Blood Lead Levels in Residents Around Used Battery Recycling Industries and Their Correlation with Clinical Laboratory Findings

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KEYWORDS

Lead, Heavy Metal, Recycling, Toxicity, Poisoning.

ABSTRACT:

Introduction: Lead exposure from used battery recycling factories has been reported to have major negative impacts on humans and the environment. This study aimed to evaluate blood lead levels and their association with hemoglobin, reticulocyte, albumin, urea, and creatinine levels in residents around a used battery recycling factory in Kadu Village, Tangerang Regency, Indonesia.

Objectives: By adopting a cross-sectional design and employing validated laboratory techniques, this research seeks to provide reliable evidence about the extent of lead toxicity and its clinical implications. The findings are expected to contribute to a better understanding of the health risks posed by lead exposure and to provide evidence-based recommendations for public health interventions.

Methods: The participants of this cross-sectional study were 40 residents of Kadu Village. Blood lead levels were measured using the Inductively Coupled Plasma Optical Emission Spectroscopy method. Albumin, urea, and creatinine levels were measured using a Cobas C311 spectrophotometer, while hemoglobin levels and reticulocyte counts were measured using a Sysmex XN-450 hematology analyzer.

Results: Median blood lead levels were 207.8 µg/L with a range of 126.6 - 379.3 µg/L. Participants who had hemoglobin levels below the reference values of 90 percent. Based on the Spearman test, blood lead levels were shown to have significant associations (p-value <0.05), respectively, with hemoglobin (r = -0.542), reticulocytes (r = 0.706), albumin (r = 0.609), urea (r = 0.665), and creatinine (r = 0.612).

Conclusions: Lead levels in residents around the used battery recycling factory in Kadu Village far exceed the threshold and be significantly associated with several important biomarkers. Apart from that, some residents are also starting to show signs of anemia. Further clinical treatment and community-based policies by the government are needed to eliminate lead exposure to residents.

1. Introduction

Lead exposure has become one of the chronic crucial health problems that need to be addressed, especially because of the toxic nature of lead, which impacts almost all of the human body's physiological systems (Gidlow, 2015; Ara & Usmani, 2015). Lead exposure to the body is always toxic, not only because lead does not play any role in metabolism or physiological processes but also because it interferes with enzyme activity and the immune system and triggers inflammation, thus negatively impacting many body functions, even at low concentrations (Cuomo et al., 2022; Harshitha et al., 2024).

The industrial sector is one of the main sources of lead exposure, and one of the main industries that is a source of chronic and high-concentration lead exposure is the battery industry (Kumar et al., 2020; Poudel et al., 2024). Studies on battery factory workers show high lead exposure to their bodies. In addition, a systematic review and meta-analysis also reported that battery factory workers in low- and middle-income countries had an average blood lead level of 37.996 µg/dL (30.680–45.312). This figure exceeds the blood lead level limit for workers recommended by the American Conference of Governmental Industrial Hygienists (ACGIH), which is 20 µg/dL (Kuraeiad & Kotepui, 2021; Lentini et al., 2017; Kalahasthi & Barman, 2018).

Lead exposure from used battery recycling factories, especially in developing countries, appears increasingly concerning (Chen et al., 2019). A modelling study by Ericson et al. estimated that there are approximately 10,599–29,241 informal used battery recycling sites in 90 low- and middle-income countries, with an estimated 1,594–1,849 sites in Southeast Asia (Ono & Horiguchi, 2021; Olana et al., 2022). The study also estimated that in Southeast Asian countries—excluding Indochina, the used battery recycling industry exposed 916,633 to 1,063,431 people to lead, resulting in mean blood lead levels of 31.15 µg/dL (19.5–55.8 µg/dL) in children aged 0–4 years and mean blood lead levels of 21.2 µg/dL (9.7–49.5 µg/dL) in adults living near the factory sites (Hygienists, 1995; Ericson et al., 2016). Studies in several countries have shown evidence that also verifies lead exposure from used battery factories to workers or residents in the surrounding area, for example, the study by Feng Zhang et al. in China, the study by Gomes et al. in Brazil, the study by Chien-Juan Chen et al. in Taiwan, and the study by Irawati et al. in Bogor Regency, Indonesia (Zhang et al., 2016; Gomes et al., 2023) (Ihtiaringtyas et al., 2024).

One of the used battery industries in Indonesia is located in Kadu Village, Tangerang Regency, Banten, Indonesia. Evidence shows high concentrations of lead in dust in people's homes, also in plants in the environment around the factory (Irawati et al., 2022; Budiyono et al., 2016). Studies on lead exposure in the population living in the environment around the factory have begun to be conducted, reporting indications of high urinary lead levels in adolescents, and high blood lead levels in the adult population and the population of elementary school-aged children. However, studies to further reveal the association or impact of lead exposure with health problems in the population around the factory in Kadu Village are still limited to previous studies, which showed a significant association between blood lead levels and serum glutamic oxaloacetic transaminase (SGOT) and serum glutamate pyruvate transaminase (SGPT) levels (Bobu & Noor, 2013; Levanta & Hananingtyas, 2023). This study aims to evaluate blood lead levels in residents around a used battery recycling industry in Kadu Village and their association with several important biomarkers of body function, namely albumin, hemoglobin, reticulocytes, urea, and creatinine (Hidayat et al., 2019; Levanta & Hananingtyas, 2023).

2. Methods

We conducted the study following ethical standards for health research. The study protocol has been reviewed and declared ethically acceptable by the Health Research Ethics Commission of Poltekkes Kemenkes Jakarta III (No. LB.02.02/F.XIX.21/3562/2024) (Lestari et al., n.d.).

This cross-sectional study was conducted in March-April 2024. The subjects lived in houses around a used battery recycling factory in Kadu Village, Curug District, Tangerang Regency, Banten Province, Indonesia. We have obtained permission from the local government and authorities, the Tangerang Regency Health Office, the Curug District Public Health Center, and the Kadu Village Head Office, to conduct the study (Lestari et al., n.d.).

Inclusion criteria included residents who had lived for at least a year in a house within a 600-meter radius of the used battery recycling industry location, were at least 19 years old, were not sick at the time of data collection, and were willing to participate voluntarily in this study. Meanwhile, exclusion criteria include women who are menstruating or residents who have a history of thalassemia (Organization, 2021).

Data collection and measurement

We explained this study both verbally and in writing to prospective participants. Prospective participants willing to volunteer to participate in this study then provide written consent. We used face-to-face interviews with participants guided by a written questionnaire to determine their socio-demographic profile, lifestyle and hygiene patterns, health history, knowledge of lead hazards, and housing conditions.

Venous blood specimens were used to determine lead, hemoglobin, reticulocytes, urea, creatinine, and albumin levels. Blood specimens were taken using the closed system method and collected in 3 ethylenediaminetetraacetic acid (EDTA) tubes and 1 plain tube, each containing 3 mL of blood, so the total blood specimen taken from each participant was 12 mL. Blood specimens in 2 EDTA tubes were used to examine blood lead levels, 1 EDTA tube was used to examine hemoglobin levels and reticulocyte counts, and 1 plain tube was used to examine albumin, urea, and creatinine levels (Nogueira et al., 2021).

A blood sample examination was conducted at the Regional Health Laboratory of the Special Capital Region of Jakarta Province. This laboratory has been certified by the Indonesian National Standard (SNI) International Organization for Standardization/International Electrotechnical Commission (ISO)/IEC 17025:2017. Examination of blood lead levels using the inductively coupled plasma optical emission spectroscopy (ICP-OES) method; examination of urea, creatinine, and albumin levels using the Cobas C311 spectrophotometer, while examination of hemoglobin levels and reticulocyte counts using the Sysmex XN-450 hematology analyzer (Otieno et al., 2022).

Hemoglobin, reticulocyte count, urea, creatinine, and blood albumin levels were categorized into three: “above the reference values”, “within the reference values” (within normal limits), or “below the reference values”. The reference limits refer to the values used in the Regional Health Laboratory of the Special Capital Region of Jakarta Province.24: hemoglobin (male 13.2–17.3 g/dL; female 11.7–15.5 g/dL), reticulocyte count (0.75–2.63%), urea (17–38 mg/dL), creatinine (0.45–0.75 mg/dL), and albumin (3.4–4.8 g/dL).

Statistical methods

Data analysis was performed with alpha 0.05 at a 95 percent confidence level. The Shapiro-Wilk test is used to determine the normality of data distribution of blood lead levels, hemoglobin, reticulocyte count, urea, creatinine, and albumin to determine bivariate tests. The Pearson or Rho Spearman correlation test was used to determine the correlation of blood lead levels, each with hemoglobin, reticulocyte count, urea, creatinine, and albumin. While the T test or Mann-Whitney test was used to determine differences in blood lead levels based on participant characteristics. Statistical analysis using IBM SPSS 20 (Himani et al., 2020).

3. Results and Discussion Neuron Density with HE Staining

40 participants volunteered to participate and met the criteria for this study. Table 1 shows that most participants were female; the average age was 42 years, a small number smoked. The furthest distance of the participant's house from the used battery recycling factory was 200 meters, while the closest was 5 meters. Most participants had lived around the factory location for more than 20 years, and some had lived there since birth. Most participants lived at home all day. The majority of participants claimed to have no history of serious illness. The proportion of participants who knew the dangers of lead exposure was only 30 percent (Wang et al., 2021; Nakhaee et al., 2019).

Table 1. Characteristics of participants

Variables		**Frequency**	**Proportion**
Sex	female	35	87.5%
	male	5	12.5%
Age (years)		mean ± SD: 42.4 ± 14 median (min - max): 42 (19 – 79)	
	≥ 60 years	5	12.5%
	< 60 years	35	87.5%
Distance from house to the factory (meters)		mean ± SD: 71.4 ± 60.9 median (min - max): 50 (5 – 200)	
	< 100 meters	25	62.5%
	100—200 meters	15	37.5%
Length of residence (years)		mean ± SD: 33.5 ± 18.4 median (min - max): 30 (1 – 79)	
	< 20 years	6	15.0%
	≥ 20 years	34	85.0%
Time spent at house per day (hours)		mean ± SD: 23.1 ± 2.6 median (min - max): 24 (12 – 24)	
	24 hours	34	85.0%
	< 24 hours	6	15.0%
Smoking habit	no	36	90.0%
	yes	4	10.0%
Habit of washing hands using soap	rarely	16	40.0%
	often	24	60.0%
Habit of eating using a spoon	rarely	33	82.5%
	often	7	17.5%
Habit of consuming supplements (vitamins)	not regular	35	87.5%
	regular	5	12.5%
History of serious illness	nothing	39	97.5%
	yes	1	2.5%
Knowing the dangers of lead exposure	no	28	70.0%
	yes	12	30.0%
House ventilation	yes/yes, but not sufficient	12	30.0%
	yes, sufficient	28	70.0%
SD - standard deviation; min – minimum; max - maximum			

All participants had blood lead levels exceeding 100 µg/L, with the highest blood lead level reaching 379.3 µg/L. The proportion of participants with hemoglobin levels below the reference values reached 90 percent. Meanwhile, 30 percent of participants had reticulocyte counts that exceeded the reference values. In addition, 55 percent of participants had urea and creatinine levels that exceeded the reference values (Table 2).

Tabel 2. Blood lead levels, hemoglobin, reticulocyte count, albumin, urea, creatinine

Variables	Frequency	Proportion
Blood lead levels (µg/L)	mean ± SD: 219.6 ± 66.7 median (min - max): 207.8 (126.6 – 379.3)	
0 – 49.9 µg/L	0	0%
50 – 99.9 µg/L	0	0%
100 – 199.9 µg/L	19	47.5%
200 – 299.9 µg/L	14	35.0%
≥ 300 µg/L	7	17.5%
Hemoglobin (g/dL)	mean ± SD: 11.2 ± 0.8 median (min - max): 11.3 (8.4 – 12.5)	
above the reference values	0	0.0%
within the reference values	4	10.0%
below the reference values	36	90.0%
Reticulocyte count (%)	mean ± SD: 2.3 ± 0.9 median (min - max): 2.1 (0.7 – 4.8)	
above the reference values	12	30.0%
within the reference values	28	70.0%
below the reference values	0	0.0%
Albumin (g/dL)	mean ± SD: 4.2 ± 0.5 median (min - max): 4.3 (3.2 – 4.9)	
above the reference values	1	2.5%
within the reference values	36	90.0%
below the reference values	3	7.5%
Urea (mg/dL)	mean ± SD: 36 ± 8 median (min - max): 39 (16 – 52)	
above the reference values	22	55.0%
within the reference values	17	42.5%
below the reference values	1	2.5%
Creatinine (mg/dL)	mean ± SD: 0.8 ± 0.2 median (min - max): 0.8 (0.5 – 1.6)	
above the reference values	22	55.0%
within the reference values	18	45.0%

below the reference values	0	0.0%
SD - standard deviation; min – minimum; max - maximum		

The results of the Shapiro-Wilk test showed that the data on blood lead levels, hemoglobin, reticulocyte count, urea, creatinine, and albumin were not normally distributed (p-value <0.05), so that the bivariate analysis used a nonparametric method (Kalahasthi & Barman, 2016). Table 3 shows the results of the bivariate test. The results of the Mann-Whitney test showed that statistically, there was no significant association between sex, smoking habits, handwashing habits, eating habits using spoons, supplement consumption habits, history of long-term illness, knowledge of the dangers of lead exposure, and the amount of ventilation in the house with blood lead levels (p-value > 0.05). In addition, although there were differences in blood lead levels based on age, distance from the house to the factory location, length of residence, and time spent at house per day, these differences were not statistically significant (p-value > 0.05). Meanwhile, in Figure 1, it can be seen that blood lead levels are proven to be statistically significantly correlated, respectively, with hemoglobin, reticulocyte, urea, creatinine, and albumin levels (p-value < 0.05).

Table 3. Blood lead levels based on participant characteristics

Participant characteristics		**Blood lead levels (µg/L)**		**P-value**
		Mean ± SD	**Median (min – max)**	
Sex	male	233.1 ± 66.6	249.4 (126.6 – 308.3)	0.449
	female	217.7 ± 67.4	190.7 (128.4 – 379.3)	
Age	≥ 60 years	228.6 ± 78.1	254.5 (126.6—316.2)	0.698
	< 60 years	218.3 ± 66.1	204.8 (128.4—379.3)	
Distance from house to the factory	< 100 meters	224.1 ± 70.4	210.8 (126.6—379.3)	0.665
	100—200 meters	212.1 ± 61.4	189.3 (128.4—362.0)	
Length of residence	< 20 years	243.0 ± 71.4	226.8 (153.0—362.0)	0.384
	≥ 20 years	215.5 ± 66.0	190.1 (126.6—379.3)	
Time spent at house per day	24 hours	223.9 ± 69.8	207.8 (126.6—379.3)	0.344
	< 24 hours	195.4 ± 40.7	192.0 (153.0—249.4)	
Smoking habit	yes	259.8 ± 34.5	252.0 (226.8 – 308.3)	0.087
	no	215.1 ± 68.1	190.1 (126.6 – 379.3)	
Habit of washing hands using soap	rarely	219.7 ± 63.9	210.9 (128.4 – 362.0)	0.761
	often	219.5 ± 69.8	200.1 (126.6 – 379.3)	
Habit of eating using a spoon	rarely	218.8 ± 66.0	210.8 (126.6 – 379.3)	0.986
	often	223.4 ± 75.0	189.3 (159.4 – 362.0)	
Habit of consuming supplements (vitamins)	not regular	219.3 ± 65.2	210.8 (126.6 – 379.3)	0.759
	regular	221.8 ± 84.4	189.3 (159.4 – 362.0)	
History of serious illness	yes	308.3 ± 0.0	308.3 (308.3 – 308.3)	0.242
	nothing	217.3 ± 65.9	204.8 (126.6 – 379.3)	

Knowing the dangers of lead exposure	no	226.8 ± 70.7	215.2 (126.6 – 379.3)	0.360
	yes	202.8 ± 55.3	185.1 (128.4 – 308.7)	
House ventilation	yes/yes, but not sufficient	240.2 ± 79.4	232.6 (137.9 – 379.3)	0.302
	yes, sufficient	210.8 ± 59.9	197.8 (126.6 – 362.9)	
SD - standard deviation; min – minimum; max – maximum;				

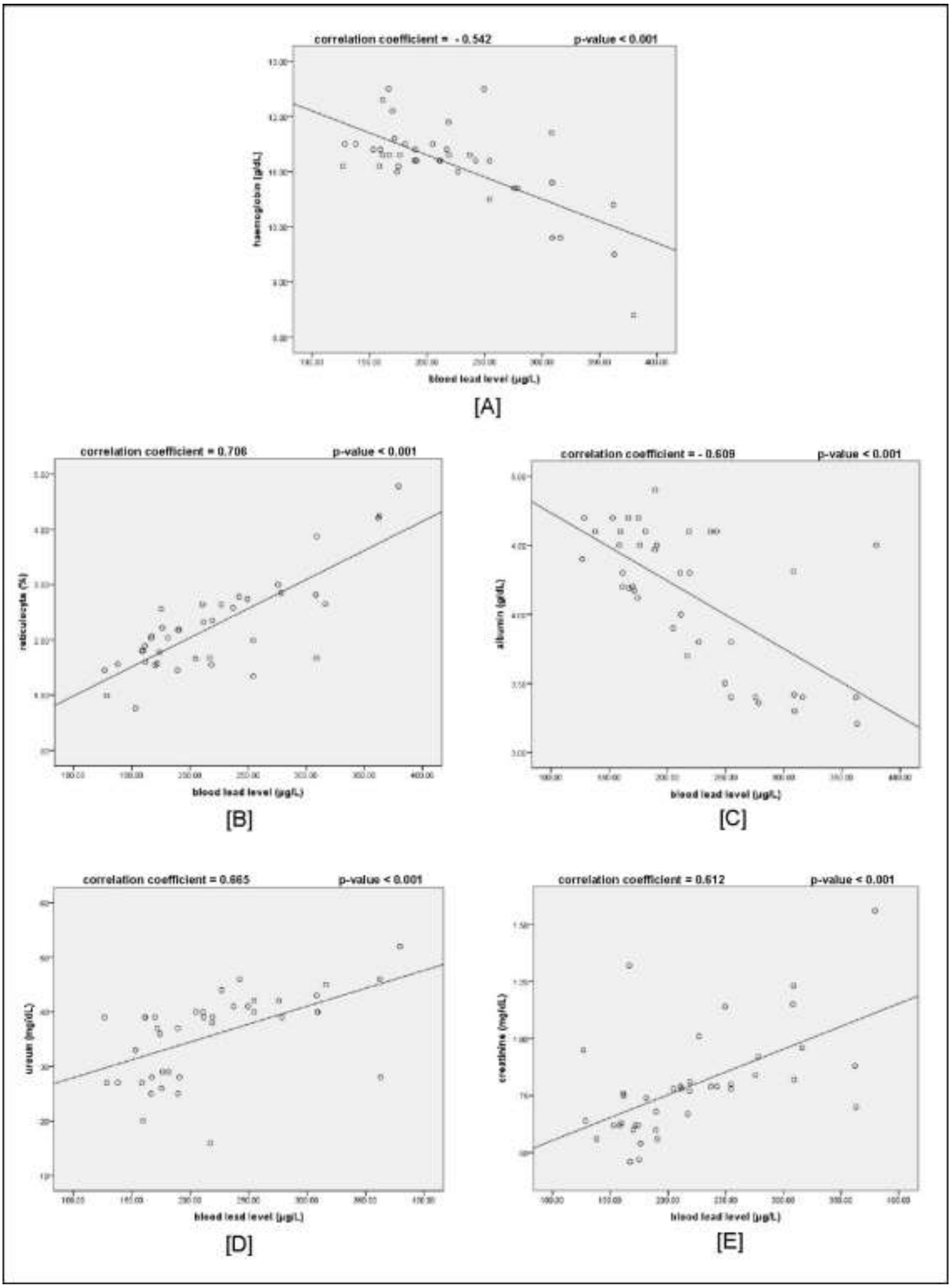

Figure 1. Correlation of blood lead levels with hemoglobin [A], reticulocytes [B], albumin [C], urea [D], and creatinine [E]

Discussion

The blood lead level threshold recommended by the World Health Organization (WHO) is 5 µg/dL (50 µg/L). Thus, all participants in this study had blood lead levels exceeding this threshold, showing evidence of lead toxicity in residents around the used battery recycling factory in Kadu Village. Comparing with the results of a previous study by Lestari et al., which also reported that in 2021 all participants in their study had blood lead levels exceeding the threshold, it appears that lead levels in the population are currently still high. Given that blood lead levels are an indicator of lead exposure at the time of the examination, this indicates that high lead exposure in residents around the used battery recycling factory in Kadu Village continues to occur (Słota et al., 2022).

Currently, we have not found any recent studies on lead concentrations in the residential environment of Kadu Village. However, a study by Bobu et al. in 2011 showed high lead concentrations in dust in residents' houses around the factory (with an average range of 442-558 µg/ft² in indoor floor dust and 505-5066 µg/ft² in yard soil dust). The range of values far exceeds the upper limit of lead concentration in floor dust according to the United States Environmental Protection Agency (EPA) at that time, which was 40 µg/ft² (the EPA then lowered the limit to 10 µg/ft² in 2019, and in 2024 it is considering lowering the threshold again to 5 µg/ft²). In addition, a study by Hidayat et al. in 2017 also showed high lead concentrations in tree leaves around the Kadu Village area (with a range of 152.1-700.8 ppm). It is likely that, even at this time, lead contamination in dust and the environment around the factory in Kedu Village is still high because the factory is still operating. In addition, it is possible that lead from the used battery factory also contaminates vegetables and water in the environment, considering that evidence in other countries shows that soil, vegetables, and water around used battery factories tend to be more contaminated with lead. Lead contamination in dust and the environment is what most likely—especially through the respiratory and digestive routes—causes high blood lead levels in the participants of this study (Firoozichahak et al., 2022).

In this study, there was no significant association between participant characteristics and their blood lead levels. Although groups of participants with certain characteristics, such as male, over 60 years old, distance from house to the factory location less than 100 meters, length of residence there less than 20 years, or living at home all day, tended to have higher blood lead levels, it was not statistically significant. In our study, it seems that participants were too dominated by one characteristic. For example, most females, reaching 87.5 percent, have lived in the area for more than 20 years, and 85 percent of participants live all day in the house. All participants also live in houses within a radius of 200 meters or less from the factory location. Previous study showed high dust concentrations exceeding the threshold even up to a radius of 600 meters from the factory location. It seems that the difference in houses distance in this study was not enough to cause a significant difference in blood lead levels in participants. However, in this study, the large difference in the number of participants between groups of different characteristics may have contributed to the bias of statistically insignificant differences in blood lead levels between groups (Kalahasthi et al., 2019).

Several previous studies in other countries showed that differences in participant characteristics and residence were significantly associated with blood lead levels (Harari et al., 2018). A study by Feng Zhang et al. showed that blood lead levels in children who lived near a used battery factory were higher in children who lived in houses closer to the factory; according to them, perhaps because at a closer distance, lead contamination was carried by dust that tends to be much more. Feng Zhang et al.(Zhang et al., 2016) also reported that blood lead levels in younger children tended to be higher, possibly due to more frequent hand-mouth movements and more active intestinal absorption in children. However, there is another study that reported higher blood lead levels in older battery factory workers. The relationship between age and blood lead levels may be a local population influenced by many factors and is more complex (Reilly et al., 2018).

Meanwhile, there are also studies that report that lead toxicity in males tends to be higher. In the children's population, boys tend to play outside more often so that they are more often exposed to lead from dust, which makes their blood lead levels higher than girls. In the adult population, lead levels in males tend to be higher, perhaps because the higher hematocrit in men causes lead binding to erythrocytes also to increase.

Most of our study participants had hemoglobin levels below the reference values. There was a tendency for some participants to start experiencing mild anemia. In addition, it appeared that some participants began to experience an increase in reticulocyte counts. This indicates that lead toxicity began to interfere with the hematological system in some of the population. Most participants still had albumin levels within the normal range, indicating no significant disruption of albumin formation. It appears that lead toxicity in the population has not yet disrupted liver function. The results of previous studies showed no increase in SGPT, and although a small number of participants began to show a slight increase in SGOT, it did not appear to be significantly significant (Yimthiang et al., 2022). In addition, although statistically, more than half of the participants had urea and creatinine levels slightly above the reference values, the increase did not appear to be significant. It did not indicate significant kidney function impairment. The results of a previous study on battery factory workers in India showed that although there was an increase in urea and creatinine in workers, the increase was not immediately clinically significant. The clinical impact of elevated blood lead levels in people living around battery industries is likely to occur slowly. Anemia is one of the clinical disorders that will first appear along with elevated blood lead levels, and the results of this study seem to be one of the supporting pieces of evidence.

Our study showed that blood lead levels had significant associations with hematological biomarkers: negatively correlated with hemoglobin and positively correlated with reticulocytes. These results strengthen previous evidence that confirms the relationship between lead and anemia and reticulocytosis. Lead is associated with the risk of anemia because it interferes with important enzymes in heme synthesis and increases the risk of erythrocyte damage. However, a study by Irawati et al. reported that blood lead levels in children living around a used battery recycling factory did not have a statistically significant association with hemoglobin levels (Rana et al., 2018). The emergence of variations in study results on this matter may be due to differences in population size and age range, as well as the impact of differences in sources, duration, and severity of lead exposure that cause differences in its toxic impacts.

In this study, it was proven that blood lead levels were significantly negatively correlated with albumin levels. These results are in accordance with a cohort study by Firoozichahak et al. in Iran, which reported that blood lead levels in lead mine workers were significantly negatively correlated with albumin, globulin, total protein, and triglycerides. However, our study results contradict the study of Kalahasthi et al. in India, which reported that blood lead levels in battery factory workers were not significantly correlated with serum albumin levels. However, they were significantly correlated—with relatively weak correlation coefficients—with total serum protein, serum globulin, and albumin/globulin ratio, respectively. However, a significant decrease in albumin may indicate that lead can interfere with serum protein synthesis, and may also indicate that lead begins to interfere with liver function (Camaj et al., 2020; Barregard et al., 2022).

Our study also proved that blood lead levels were positively correlated with urea and creatinine levels. These results support previous studies, which proved the association of blood lead levels with decreased kidney function. Evidence from a previous cohort study also showed that lead toxicity causes decreased kidney function even at low blood lead levels. Nephrotoxicity by lead is a very serious problem because it is the most common metal that is toxic to the kidneys and exposes humans through various routes: air, water, and food. The interaction of lead with other metals can also increase its toxicity. The characteristics of lead that can be absorbed and concentrated by the kidneys cause this metal to be nephrotoxic, with the degree of damage being influenced by the dose and duration of exposure. The mechanism of nephrotoxicity by lead may occur through the oxidative stress pathway and lipid peroxidation that damages kidney cell organelles or through calcium homeostasis disorders that damage mitochondria, thus disrupting fat metabolism, ultimately damaging kidney cells. In addition, the nephrotoxic properties of lead will also ultimately affect hematology because of their effect on erythropoietin production. Lead toxicity at medium to high doses to the kidneys can be identified through histopathological damage, although at low doses it may not be sufficiently manifested.

These results also provide evidence of lead toxicity in residents around used battery recycling factories. The results of this study also contribute to proving the association of lead with the risk of liver, hematology, and kidney damage. However, we realize that this study has several limitations. All of our study participants live within a close radius of the factory. Participants with more varied home distances from the factory location may be better at revealing the level of risk of increased blood lead levels based on home distance. In addition, limited access and resources made it impossible for us to include a group of factory workers to quantify the level of risk of increased blood lead levels for residents living around the factory compared to factory workers. Most of our study participants were also housewives who spent more time at home, so our study results may not sufficiently represent other population groups around the factory.

4. Conclusion

Lead toxicity in residents around a used battery recycling factory in Kadu Village shows that lead exposure in residents continues to occur, not yet indicating effective control of lead exposure. There are indications of a decrease in hemoglobin levels among residents. In addition, blood lead levels in the population have also been shown to have a significant association with hemoglobin, reticulocytes, albumin, urea, and creatinine. WHO25 recommends both community-based clinical management and actions to reduce or eliminate sources of lead exposure in cases where blood lead levels exceed the threshold. There needs to be a clinical intervention with a community approach from the local health office and health center around the used battery factory in Kadu Village. In addition, the local government also needs to review and further consider policy options to eliminate lead exposure from the used battery recycling factory. Further studies may need to be conducted to identify the extent and level of lead exposure in residents within a greater radius of the house from the factory location and to evaluate the concentration of lead in dust and the environment around Kadu Village. In addition, studies also need to be conducted with a larger sample size, covering residents with more varied characteristics, and including factory workers as participants.

Conflict of Interest

This study does not have any conflicts of interest because the researcher's publication or research would not be influenced by any financial or personal interests.

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