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Ridwan Fauzi

Center for Standardization of Environmental Quality Instruments, The Ministry of Environment and Forestry, PUSPIPTEK, Serpong 15314, Indonesia, ridwanfkt@gmail.com

Muhamad Yusup Hidayat

Center for Standardization of Environmental Quality Instruments, The Ministry of Environment and Forestry, PUSPIPTEK, Serpong 15314, Indonesia

Bambang Hindratmo

Center for Standardization of Environmental Quality Instruments, The Ministry of Environment and Forestry, PUSPIPTEK, Serpong 15314, Indonesia

Siti Masitoh

Center for Standardization of Environmental Quality Instruments, The Ministry of Environment and Forestry, PUSPIPTEK, Serpong 15314, Indonesia

Grace Serepina Saragih

Center for Standardization of Environmental Quality Instruments, The Ministry of Environment and Forestry, PUSPIPTEK, Serpong 15314, Indonesia

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Lead Concentration in The Soil Around a Used Battery Recycling Site in Tangerang Regency, Indonesia

Ridwan Fauzi*, Muhamad Yusup Hidayat, Bambang Hindratmo,
Siti Masitoh, and Grace Serepina Saragih

Center for Standardization of Environmental Quality Instruments, The Ministry of Environment and Forestry,
PUSPIPTEK, Serpong 15314, Indonesia

*E-mail: ridwanfauzi@menlhk.go.id

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Abstract

Long-term lead (Pb) exposure can affect human health. Used battery recycling is a source of Pb emission, and the smoke from the facility carries Pb particles that accumulate in the soil. This study aimed to determine the concentration of accumulated Pb in the soil around Kadu Manis Battery Recycling Industrial Estate, Tangerang Regency, Banten Province, Indonesia in 2018. Soil samples were collected by employing a purposive strategy in four directions from the hot spot at a 0–7.5 km radius. Pb content in the soil was analyzed using a modified version of the official method from American Public Health Association number 3030-H in 2012 and work instructions for metal 01 in 2014. Results showed that the Pb concentration in the soil around this site was below the threshold with an average value of 94.43 mg/kg dry weight and a range of 16.56–279.42 mg/kg dry weight. The soil closest to the facility had the highest Pb concentration. These findings indicated that the management of emission from used battery recycling site must be improved.

Keywords: battery recycling, heavy metal, lead, soil contamination

Introduction

Prolonged lead (Pb) exposure affects human health. This metal can enter the human body through inhalation and digestion [1, 2]. Pb is toxic to the human body and can interfere with organ functions when its concentration exceeds the permissible exposure limit [3–5].

Pb pollution in Indonesia is prevalent around sites for used battery recycling [6, 7], which aims to extract and collected Pb from batteries. Owing to improper recycling practices, Pb might be released and consequently pollute the surrounding area [7, 8]. High Pb concentrations in the soil are caused by the smelting activity of used battery facilities that are still operating in the vicinity [9, 10].

The used battery recycling industry is suspected as the cause of high Pb concentration in children's blood [11]. Kadu Manis Industrial Estate is a used battery recycling industry in Tangerang that was established in 1986. Blood Pb concentrations in children living near Kadu Manis have reached 39,18 µg/dL [7, 11], which is higher than the prescribed threshold (5 µg/dL) [7, 12]. In addition, plants around the facility have high Pb concentrations, particularly the leaves containing 12.23–770.8 mg/kg Pb [6, 8].

Pb emissions are distributed through intermediary media such as water and air [13, 14]. Scattered Pb pollutants from used battery smelting can accumulate in the soil, plants, and other living things. In particular, Pb accumulation in the soil is greater than that in air and water [15–17] due to the disposal of smelting waste to the surrounding area. As a source of Pb pollutants, the used battery recycling industry has the potential to spread Pb pollutants through air [18]. Pb particles carried through air can be trapped in the plant tissues within the distribution range [18, 19]. The high Pb concentrations in plants are influenced by the amount of Pb accumulation in the soil and surrounding air [20, 21]. The soil supplies the plants with nutrients [22, 23] and distributes the accumulated Pb to various parts, thus increasing their Pb concentrations [24]. Therefore, research on soil Pb levels is important to analyze Pb pollution around used battery recycling facilities.

This study aimed to detect Pb concentrations in the soil around used battery recycling sites. The obtained values can be used as an indicator in evaluating whether the industry effectively mitigates and controls Pb pollution.

Methods

Soil samples were gathered from the used battery recycling industry in Tangerang Regency, Banten Province, Indonesia in May 2018.

The soil samples were obtained in four directions from the hot spot, the Kadu Manis Battery Recycling Industrial Estate. In each direction, soil sampling was carried out in three distance ranges (0–2.5, 2.5–5, and 5–7.5 km). The soil was collected compositely at a 0–20 cm (effective root) depth with duplo samples for each sample. Soil sampling points are shown in Figure 1.

Tools and materials. Tools for soil sampling include auger, shovel, tray, plastic silk, glassware, analytical balance, porcelain dish, desiccator, oven, hot plate, and atomic absorption spectrophotometer (AAS). The materials for Pb analysis are standard Pb metal with 1000 mg/L concentration, Certified Reference Material Era, Standard Reference Material Montana soil for soil, 0.45 m pore filter paper, HNO₃ pa., HClO₄, distilled water, and boiling stones.

Testing procedure. Water content in the soil was determined prior to destruction by using the 1996 USEPA 3540C method. Pb levels in the soil were measured through acid digestion using AAS by referring to the Official Methods of Analysis (AOAC) 975.03 published in 2005.

Pb concentration in the soil was measured from the AAS tool and calculated using the linear equation $y = ax + b$, where y is the absorbance value displayed on the device, x is the concentration measured in the tool, a is the slope of the straight-line curve (slope), and b is the intersection of the curve with vertical axis (intercept). The values were converted to dry sample weight to obtain units (mg/kg).

Soil Pb analysis was carried out with two replications, and Pb concentration was calculated using the following equation:

$$\text{water content (\%)} = \frac{A-B}{A} \times 100\%, \quad (1)$$

where,

A: sample weight before heating (g) and
B: weight of sample after heating (g).

$$\text{Lead concentration } \left(\frac{\text{mg}}{\text{kg}}\right) = \frac{C \times V \times fp}{B}, \quad (2)$$

where,

C: Pb concentration of the instrument (μg/mL),
V: final volume (mL),
fp: dilution factor (if no dilution is done, then fp = 1), and
B: dry weight of the test sample (g);
(wet weight – (wet weight × water content)).

ANOVA was used to examine differences in soil Pb concentration at each sampling location.

Figure 1. Location of Soil Sampling in Kadu Manis Industrial Estate, Tangerang Regency

Results and Discussion

Detecting Pb concentrations in the soil around used battery recycling facilities is crucial. The obtained values can be used as a reference in managing contaminated land when the Pb concentrations exceed the quality standard. High Pb concentrations in the soil are caused by continuous Pb exposure from pollutant sources in the vicinity over a certain period [2, 15, 17]. This research is important to prove that used battery recycling facilities, particularly Kadu Manis Industrial Estate, emit Pb that can pollute the surrounding environment. The Pb concentration of the soil sample is shown in Table 1.

Table 1 shows that the highest and lowest soil Pb concentrations were 279.42 and 16.56 mg/kg dry weight, respectively, and the average value was 94.43 mg/kg dry weight. The highest Pb concentration (sample code J) was recorded for the soil from the south portion of the used battery recycling area in a 0–2.5 km radius and can be attributed to the activities of the surrounding community engaged in recycling used batteries. Community involvement includes the collection and sorting of used battery plastics with their metal materials. Considering the characteristics of the pollutants disperse in the air, the soil samples were obtained in four directions from the emission source. Sampling at different directions and distances effectively ensures that the contamination originates from the same source [25, 26]. Given that several sampling points are close to the road, the use of motorized vehicle fuel containing Pb might affect the results; however, the government banned this type of fuel in 2006 [27]. Random soil sampling was adopted to minimize bias toward the samples taken around the watershed. However, Pb pollutants can move with the water flow.

The maximum limit of soil Pb is stipulated at 300 mg/kg by the Government Regulation of the Republic of Indonesia number 22 in 2021 regarding the Implementation of Environmental Protection and Management. On this basis, the average Pb content in the soil around the used battery recycling facility up to a radius 7.5 km is below the toxic category. However, the Pb concentrations in this study were higher than those reported by Kabata-Pendias and Mukherjee, that is, 40 and 90 mg/kg lowest and highest soil Pb concentrations, respectively [28]. Another research in the concrete industrial area in Kingston, Jamaica categorized 32 mg/kg soil Pb as extremely high [29]. The high Pb concentrations in the soil indicated that the used battery recycling area is contaminated with Pb. In particular, Pb tends to be high in industrial sites and urban areas [20,

30]. Therefore, government regulations related to the Pb threshold in soil must be integrated with stringent criteria to protect the public from Pb contamination, especially those living around used battery recycling facilities.

ANOVA results revealed that Pb concentration in the soil is influenced by distance from the pollutant source. Soil samples obtained at a far distance from the used battery recycling site contained low Pb concentrations. Related the figure 2, the estimation model shows an R^2 value of 0.405 with a significance of $p < 0.01$ (0.001). This finding proves that distance from the pollutant source significantly influences the amount of Pb accumulation in the soil [2, 22, 24]. In addition, Pb particle mass affects its dispersion distance [31]. A far sampling location is correlated with a low risk of Pb exposure. By contrast, close proximity to the Pb pollution source induces a great risk of Pb exposure.

ANOVA was used to determine which direction from the hot spot has the greatest effect on Pb concentration as indicated by a significance value of more than ($>$) 0.1 ($P > 0.1$ and $P: 0.974$). The Pb concentrations in the soil from the north are generally high, indicating that this side has a great risk of exposure to Pb pollution. This phenomenon is attributed to the wind direction, which tends to dominated toward the north sampling location [32]. Pb particles easily move in the direction of the wind. When the wind speed accelerates, the Pb particles are widely distributed through the air [14, 33]. Pb pollutants released by the used battery recycling industry can pass through water and air. In particular, the Kadu Manis facility has the potential to release Pb pollutants through air. Therefore, the sampling model in this work was divided based on distance (radius 0–7.5 km) and four directions to avoid sampling errors. In line with the initial hypothesis that the pollutant source is the center point, the battery recycling site was designated as the central point of the samples.

Soil Pb concentrations are also related to traffic volume. High soil Pb concentrations are found in areas close to major roads [30, 34, 35]. This phenomenon could be attributed to the use of leaded gasoline in motor vehicles. However, in Indonesia, this type of fuel was completely banned in 2006. This policy was initiated in 1996 through a government program, “Program Langit Biru” (Blue Sky Program) [36, 37]. The high Pb content in a location very close to the highway is possible from the accumulation of Pb pollutants from motorized vehicles in the past. Thus, monitoring soil Pb is important as an indicator of the Pb contamination around the used battery recycling industry.

Table 1. Lead Concentrations in the Soil Around the Used Battery Recycling Area in Tangerang Regency

Direction from Hot Spot	Distance to the Used Battery Recycling (km)	Lead Concentration in Soil (mg/kg dry weight)	Sample Code
West	1.17	46.82	P
	1.22	142.96	D
	3.14	40.73	Q
	3.22	82.77	E
	5.77	35.67	T
	5.92	38.04	F
	$\bar{x}$	64.50	
South	0.66	279.42	J
	1.48	81.2	W
	3.14	164.84	K
	3.15	55.3	X
	5.1	37.04	L
	7.17	25.44	V
	$\bar{x}$	107.21	
East	1.26	93.03	U
	1.66	269.48	I
	4.26	35.68	R
	4.29	82.29	H
	5.32	49.98	G
	5.32	16.56	S
	$\bar{x}$	91.17	
North	1.72	89.25	A
	1.72	262.9	M
	2.96	76.95	B
	2.96	137.14	N
	5.34	77.45	C
	5.63	45.3	O
	$\bar{x}$	114.83	
$\bar{x}$ Total (West, South, East, and North)		94.43

Figure 2. Mean Lead Concentration in the Soil in Relation to its Distance to the used Battery Recycling Site

Figure 3. Mean Lead Concentration in the Soil from Different Directions

Conclusion

An average of 94.43 mg/kg Pb content is detected in the soil around a used battery recycling facility in Tangerang Regency in a radius of up to 7.5 km. According to Indonesia regulations, this concentration is below the threshold for the toxic category. However, the measured soil Pb concentrations in this study are higher than those previously reported. Early mitigation actions for Pb pollution can be carried out by supervising and improving Pb processing to minimize the risks of Pb exposure to residents.

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