ISSN (Print): 0972-4397
ISSN (Online): 0974-0805

Journal of Ecophysiology and Occupational Health, *Vol 20(3&4), DOI: 10.18311/jeoh/2020/26134, 145–154, July–December 2020*

Blood Lead Levels and their Relationship with Lead in Ambien Air in Children in the Area of used Lead-Acid Battery in Depok City, Indonesia

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Abstract

The informal Used Lead-Acid Battery (ULAB) activities impact air pollution from smoke, dust, and waste containing lead. This study aims to determine the effect of air lead concentration on Blood Lead Levels (BLLs) in children aged 7-13 years in the informally ULAB area in the city of Depok. This study uses secondary data from the 2014 Special Research on Environmental Pollution for Traditional Battery Processing conducted by the National Institute of Research and Development. Cross-sectional study design, the study population was children aged 7-13 years in selected ULAB areas, with a total sample of 94 people. Each respondent took a venous blood sample and measured it with a portable blood lead gauge. The concentration of lead in the air was measured using a High Volume Air Sampler and analyzed by atomic absorption spectrometry. Normality test on BLLs and lead variables in the air. Linear regression test to determine the relationship between lead variables in the air and BLLs. The respondents' average BLLs were 8.58 μg/dL, with intervals of 3.8 - 14.6 μg/dL. There was a strong relationship ($r = 0.777$) and statistically significant ($p = 0.000$) between air lead levels and BLLs. It has a lively pattern equation, meaning that if the lead level in the air increases, the BLLs will increase. Although BLL in children is still below World Health Organization (WHO) recommended, there needs to be measured to prevent children from being exposed to lead, because low BLLs for long periods can endanger children's health.

Keywords: Blood Lead Levels, Children, Informally Used Lead-Acid Battery, Lead in the Air

1. Introduction

Lead is a poisonous heavy metal, non-degradable, quickly accumulates in living things, and can cause severe illness and disorders[1,2]. Tin enters the body through inhalation, food, and drink in a form that dissolves quickly and is easily absorbed by the body[3,4]. Once absorbed, lead can affect nearly every organ and be in the teeth and bones for some time[5,6]. Acute lead exposure is strongly associated with disease incidence in children because their brains and nervous systems can absorb four to five times more lead than adults[6,7]. The nervous system of children is more sensitive to the damaging effects of lead[8]. Lead exposure can cause various disorders of the nervous system such as headaches, nausea, tremors, numbness, and at the worst level, lead to a lead buildup in the gums[3,9]. Children are a group at risk for anemia due to lead exposure[10]. They occur because BLL can interfere with the heme biosynthesis system, which functions as a builder of red blood cells and can shorten erythrocytes' lives, thus risking anemia.

The WHO estimates that 0.6 million children with mild to moderate mental retardation occur annually due to lead poisoning[11]. Lead exposure in children annually contributes to 600,000 new cases of children with intellectual disabilities, 99% of whom live in developing countries[12]. According to the Global Burden of Disease study in 2015, it found that 9.3 million disability associated

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life years (DALYs) were due to lead exposure, with an incidence of premature death of 0.5%, 2.5% causing heart attacks, and 12.4 % impaired intelligence decline (mental retardation)[13,14].

Even with the elimination of lead-containing fuels, in developing countries, there is still an increase in BLLs as a result of lead pollution in the environment due to the recycling of used batteries. Global lead production continues to increase, with an estimated 85% of global lead demand from the lead manufacturing industry and ULAB. Therefore makes the lead-acid battery manufacturing and recycling industry a primary source of lead contamination[15,16].

In 2014 the Commission for the Elimination of Lead Gasoline (KPBB) conducted a mapping of ULAB's informal activities in the Jabodetabek area. A total of 71 informally ULAB locations and battery storage locations are scattered in the Jabotabek area[17]. Depok City is one area where ULAB is located close to residential areas (Pancoran Mas and Beji). This study was conducted to prove the relationship between lead exposure in the air and BLL in children aged 7-13 years in the informal ULAB area.

2. Materials and Methods

2.1 Study Area

The research area is in the city of Depok, West Java Province, Indonesia. The sampling locations are in the Pancoran Mas and Beji sub-districts, which are in Depok, where there are informal recycling activities of used batteries that are close to residential areas and far from manufacturing industry activities.

2.2 Experimental Design

This study uses secondary data from the 2014 Special Research on Environmental Pollution for Traditional Battery Processing conducted by the National Institute of Research and Development. Cross-sectional study design, the study population was children aged 7-13 years in the informally ULAB area in selected areas. The total research sample in the city of Depok was 94 people. At the time of data collection, the selection was determined using a population list of children aged 7-13 years who were at the local health service post (posyandu cadres), and then randomly selected. The number of samples in each area is determined proportionally, provided that they live <700 m from the ULAB location, and the respondent is willing to participate in research activities.

2.2.1 Data Collection Instruments

Researchers conducted interviews by asking some structured questions (questionnaires) to respondents accompanied by parents or guardians. The questions contain information about individual characteristics such as age, the gender of the child, parental education, parent's occupation, and the child's habit of putting things in the mouth. The researcher observed the environment where the students lived, such as the distance between the house and the road, the materials used in the house (brick or wood), and the outside of the house (using paint or not).

2.2.2 Measurement of Pb Samples in Ambient Air

Lead measurement in ambient air at 14 points spread over two urban villages in Depok city, namely 7 points in Beji village and 7 points in Pancoran Mas village. A sampling of lead in ambient air has a ratio of 1:7, meaning that 1 sample of Pb measurement in ambient air represents seven respondents who live in the area of the sample measurement point. Measures in sunny weather, with a height of ± 1.25 m from the ground or as high as the children's respiratory tract. The sample measurement radius is at the farthest point ± 700m from the ULAB activity location. Measurement of Pb concentration in air by collecting lead particles in the air (aerosol) using a High Volume Air Sampler on the filter, then dissolving any lead in the filter and analyzing the sample solution using the Atomic Absorption Spectrometry (AAS) method at an ISO accredited laboratory 17025[18].

2.2.3 Blood Sample Collection

Invite the parent or guardian of each child to come to the designated health unit with their child. Blood samples were collected from study subjects in the morning around 8 to 10 am. Collect as much as 10 ml of a blood sample through the venipuncture technique. Then the sample is stored in a royal blue EDTA tube. The subject's body's sampling location was first washed with soap and water, dried, and washed with alcohol (70%) swab. Blood draw using venipuncture with a phlebotomy needle[19]. Blood flow through the tube wall of the EDTA tube as much as 10 ml. Homogenize the blood with anticoagulant in the EDTA tube, with hot coals 8-10 times to prevent clotting.

Each specimen tube is labeled specimen identification. The specimens were stored at 4°C[20]. Pb in the blood was carried out by anodic stripping voltammetry (ASV) analysis method with Lead Care Analyzer II, using a sample of 50 µl[21,22]. Lead Care Analyzer II accuracy in reading BLLs from 0 - 65 µg/dL.

2.2.4 Collection of Soil Samples

Soil samples were collected at the same location as the air lead and well water measurements. All soil samples (N = 9) were collected, then air-dried for one week, milled with a mortar and then porcelain, passed through a 0.5 mm sieve, and then stored in a clean plastic bag. Soil samples were digested using the standard method. 1.0 g soil was placed in a 50 ml round bottom flask with 10 ml aqua regia (HCl: HNO_3 = 1:3). The solution was kept at room temperature overnight before a water condenser was attached and the solution was heated to boiling for two h. 10 ml of water was added down the condenser before filtration of the mixture through using a Whatman No. 42 filters. The filtered residue was rinsed twice with 5mL of water, and the solution was made up to 50mL. All solutions were prepared with 18.3 MΩ deionized water. The above procedure was also used to obtain a blank and control samples, and all samples were blank-corrected. The concentration of Pb in digested sample solutions were analyzed using AAS at an ISO 17025 accredited laboratory.

2.3 Data Analysis

Univariate analysis was carried out to explain children's socio-demographic characteristics, parental education, parental occupation, and neighborhood environmental conditions. The normality test for the variable lead in blood and the air's variable lead uses the skewness value divided by the standard error value. If the skewness test results are divided by the standard error resulting in a number ≤ 2, then the variables are normally distributed. Boxplot diagrams are used to show variations in air lead exposure data and BLLs according to age levels, based on the mean, minimum, and maximum data[23]. A simple linear regression test between variables is carried out to see the air's lead to lead levels in the blood. Lead in the air with variable lead in blood. The value of r = 0.51 to 0.75 signifies that the two variables have a healthy relationship, while a robust relationship is obtained if r = 0.76 to 1.00[24].

3. Results

A total of 94 children were enrolled in this study. Among them, 94.7% are women, 68.1% are aged 7-10 years, and 54.3% have the behavior of inserting objects into their mouths. Most of the respondents' parents have low education (61.7%) and work in the informal sector (78.7%). Most of the residences of the respondents are <100 m from the main road (34.0%), have brick houses (90.4%), and use paint as wall coverings (90.4%) (Table 1).

The measurement results in (Table 2) show that the average lead level in the respondent's blood was 8.58 µg/dL, with intervals of 3.8 - 14.6 µg/dL. For the measurement results, the average value of lead concentration in ambient air in residential areas close to ULAB is 0.4 µg/m^3, with an interval of 0.29 - 0.41 µg/m^3. Measurement of the average value of lead content in the soil in the area around residential areas is 13.95 µg/gr, with an interval of 1.95 - 44.08 µg/gr.

Figure 1 shows the average, minimum, and maximum airborne lead and blood lead BLLs levels according to the child's age level. According to the age level, the average BLLs has an interval of 7.47 - 10.51 µg/dL. The linear regression test results between the BLL variable and the age variable showed a weak relationship (r = 0.109) and not statistically significant (P = 0.294). On average, the BLLs score in boys was found to be higher than that of girls.

The mean blood lead level (BLL) in Figure 2(a) for all groups of lead exposure to air is in the interval 12.13 - 4.54 µg/dL, with an average value of lead exposure in the air of 0.29 - 0.52 µg/m^3. Meanwhile, the linear regression

Table 1. Respondents' socio-demographic characteristics (n=94)

Variable	Total	(%)
Gender (girls)	89	94.7
Age (7- 10 year)	64	68.1
The behavior of putting things in the mouth (yes)	51	54.3
Parents Education (< 9 year)	58	61.7
Parents job (Informal workers)	74	78.7
Main roadhouse distance (<100m)	32	34.0
Home construction materials (Brick)	85	90.4
Use of paint as a wall coating (Paint)	85	90.4

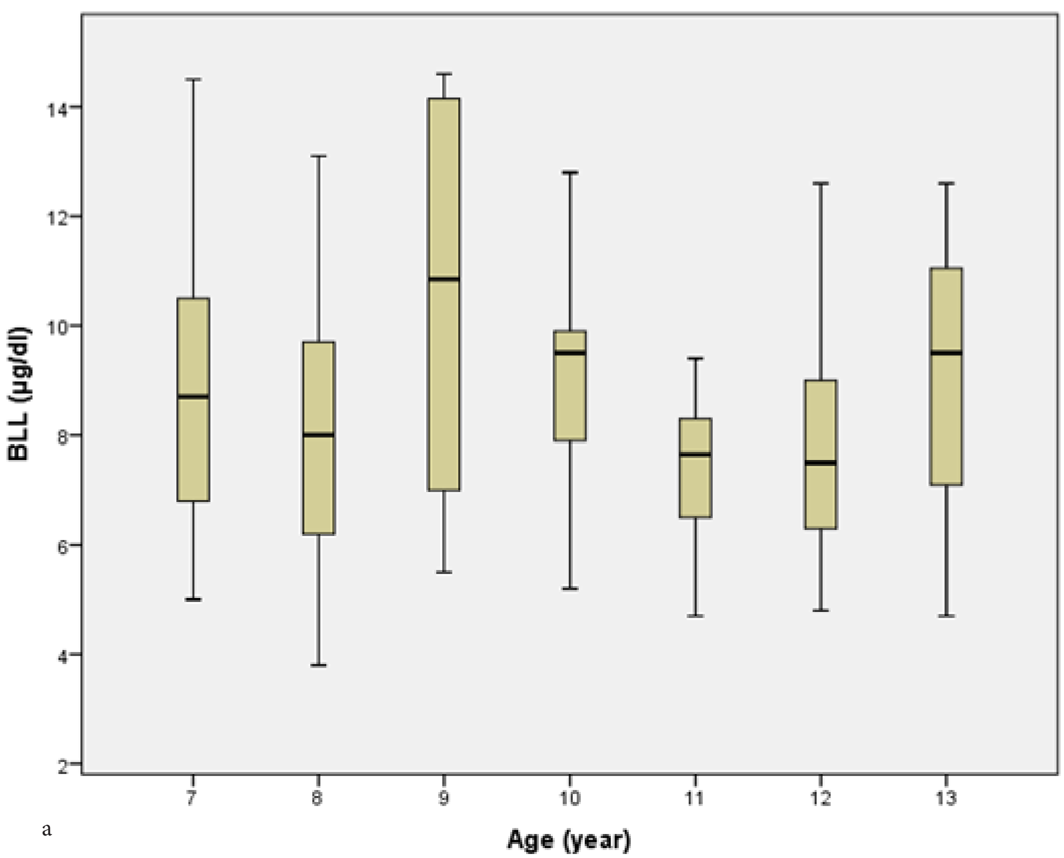
Table 2. Distribution of BLL among children aged 7-13 years (n = 94) and the concentration of lead exposure in ambient air in the sample village area (N = 14)

Variabel	N	Mean	Median	SD	Min-Max	95% CI
BLLs (µg / dL)	95	8.58	8.15	2.62	3.80-14.6	8.05-9.12
Pb in Air (µg/m³)	14	0.4	0.4	0.06	0.29 -0.52	0.39 –0.41
Pb in Land (µg/gr)	9	13.95	12.28	12.8	1.95-44.08	4.11-23.8

test shows that there is a strong relationship ($r = 0.777$) between lead exposure in the air to an increase in BLLs and has a positive pattern equation, which means that if the lead level in the air increases, the lead level in the blood increases. Statistically ($R^2 = 0.604$, $F = 140.46$, and $P = 0.000$) shows that linear regression between the two variables has a significant relationship.

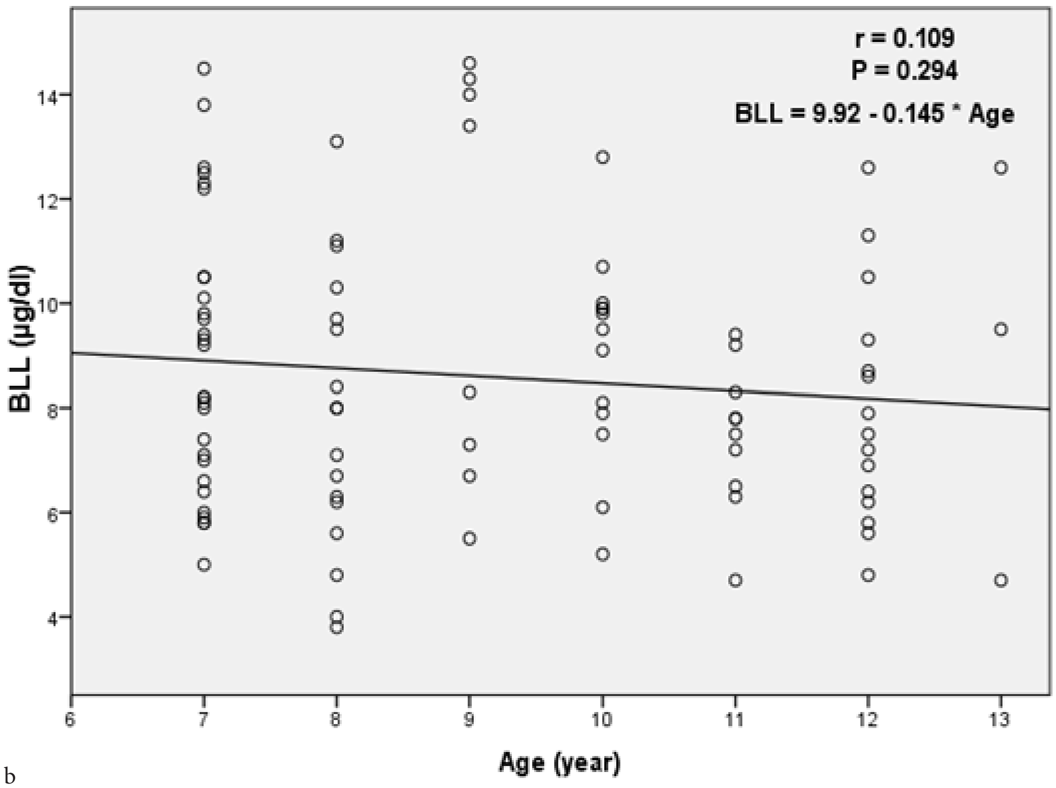
4. Discussion

The study results found that more than half of the respondents had the behavior of putting their hands in their mouths. Children are at risk for lead poisoning due to the habit of putting their hands in their mouths, as they are more likely to eat lead-contaminated dust, paint, and soil[25]. A 2007 study in China found a positive correlation between children's hand-to-mouth and object-to-mouth behavior and increased BLLs[26]. Other potential sources, such as lead pigments used in wall paints, in this study, were not further verified. The results of the study, almost all residences of the respondents used to paint as wall coverings. The IPEN report found that 77% of store-bought enamel paints, randomly selected, contained



a

(a)



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(b)

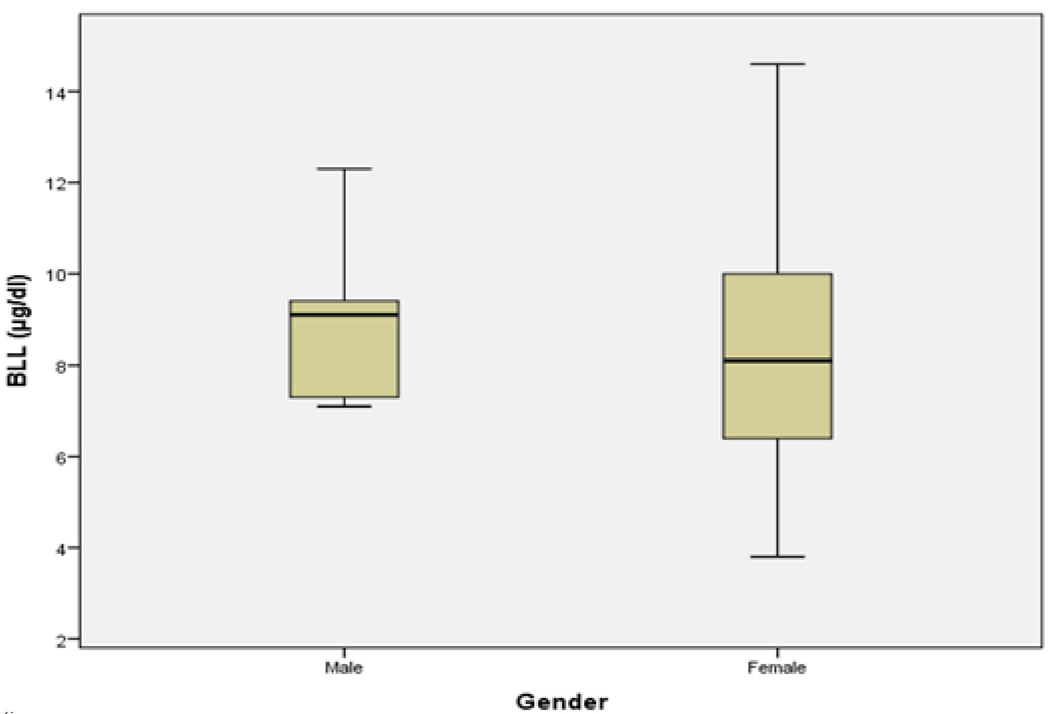

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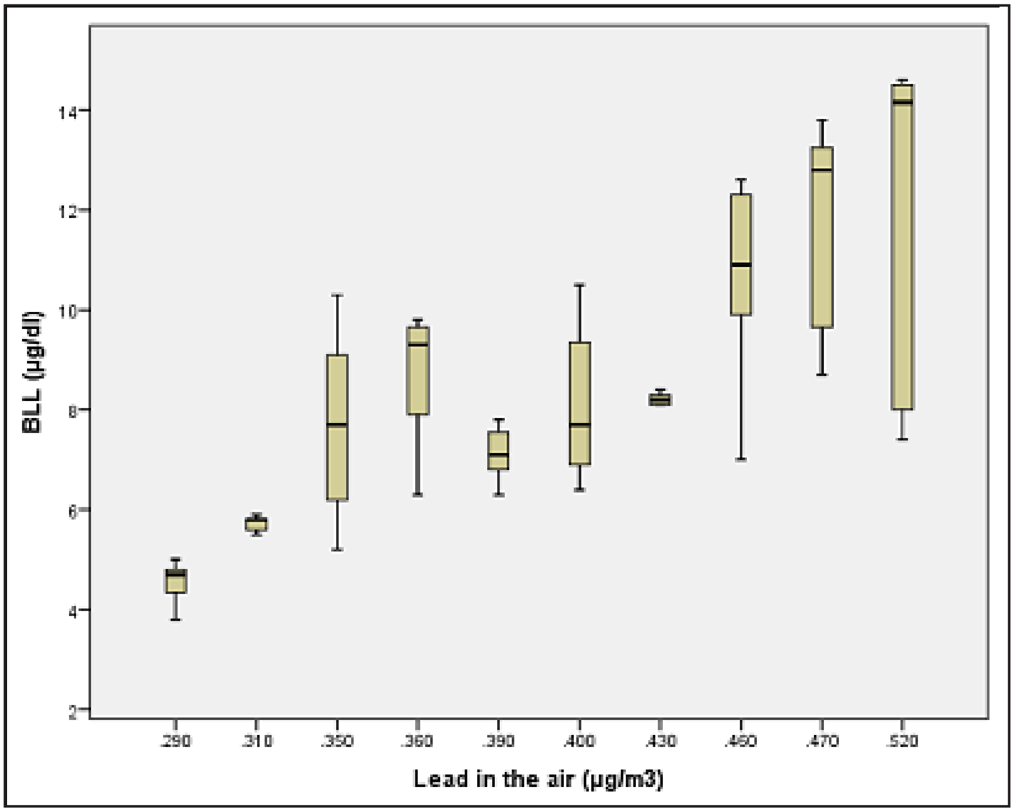
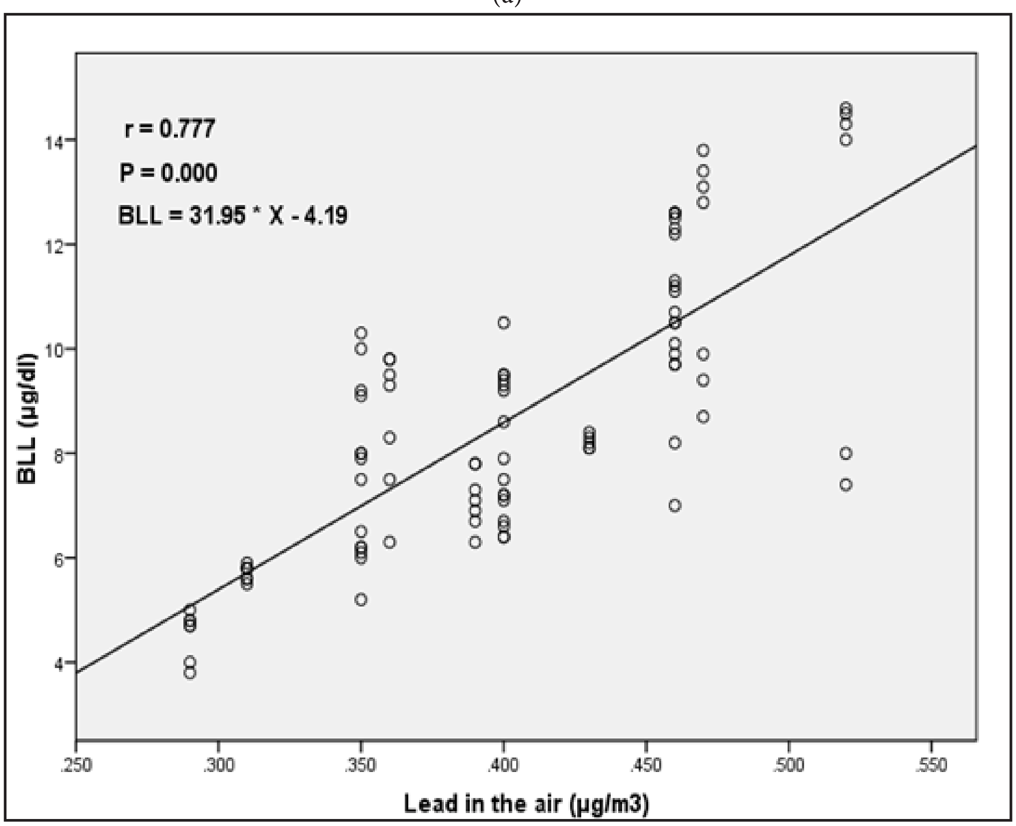
Figure 1. (a) Boxplot between BLL and age levels; (b) Regression between BLL and age levels; (c) Boxplot between BLL and age.



(a)



(b)

Figure 2. (a) Boxplot between BLL against increased airborne lead exposure; (b) Regression between BLL and airborne lead exposure.

N90 mg/kg of lead, which means the paint was lead-based[27]. However, another study in Jakarta found that only 2.7% of all enamel and non-enamel paint samples could be classified as lead-based paints, suggesting that the risk of exposure to lead-based paints appears below[28]. The study also found that most of the respondents' parents had a low level of education. Low parental education is associated with higher BLL among children, education level as an indirect measure of socioeconomic conditions. This finding is consistent with the literature[29,30].

This study showed that BLLs in children living in the vicinity of ULAB was 8.58 μg/dL, this value is lower than the figure recommended by WHO of 10 μg/dL[31]. However, still above the figure recommended by the CDC of 5 μg/dL[32]. This result is lower than the Blacksmith Institute's measurement in Curug District, Tangerang Regency, where the average BLL value was 24.18μg/dL[33]. Another finding from this study results is that the average value of a lead in ambient air in residential areas close to ULAB is 0.4 μg/m^3. This value is lower than the standard set by the Indonesian government of 2 μg/m^3 [34]. These results differ from the findings of a 2011 study conducted by the Ministry of Environment and Forestry and BATAN at two locations where ULAB activities were present. Where found levels of lead in the air with an average value of 5.18 μg/m^3 in Cinangka, Bogor Regency, 17.50 μg/m^3 in Parung Panjang, Bogor Regency, and 4.14 μg/m^3 in Manis Jaya, Tangerang Regency[35]. While the results of the measurement of the average lead content in the soil in the area around residential areas are 13.95 μg/gr, this figure is much lower when compared to the results of research conducted by KLHK in 2019 where lead levels were obtained in the soil around the ULAB location. In the Cinangka area, the amount of 14393 μg/gr, and Parung Panjang was 10421 μg/gr[36].

The linear regression test results between the BLL variable and the age variable showed a weak relationship (r = 0.109), not statistically significant (P = 0.294), and had a negative equation. This result is different from several studies in China, which showed a tendency to increase BLLs with age[37,38]. The negative equation obtained from the regression test of this study is likely because children aged 7-11 years in Indonesia spend more time playing around their neighborhood than children aged 12-13 years so that children aged 7-11 years become more a lot of lead exposure. Apart from that, the study results also found that the mean BLLs score was higher in men than women. This finding is consistent with the literature[38,39,40].

ULAB unofficially in residences can be a source of lead exposure for nearby residents, particularly children[41]. This study's main finding was that a very strong (r = 0.777) and statistically significant (P = 0,000) between lead exposure to ambient air and BLLs in children aged 7-13 years. This finding is by the results of a study in Congo, where there was a significant relationship between lead in indoor air and BLL (r = 0.488; P = 0.0002) in children aged <3 years[42]. Meanwhile, a study in the United States using the National-Scale Air Toxics Assessment (NATA) data shows a significant relationship between lead levels in ambient air and BLLs in childhood[46]. Pb exposure in children occurs by swallowing and inhaling. The amount absorbed from the respiratory system depends on the particle size (<1 μm), the exhalation volume, the amount of precipitation, and the mucociliary clearance of inhaled Pb[43].

The quality standard for lead in the Indonesian government's air in Government Regulation Number 41 of 1999 is two μg/m^3 for 24-hour measurement time[34]. It is felt that it is still loose. Generally, in some countries, the quality standard for 24-hour measurements range from 0.75- 2μg/m^3 and 0.25-1μg/m^3 for 1-year measurements[44]. In India, the quality standard for lead in the air is divided into two categories: a). Ecologically Sensitive Areas (0.50-1.0 μg/m^3); b). Industrial, Residential, Rural, and Other Areas (0.50-1.0 μg/m^3)[45]. Meanwhile, in China, the quality standard for air lead is divided into Grade 1, 2, and 3 depending on the measurement location. The application of quality standards based on the area can also be applied in Indonesia, but this still cannot be realized because it is constrained by the spatial conditions of the area that are still not regular, such as industries in residential areas, schools and trade centers.

Despite these limitations, research results have found a strong and statistically meaningful association of elevated blood lead levels to airborne lead exposure in children living in used battery recycling areas. However, there have been no prior reports of environmental lead contamination. This finding can be one of the literature references to make a policy change related to determining the quality standard for lead in the air based on the area use function (area division). It is necessary to localize the handling of used battery recycling management, to reduce the possibility of sustainable contamination of lead exposure in the environment local. However, the blood lead levels in children aged 7-13 years, obtained from the study results, were still below the lead poisoning criteria[46]. But always must take measures to prevent children from exposure to lead because low levels of lead in the blood can endanger children's health.

5. Conclusion

Some children have the behavior of putting their hands in their mouths, using lead paint as a coating on the house walls, and having parents with low educational levels. The average value of lead content in ambient air was 0.4 μg/m^3, and the lead content in the soil was 13.95 μg/g. There was a weak relationship between the BLLs and the age (r = 0.109), and it was not statistically significant (P = 0.294). However, the average BLLs score for men was higher than that for women. There was a strong relationship (r = 0.777) and statistically significant (p = 0.000) between air lead levels and BLLs. It has a positive patterned equation, which means that if the air's lead level increases, the blood's lead level will increase. Even though the BLLs level in children was 8.58 μg/dL, it was still below the WHO recommendation. But we still have to take action to prevent children from being exposed to lead because low levels of lead in the blood for a long time can harm children's health.

6. Ethical Clearance

Research ethics permit is obtained from the Ethics Commission National Institute of Research and Development, Ministry of Health of Indonesia.

7. Conflict of Interest

The authors declare no conflict of interest.

8. Acknowledgments

Thank you to the Head of the Research and Development Agency, Head of the Center for Public Health Efforts, and Dr. Inswiasri, ST, M. Kes for giving the confidence to carry out the publication of this article.

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