Informal Used Lead Acid Battery Recycling: Assessment of Topsoil Contamination from their Operational Activities

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Abstract— The recycling of used lead-acid batteries (ULAB) has caused numerous health and environmental problems in developing countries. Soil pollution from ULAB recycling activities has been associated with elevated lead concentrations in human blood. We measured lead concentrations at 25 different smelter sites. Lead concentration was determined using an iCE 3000 series atomic absorption spectrophotometer. The average lead concentrations at the smelter site, 20 meters, and 40 meters from the smelter site were 39,800 mg/kg, 6,310 mg/kg, and 4,720 mg/kg, respectively. All samples at the smelter site exceeded the U.S. residential limit (EPA) of 400 mg/kg and the U.S. bare soil limit (EPA) of 1,200 mg/kg. The highest concentrations of lead in soil were found in the smelter or collection site. Soil lead concentrations decreased significantly with distance along the road from the ULAB recycling facility. The result shows that the topsoil is highly contaminated where informal ULAB recycling is conducted, which poses a potential health hazard to the surrounding communities.

Keywords: Used Lead Acid Batteries, Informal recycling, Lead, Ibadan, toxicity

1. INTRODUCTION

Lead is a toxic metal whose widespread use has caused extensive environmental contamination and health problems in many parts of the world. Lead exposure accounts for "almost 1% of the global burden of disease, with the highest burden in developing nations [1]. Health problems associated with lead poisoning can include neurological damage, physical growth impairments, nerve disorders, etc., while exposure to high concentrations of lead can cause seizures, delirium, coma, and in some cases, death [2], [3]. While rates of lead exposure and release are carefully controlled in developed countries, in Low to middle-income countries (LMICs) they can be considerably higher through a number of applications including used lead-acid batteries (ULAB) recycling [4].

Several countries suffer from environmental contamination and exposure to lead arising from lead recycling [5], [6]. The most common reason for this is that it is frequently carried out without the necessary processes and technologies to control lead emissions, and it is poorly regulated in many developing countries [5]. The unregulated, informal recycling of ULAB presents problems as it is mainly carried out by small family businesses, often in domestic backyards, and sometimes in secret [7], [8]. Lead concentrations have been determined with a greater accuracy using techniques such as Atomic absorption spectroscopy (AAS) methods [9], graphite furnace absorption spectrometry (GFAAS), and inductively coupled plasma mass spectrometry (ICP-MS) [10], [11], [12], [13], [14]. High levels of lead concentrations in human blood, urine, and hair have been reported due to ULAB recycling in Vietnam [15], Senegal [2], and Kenya [16].

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Table 1. Environmental Lead Exposure limits

Source	Limit
Air	0.15 µg/m3 [17]
Soil	Bare soil: 1200 mg/kg [18] Bare soil in children's play area: 400 mg/kg [18]
Portable water	0.01 mg/L [19]

Public health concerns are raised because of the high levels of occupational and environmental exposure associated with recycling used lead-acid batteries. In this research work, atomic absorption spectroscopy was used to determine lead in soil samples where ULAB operational activities are conducted in Ibadan, Oyo State. Lead concentrations were measured at the smelter site and 20 and 40 meters from the smelter site to investigate the environmental impact of lead as a function of distance.

2. MATERIALS AND METHODS

2.1 Collection of Samples

Soil samples were collected from a total of 25 ULAB smelter sites in Ibadan, Oyo State. Topsoil was collected from three sampling points at a depth of about 0-15 cm. The first sampling point is located 0-2 meters from the smelter, the second and third 20 and 40 meters from the smelter respectively.

2.2 Measurement of lead concentrations

One gram of the soil sample was accurately weighed with an analytical balance and quantitatively transferred to a digestion tube. 20 ml of aqua regia (1:3 HCl: HNO_3) was added to the soil sample in the digestion tube. The mixture was heated on a hot plate until the volume was reduced to approximately 5 mL. The mixture was then transferred quantitatively and made up by adding deionized water to a 50 mL standard flask. This was then filtered through a filter paper and analyzed for lead using an atomic absorption spectrophotometer (iCE 3000 Series, Atomic Absorption Spectrophotometer, Thermo Scientific)

3. RESULTS AND DISCUSSION

The arithmetic mean of the lead concentration for the 25 soil samples taken at 3 different points 20 meters apart is as follows: At 0 to 2 meters, the arithmetic mean lead concentration for the 25 soil samples was 39,800 mg/kg, with results varying from 1,680 mg/kg to 135,000 mg/kg. At a 20 m distance, the mean lead concentration was 6,310 mg/kg, and results ranged from 234 mg/kg to 30,200 mg/kg and at a 40 m distance, the mean lead concentration was 4,720 mg/kg and results ranged from 208 mg/kg to 2,850 mg/kg. All samples collected from 0 to 2 meters from the smelter site exceeded the U.S. Environmental Protection Agency residential hazard level of 400 mg/kg and the U.S. Environmental Protection Agency bare soil limit of 1,200 mg/kg [18] as shown in Table 1.

For samples collected 20 meters from the "hot spot," only 9 of the 23 soil samples exceeded the U.S. limit EPA for bare soil, which is 1,200 mg/kg, while 20 of the 23 soil samples exceeded the U.S. limit EPA [18] for bare soil in children's play areas, which is 400 mg/kg (Table 2). No soil samples were collected at two recycler sites because all areas were covered with concrete. For the samples collected 40 meters from the "hot spot," only 2 soil samples exceeded the U.S. limit EPA for bare soil, which is 1,200 mg/kg, and only 9 soil samples exceeded the U.S. limit of 400 mg/kg for bare soil in the children's play area EPA. All 25 samples exceeded 80 mg/kg lead - the soil screening level used by the California Environmental Protection Agency for residential remediation [20]. The high concentrations of lead in topsoil 20 and 40 meters from the "hot spot" indicate that lead is being transported over a wide area. These results indicate that topsoil is highly contaminated in locations where informal recycling of lead batteries occurs, posing a potential health hazard to surrounding communities.

Table 2. Lead Contration at Smelting site, 20 meters, and 40 meters away

Sample code	Lead concentration (mg/kg)			
	Address	Smelting point	20 meters away	40 meters away
SGG1	Sango garage	7310	9060	930
AYD	Ayorinde Street, Dugbe	23600	1810	2850
ADM1	Adamasingba beside total petrol	57700	-	-
MVB1	Mechanic Village, Oju-Irin, Bodija	121000	8540	1990
BWB	Beside Wema bank, along new Ife road	114000	30200	1370
DUR	Beside Dugbe railway	5290	335	4340
MSC	Mameloye shopping complex, Iwo road	4920	914	-
AAO	Ajao street, Agbowo/Ojoo Express	48500	1060	-
ORA	Opeyemi road, along new Ife road	137000	9480	-
SER	Sango Eleyele road, beside bolajoko shopping	46700	1680	272
AGR	Agodi road, beside union bank	3080	745	208
OGA	Ogunyase street, Agbowo	49200	1070	700
TRP	Trans amusement Park, Samonda	2330	234	704
SGG2	Sango garage 2	39400	835	548
AJI	Ajibode road, behind Ojoo police station, Ojoo	3210	239	619
MVB1	Mechanic Village, Oju-Irin, Bodija	40200	498	911

Sample code	Lead concentration (mg/kg)			
	Address	Smelting point	20 meters away	40 meters away
YEM	Yemetu, Ibadan	3470	275	799
YAO	Yanbule street, Agbowo/Ojoo express	94900	770	494
AGG	Agodi gate (battery chargers headquarters, Ibadan)	28500	833	913
IBB	IB Balogun Street, Mokola, Ibadan	41000	27200	-
OJE	Oje road, Ibadan	4540	29800	-
MVB2	Mechanic Village, Oju-Irin, Bodija	128000	25100	-
ADM2	Adamasingba, oke-tedo	20300	680	-
UIM	UI maintenance	9370	691	-
NER	Beside kappa petrol station, new Eleyele road	8860	-	-
CONTROL 1	Botanical garden, UI	101	-	-
CONTROL 2	Botanical garden, UI	64	-	-
CONTROL 3	Ogunyase street, Agbowo, UI	145	-	-

Surface and groundwater sources may also be affected by soil contamination and wastewater discharges. The lead concentration of the control samples collected from the botanical garden and Ogunyase street, Agbowo, University of Ibadan are 101 mg/kg and 145 mg/kg respectively. The lead concentration in the soil at 0 to 2 meters from the recycling site is more than 100 times higher than the lead concentration in the topsoil of the control samples. This shows that topsoil contamination is mainly due to the informal recycling of lead at the smelter site.

According to the data from soil samples obtained within 1-2 cm of the surface within a 1 km radius of a lead-acid battery recycling plant in China, there is a statistically significant relationship between direction and distance from the recycling facility [21]. When soil lead concentrations were examined in an area outside an official lead-acid battery recycling facility in Banten, Indonesia, values ranging from 240 to 1780 mg/kg were found at 300 to 600 meters from the facility [22].

As shown in this report, there is an inverse relationship between lead concentration and distance from the smelter. The result of our study confirms this previous work, as the lead concentration decreases with distance from the smelters: 0-2 meters, 20 meters, and 40 meters have mean lead concentrations of 39,800 mg/kg, 6,310 mg/kg, and 4,720 mg/kg, respectively. This shows that lead is also transported over long distances from the recycling point.

The study found that the arithmetic mean lead concentration of soil collected from 25 recycling sites in Ibadan metropolis was 39,800 mg/kg for 0-2 meters, 6,310 mg/kg for 20 meters, and 4,720 mg/kg for 40 meters, with all 25 soil samples for 0-2 meters exceeding the U.S. Environmental Protection Agency limit of 400 mg/kg. Few studies have provided similar data on soil lead contamination at recycling facilities. A previous study reported lead concentrations in soil collected from the site of a decommissioned lead-acid battery manufacturing facility in Nigeria. Lead concentrations in soil ranged from 243 to 126,000 mg/kg, and 98% of the samples were above 400 mg/kg [23]. Several studies have shown that soil contamination near lead battery recycling facilities can result in significant exposure to surrounding communities [24], [25]. The result of the study of massive lead poisoning from informal used lead batteries in Dakar, Senegal, showed that leadLevel in the blood of the 50 children tested ranged from 39.8 to 613 mg/L, with a mean of 130 mg/L [2]. Houses and soils in the surrounding area were heavily contaminated with lead due to ULAB recycling (up to 14,000 mg/kg indoors and 302,000 mg/kg outdoors). This is largely consistent with our result with an arithmetic mean of 39,800 mg/kg.

4. CONCLUSION

Soil contamination with lead in and around the informal recycling of lead-acid batteries in the Ibadan metropolis is a long-term health hazard that is not recognized and generally not addressed. The smelting process is generally conducted in an open environment, and the proximity of the smelting process to residential areas threatens the health and well-being of these communities. There is an immediate need for further investigation and remediation to protect these communities, as topsoil is contaminated both at the point of recovery and several feet away from the point of recovery. There is also an urgent need for regulations to prevent the continued emissions and resulting soil contamination

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