations were also found to vary according to distance from the Pb melting furnace. It recorded the highest concentration, 292.13 ppm, which is approximately 15 times higher than the background level. This high level of pollution could adversely affect human health, animals, plants, crops, etc. As a result of this study, environmental restorationists and local policymakers can learn more about Pb pollution in Khulna.

Keywords: Pb, Pb toxicity, Pb-acid battery, Battery recycling, Soil pollution.

1. Introduction

Pb (from the Latin plumbum) is a chemical element with the symbol Pb and the atomic number 82. The periodic table's Group 14 (IV A) contains this blue-white lustrous metal. At Çatalhöyük, metallic Pb globules made in 6400 BC were found (presently in the Republic of Turkey). Its melting point is 600.61 K (327.46 °C), its boiling point is 2022 K (1749 °C), and its density is 11.34 g/cm^3.

Pb is released into the environment throughout the mining, smelting, and refining processes during the manufacturing and consumption of Pb-based goods. Lots of Pb is being released into the environment. And this results in the pollution of Pb which is alarming for our living world. Because of its widespread use in industry and the high toxicity of Pb, Pb pollution has drawn the most attention of all the heavy metals [1-3].

Pb may enter the body through a variety of routes. A buildup of even a tiny amount of Pb can lead to the illness known as Pb poisoning (plumbism) because of its inability to degrade in the environment [4] and its poor removal rate [5]. This dangerous occupational and environmental illness affects millions of adults and children worldwide. Pb poisoning is most commonly brought on by the use of tainted food or water. But Pb poisoning can also be caused by inadvertent intake of contaminated soil, dust, or Pb-based paint. One theory is that Pb, due to its rapid absorption into the bloodstream, has harmful effects on several organ systems, including the central nervous system, cardiovascular system, kidneys, and immune system [6]. One of the most common causes of Pb poisoning in the household is through water pipes [7].

Bangladesh is a developing country with a large population. Heavy metal and metalloid pollution in Bangladesh are currently one of the major concerns to the country's residents due to its unregulated industrialization. In recent years, the number of cases of heavy metal and metalloid poisoning in Bangladesh has increased [8,9]. Due to rapid growth in the industrial and urban sectors, as well as a variety of human activities, Pb has been widely dispersed throughout the environment. Rivers surrounding different divisions are heavily polluted by these heavy metals.

Dhaka, Gazipur, Khulna, Chattogram, Rajshahi, and Bogura all have excessive heavy metals and metalloids in the soil near their industrial regions [10]. Heavy metal and metalloid contamination in water and soil is also caused by large traffic loads [11]. Heavy metals and metalloids in high quantities have been identified in agricultural products grown on polluted soil, and this poses a serious threat to human health [12]. Bangladesh's vast heavy metal and metalloid contamination has garnered international attention, and there have been several outstanding assessments of individual metals or environmental media [13,14].

The production of Pb-acid batteries in Bangladesh has caused most of the Pb pollution in present times. It has been increasing at an alarming rate recently. Over 88% of Pb mining is used to make Pb-acid batteries (LABs) [15]. LABs are widely used in automobiles and households for load shading backup [15]. Because Pb is recycled from LABs, workers in the recycling process are exposed to a significant amount of Pb [16]. Due to LAB recycling's widespread use in low and middle-income countries like Bangladesh, prolonged and massive Pb emissions pose a serious threat to environmental and human health, especially in nations with a low level of economic development [17].

In Bangladesh, 97% of LAB are manufactured from scrap metal and discarded batteries [18]. Batteries were said to have grown substantially in Bangladesh's battery

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recycling sector since the introduction of LAB-operated electric 3-wheelers in 2009. There are now 147 battery recycling stations functioning across the six divisions of the nation [19]. More than 300 Pb-contaminated sites have been reported in Bangladesh by Pure Earth Bangladesh (PEB), and the World Bank believes that there are 1100 unofficial LAB recycling facilities in Bangladesh [19].

Because Pb may concentrate in soils and plants and eventually enter the food chain, these LAB recycling workshops/factories are to blame for a major part of the Pb emissions that have been detected in the surrounding soil, water, and plants [20]. Although plants absorb a large number of Pb ions from the soil and store them in their roots, only a small proportion is transferred to the stems and leaves. However, this is concerning because Pb is a well-known neurotoxin associated with a wide range of health issues in humans, even if it enters in a small quantity.

A few studies in Bangladesh have attempted also to quantify the degree of heavy metal contamination in the vicinity of the LAB facility, but the knowledge is restricted by the scarcity of soil and water samples, as well as environmental indicators [21]. Recently, increased levels of Pb were detected at an abandoned LAB recycling site in Savar, Dhaka district. Additionally, pollution of agricultural land with Pb and other elements was documented by Rahman et al., with Pb levels in drinking water and vegetables in the Noakhali region believed to be high [20]. Recent research done in southwestern Bangladesh by Kumar et al. (2021) found Pb and other elements in surface soil coming from brick kiln activities but extending to soils without taking into account food crops or water samples [22]. Meanwhile, Islam et al. found Pb in vegetables, cereals, pulses, meat, fruits, eggs, and milk in the industrial area around Dhaka; however, rice and water were not included in their study [23]. Similarly, Alam et al. [24] evaluated the presence of As, Cd, Pb, Cu, and Zn in vegetables from Samata village in the Jashore region, revealing that Pb concentrations in leafy vegetables are greater than those seen in other nations. However, the Pb concentration was less than the permissible level of 1.2 mg kg^{-1} [25]. In addition, research conducted in the Khulna area discovered Pb contamination in agricultural soil and rice grain, indicating potential health dangers for locals [26]. That's why we choose the topics to evaluate the Pb pollution quantity in this area.

We consider the area Khulna and perform atomic absorption spectrometry (AAS) to determine the amount of Pb in the soil samples collected in this area. Around the Khulna city region, there are around 14 active and 20 abandoned secondary Pb smelters [27]. The main goal of this work is to determine the Pb level in soil samples around the Pb acid battery recycling factories in Khulna and use different soil samples from different industrial areas to perform this task.

2. Materials and Methods

2.1 Study area

The industrial regions of Bangladesh Small and Cottage Industries Corporation (BSCIC) Industrial Area, Shiromoni, located in the Khulna district in southwest Bangladesh (22° 54'5 9.5" N 89° 30' 20.2" E), have been the focus of the current study.

Out of three LAB recycling facilities from where we took our samples, two of them were not registered legally and were located near the residential area. The location of the LAB recycling plants and the sampling locations for various types of samples are represented in Fig.1.

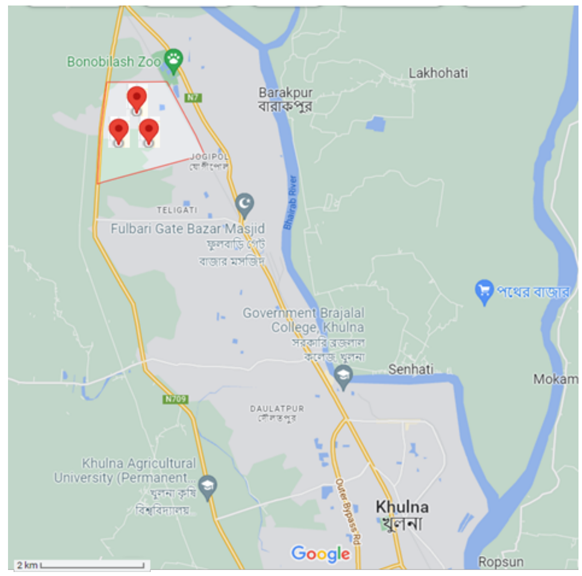

Fig.1 The sampling points of different types of soil samples around the Pb melting industries.

Table 1 shows the description of the areas which was selected for the soil sampling to determine the Pb pollution in Khulna. The industry which is mentioned as area 1 is currently running, but it is not registered legally. Another industry, which is considered area 2, was shut down in August 2020 and currently, no Pb melting has been seen there. The industry in area 3 is a renowned company in Bangladesh and one of the top manufacturers of Pb batteries. As per our knowledge, their smelters are legal.

Table 1 The activity of the industries in current times.

Area	Industry Activity
Area 1	Running
Area 2	Currently in shut down
Area 3	Running

2.2 Sampling

The soil samples were taken on February 8, 2021, and February 9, 2021. 15 soil samples were collected from three places, and the places were near the LAB recycling industries. These were collected in an air-tight ziplock bag from each sampling spot. The soil samples were taken keeping in mind that they should be collected till 12-15 cm in depth, not more than that. Also, it was ensured that the soil samples were within 500 m of the Pb smelters.

Soil samples were maintained cold and dry and also air-dried before transportation. It was critical to maintaining the integrity of the obtained sample to obtain reliable test findings. When collecting soil samples, care must be taken to ensure that the sample is not chemically changed or contaminated by extraneous elements as a consequence of contact with sampling instruments and containers, for example.

Then the soil samples were extracted. The digestion was conducted in the laboratory. After the digestion of these samples, we were able to determine the amount of Pb by Atomic Absorption Spectroscopy (AAS).

2.3 Extraction and digestion process

Each of the soil samples was homogenized before being air-dried. These were then coarsely crushed before being passed through a 2-mm mesh screen. One gram of soil passed through a 0.5-mm screen was weighed into a Teflon beaker containing 10 ml HNO_3 (70% concentration), 10 ml HF (49% concentration), and 5 ml $HClO_4$ (70% concentration) and let to stand overnight. On a heated plate, samples were digested and evaporated to near dryness. After cooling, 10 mL of HCl (38% concentration) was added, and the precipitate with soil residue was moved to 100-mL volumetric flasks and filled with deionized water. The samples were taken to, Ishwardi, Pabna in Bangladesh Sugar Crop Research Institute for extraction and digestion process.

Atomic Absorption Spectrophotometry (AAS) was used to assess Pb concentrations using an Instrumentation Laboratory Model 551 AA spectrophotometer (air-acetylene mixture) at a wavelength of 217.0 nm with deuterium arc background correction. The samples were taken to the lab for AAS in Soil Resource Development Institute, Dhaka.

2.4 Laboratory analysis

High-temperature oxidation is used in this procedure to destroy biological materials. Depending on the estimated concentration of the components to be measured, the sample size might range from 0.5 to 2.0 g. The ashing temperature can range from 475 to 600°C, and the digesting duration can range from four to twelve hours (depending on the sample weight and type of sample). Deionized water was used to dilute the ash residue to the desired volume after it had been dissolved in an HNO_3 or HCl solution.

For the dry ashing process, the sample was heated in a muffle furnace for around 5 hours at 550°C. The resulting ash was allowed to cool down, and then 5 ml of 20% HCl was used to dissolve it. The solution was warmed to dissolve any remaining residue. An acid-washed filter paper was subsequently used to remove any remaining solids from the solution. Before estimating, the filter paper was cleared, and the solution was diluted with deionized water and mixed thoroughly. After that, the ash was inspected by atomic absorption spectroscopy (AAS) to determine the Pb concentration in the sample.

3. Results and discussion

Three samples from the vicinity of each Pb smelter from three different locations were taken: area 1, area 2, and area 3. One sample from each area was collected from the immediate vicinity of the Pb melting furnace. The soil in the vicinity of the Pb melting smelter has an average Pb concentration of 292.13 ± 132.57 ppm. The amount of Pb found in soil samples is almost 15 times greater than the ambient level of 20 ppm [28].

The second set of samples was collected from 20-25m away from the vicinity of the Pb melting smelters. An average Pb concentration of 121.60±77.80 ppm was found in the soil samples in these areas. The Pb concentration here is 6 times higher than the ambient level.

Whereas, in almost double the distance (45-50m), the amount of Pb was relatively much lower. Three samples were collected from these areas. At this distance, the Pb concentration in the soil samples was 21.24±17.14 ppm, which is higher than the ambient level but almost close.

Fig. 2 showed high Pb contamination near Pb smelters. Area 1 has the highest Pb level (388.62 ppm) because this smelter is active and melts Pb continuously. Area 2 was shut down around six months before we took samples, therefore the Pb quantity was lower (140.97 ppm). Area 3's Pb level is close to Area 1's since it's likewise active.

The Pb concentration in 20-25m was about half of the distance near Pb melting smelters (Fig. 3). Area 1, was 21m, Area 2 and 3 were 23m, and 25m from the Pb smelter respectively. In Areas 1, 2, and 3, the Pb levels were 191.23, 65.48, and 186.13 respectively.

45-50m distance had less Pb than prior locations. Fig. 4 shows that the quantity of Pb in these areas are decreased as distance increases. In all places, the Pb quantity was less than 50.00 ppm, and in Area 2 it was just 10.70 since the industry had been closed for a long time, thus environmental and public reasons may be washed out/removed the topsoil intentionally. Area 1 and Area 3 had 41.01 and 12.00, substantially less than the other regions.

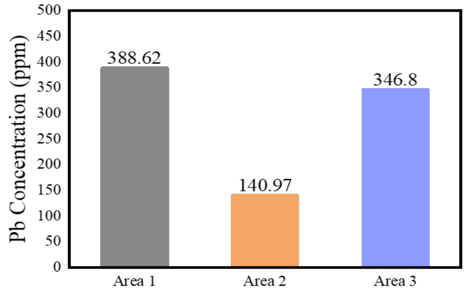

Fig.2 Concentration of Pb in soil near the smelters

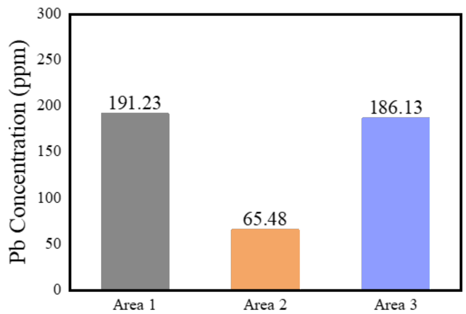

Fig.3 Concentration of Pb in soil 20-25 m from the smelters

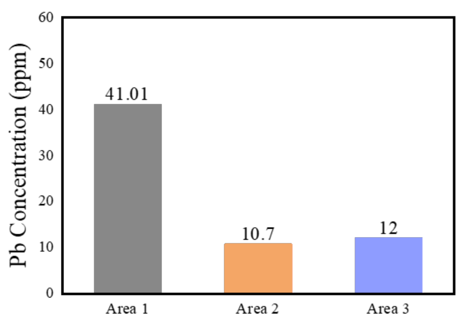

Fig.4 Concentration of Pb in soil 45-50 m from the smelters

So, this indicates that the Pb pollution near the vicinity of the Pb smelters in Khulna has been very alarming, Pb has been mixed with the soil because of the Pb melting or the Pb-acid battery (LAB) industries. And the most surprising fact is some industries are running without the proper permission of the authority, and they're melting Pb at midnight. We also saw that with the increase in distance from the vicinity of the Pb melting smelters, the amount of Pb decreases. The Pb can be mixed with the underground water, which could be the reason for having the lower Pb level near those spots.

It was very fearful because if the Pb passed into the underground water, it could be used for drinking water or for irrigation purposes. The color of the leaves of different species was also observed yellowish and whitish in the nearby regions. Also, the outlook of the trees was different from the normal trees around that area. Due to the high population density in Bangladesh, many of those Pb smelters are in the residential area. The people are using those high concentrations of Pb-affected areas for vegetation or living.

4. Conclusion

In this paper, Pb pollution in the soil near Pb smelters in the Khulna region has been discussed. This study determined the amount of Pb in the soil samples of the designated areas. It was seen that the amount of Pb concentration in the soil samples near the industries was much higher (292.13 ± 132.57 ppm) than the background concentration (20 ppm) of Pb. Even in abandoned industries, a sign of Pb pollution has been found. The soil Pb concentration can also be spread into the underground water, which could be studied in the future.

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