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LEAD EXPOSURE AND INDONESIAN CHILDREN'S HEALTH IN JAVA ISLAND

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EDITORS:

- MUCHTARUDDIN MANSYUR
- BUDI SUSILORINI
- DEWI YUNIA FITRIANI
- SARAH EDNA

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Muchtaruddin Mansyur
Dewi Yunia Fitriani
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Sarah Edna
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Tel. +62 21 319-35373; 319-30172; 319-30252
Kompleks ILRC Gedung B Lt. 1 & 2
Perpustakaan Lama Universitas Indonesia
Kampus UI, Depok, Jawa Barat 16424
Tel. +62 21 788-88199; 788-88278
E-mail: uipublishing@ui.ac.id
Website: www.uipublishing.ui.ac.id

FOREWORD

It is crucial to protect children from exposure of hazardous materials including lead, since the impacts are long term and can be irreversible. The Faculty of Medicine Universitas Indonesia hosted the Indonesian Medical Education and Research Institute (IMERI) consists of 6 education and 15 research clusters including the Occupational and Environmental Health Research Centre (OEHRC). OEHRC FKUI shares a common vision with Pure Earth in protecting individuals from hazardous material exposure in the realms of health and the environment.

On this occasion, collaboration between OEHRC FKUI and Pure Earth, was carried out to increase awareness about lead exposure in children and its health impacts. Indonesia is one of the country that have high risk of lead exposure due to high activities related to lead. These lead exposures in children were obtained from both indoors and outdoors environment which need to be addressed immediately.

This book presents the sources of lead exposure and Indonesian children's blood lead levels profiles and their health status. We hope that this book serves as a valuable reference and may trigger prompting collective actions from all concerned parties.

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LIST OF ABBREVIATIONS

BLL	: Blood Lead Level
CI	: Confidence Interval
DALYs	: Disability Adjusted Life Years
dL	: Deciliter
FDA	: U.S Food and Drug Administration
HBA	: Home Based Assessment
IDAI	: *Ikatan Dokter Anak Indonesia* / Indonesian Pediatric Society
ITS	: Institute Technology of Surabaya
KPBB	: *Komite Penghapusan Bensin Bertimbal* / Leaded Gasoline Elimination Comitte
KPSP	: *Kuesioner Pra-Skrining Perkembangan* / Pre-screenning Developmental Questionnaire
Pb	: Plumbum
PDQ	: Prescreening Developmental Questionnaire
PE	: Pure Earth
PECP	: Protecting Every Child's Potential
Ppm	: Parts per million by weight
SD	: Standard Deviation
TSIP	: Toxic Site Identification Program
ULABs	: Used Lead Acid Batteries
US-EPA	: United States-Environmental Protection Agency
WHO	: World Health Organization
XRF	: X-Ray Fluorescence

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>>>

CHAPTER

I.1 Lead Exposure and Health Hazard

It is known that pollution is a major global hazard for children, which air pollution, poor sanitation and neurotoxic substances are serious health hazards for children globally, including in Indonesia[1–3]. Lead is a highly neurotoxic substance in which pregnant women and children are the most vulnerable ones to the effects of lead[4]. A joint UNICEF and Pure Earth study by Rees and Fuller in 2020 has estimated that globally one in three children (making up 800 million) have elevated blood lead levels[5]

Since lead presents in air, soil and water, young children are particularly vulnerable to exposure from lead because of their hand to mouth activity and because they play close to, or on the ground where lead can be in the soil[6]. Ingestion is the most common way that lead in soil gets into children since they usually put fingers, toys and other objects exposed to lead into their mouth. The higher its concentration in soil, the higher the health risk from it[7]. Duration of lead being absorbed to toxic levels by a child, depends on its concentration in the dust. In a typical lead-contaminated housing unit, it takes one to six months for a small child's blood-lead levels to rise to a level of concern[8]. Furthermore, ingestion of lead by eating and smoking with unwashed hands and inhalation of lead fumes are defined as the mode of entry of lead in the occupational environment.

Lead pollution causes several devastating consequences in medical conditions and high expenditure[9]. Exposure in the human body may affect brain and nervous system, slowed growth and development, anemia, learning and behavior disorders, hearing and speech problems, failure in school, low productivity[6,10] and economic output, as well as deaths and high disability adjusted life years (DALYs)[11].

I.2 Lead Contamination in Indonesia

Informal and substandard recycling of lead-acid batteries is a leading contributor to exposure in areas in low and middle-income countries. For Indonesia lead exposures have been attributed to the haphazard collection and recycling of Used Lead Acid Batteries (ULABs)[12], lead in paint, artisanal and small-scale gold mining, industrial activities, cigarettes, metal food ware, coal-fired thermal power plants and traditional clothes dye[13, 14–18]. These and other new sources of lead exposure have increased volumes of lead in the environment. Moreover, the increased volumes, the complexity of handling and their environmental interactions have thus moved the issue of lead exposure in Indonesia beyond workplaces exposure into air, water, and soil, thus posing public health concerns to the general population.

Blacksmith Institute, now known as Pure Earth, has performed a regional inventory of contaminated sites in Asia. In 2013 data for those lead contaminated sites were published. As shown in Table 1 lead levels in soil were identified in 23 places in Indonesia (425-6.909 ppm)[15].

Table 1. Lead contaminated sites and environmental levels [19]

Country*	Contaminated sites discovered		Range of environmental lead levels	
	Lead in soil	Lead in water	Lead in soil (≥ 400 ug/g)	Lead in water (≥ 150 ug/l)
Bangladesh	0	1	-	190
India	7	21	400–6909	152–135,000
Indonesia	23	1	425–83,000	840
Kazakhstan	2	0	3399–9296	-
Pakistan	2	0	404–2505	-
Philippines	22	2	721–692981	320–488
Thailand	1	0	143,097	-
TOTAL	57	25	400–692,981	190–135,000

I.3 Used Lead Acid Batteries (ULABs) as Lead Sources

It is common in Indonesia to recycle lead batteries. Therefore, very high levels of lead in soil are reported, up to 270.000 ppm[20]. Thresholds for soil are, by US-EPA and WHO: 400 pm; while the standard in Indonesia is 300 ppm (the Government Regulation No. 22 Year 2021 and the Regulation of Minister of Environment and Forestry No. 101 Year 2018)[1,2]. We refer here to a publication, which shows some of the hotspots in Indonesia[21]. Figure 1 shows the distribution pathways of lead battery trading in Indonesia. Figure 2 shows the location of ULAB recycling related activities.

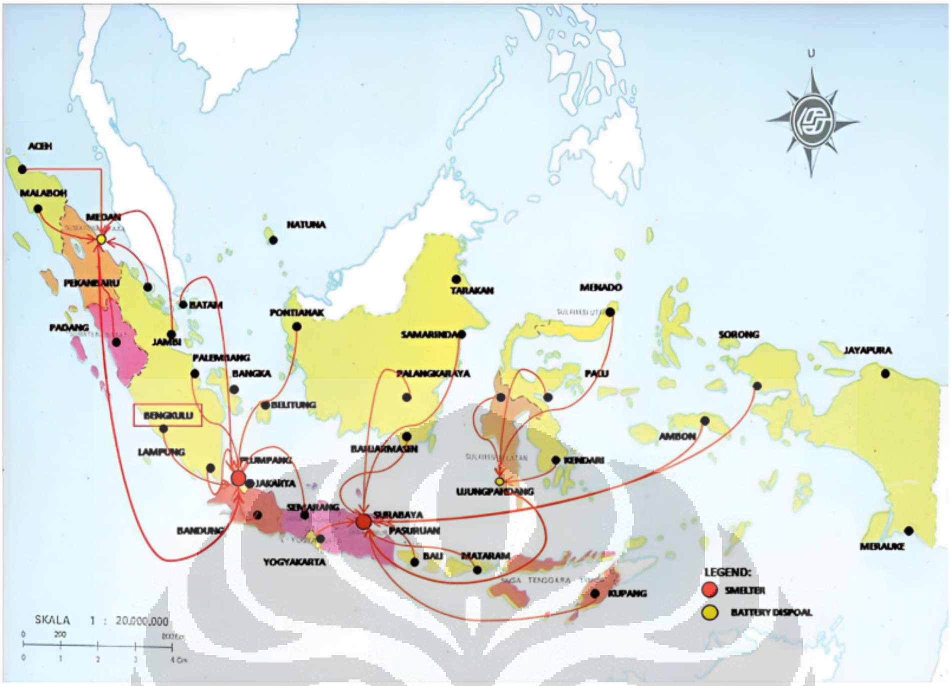

Figure 1: Distribution of lead battery trading in Indonesia[21]

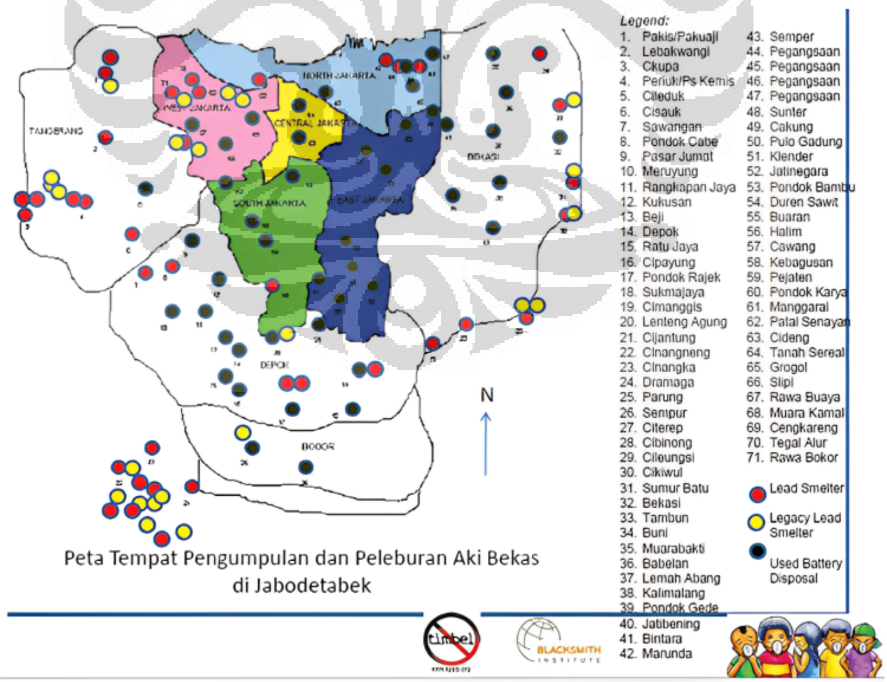

Figure 2: Lead battery recycling smelters, legacy lead smelter, and used battery disposals in Jakarta Greater area 2009 (KPBB-BSI)[21]

I.4 Previous Findings of Lead Exposures in Indonesia

There are few studies evaluating blood lead levels among Indonesian children within a city or village. In 2005, a study conducted after the phaseout of leaded gasoline in Jakarta observed a lower average BLL among primary students (4.2 µg/dL) with 1% children above 10 µg/dL in Jakarta[22]. The average of BLLs in a study with 400 children in 2013, aged 9-11 years, in Bandung was 14.1 µg/dL (3.1–11.7) µg/dL for females[23]. A study in Samarinda city in 2019 assessed BLLs of 39 street children, showing mean BLLs of 11.7 µg/dL, range 3 to 24 µg/dL[24].

Due to concerns about severe lead pollution from used lead acid battery (ULAB) recycling sites, several studies focused on children living in communities near these sites. One study was performed in 2018 in three neighborhoods of Greater Jakarta (sub districts of Pegangsaan Dua, Cipondoh, and Dadap) where ULAB recycling occurs. BLLs of 279 children aged 1-5 years living near to ULABs were assessed, with a geometric mean of 4.7 µg/dL for those children living near to an ULAB[16]. Forty-seven percent of children had BLLs ≥ 5 µg/dL and 9% had BLLs ≥ 10 µg/dL, risk factors for higher levels were older age of the child, low household income, low education of father, frequent outdoor activities[16]. Between 2011-2015, increasing BLL were found in Pesarean village, Tegal Regency with mean levels between 9.0 and 39.3 µg/dL[21].

The more recent study carried out by Irawati Y, et al [25,26] from Cinangka reported in 2021 an average BLL of 17.0 µg/dL, range 4.0 to 65.0 µg/dL, among children under 5 years of age which means there were some change from former study in Cinangka reported in 2019 BLL of 14.0 µg/dL, maximum 51.1 µg/dL, among 103 scholars[20]. Jack Caravanos from Pure Earth and co-authors estimated for Indonesia that approximately 10.000 children (0-4 years) live near lead contaminated sites[15]. They modelled the data and came up with a range of to be expected blood lead levels in children between 5.1 and 81.4 µg/dL.

Another study was held in 2021/2022 by the Sepuluh Nopember Institute of Technology, Surabaya (ITS), with technical support from Pure Earth, by implementing the “Toxic Site Identification Program” (TSIP)[27], which assessed 95 locations that have the potential to pollute lead to the environment on the islands of Java and Sumatra. Of these, 67 locations are located on Java Island and 89.6% are activities related to the recycling of used batteries. The ITS team also conducted an analysis of the ULAB supply chain, one of the findings being that ULAB collected on the island of Sumatra were sent to Java for recycling. Thus, population density and ULAB frequency are highest on Java, so we decided to perform the study on Java, in four different areas with high lead exposure for children. This project focused on locations with known previous or present operations of ULAB sites on Java Island (i.e., Cinangka (see figure 3), Surabaya (see figure 4), Pesarean (see figure 5)[5]. In 2020, the estimated population of children under 5 of the three provinces containing these communities are 2,004,029 (West Java), 1,379,446 (Central Java), and 1,438,430 (East Java).

II

CHAPTER

II.1 Awareness of Lead Exposure in Indonesia

Lead poisoning contributes to a significant disease burden in Indonesia. There is no known safe level of lead in blood[28]. As lead exposure increases, the range and severity of symptoms and effects also increases[10]. This threshold which used to be known as the 'level of concern' and later the 'blood lead reference value (BLRV)' has recently been reduced from 5μg/dL to 3.5 μg/dL[29].

Unfortunately, there are gaps in data and information availability on lead in relation to its life cycle in Indonesia including the role of the informal sector in ULAB recycling, levels of contamination from lead in products. Also, there is limitation of data in relation to environmental exposures and human biomarkers linking with health effects. Furthermore, the health sector in Indonesia does not yet have well established services for the prevention and management of lead poisoning, because lead impacts have not yet been a national priority in Indonesia and activities of health services in Indonesia to prevent lead poisoning have been only on an ad-hoc basis.

This BLL testing study can inform the Government of Indonesia of the prevalence and severity of lead poisoning among young children, the geographic variability in its occurrence, and illuminate the most significant sources of exposure. This present findings focused to assess the prevalence of high lead levels and its severity among vulnerable groups of children age 12 to 59 months in four areas with known hot spots for lead contamination from formal and informal lead-based industries (ULABs), also to compare those BLLs among children in control areas with similar socio-demographic conditions, in neighboring settlements.

Moreover, this study aimed to identify the source of lead exposure by doing home-based analysis, counting the exposure from parents, who bring lead contaminants from workplaces or outside environments.

Referring to the most recent work of Institute Technology of Surabaya (ITS), this study focused on four locations on Java Island where previous or present operations of ULAB sites took place (Tangerang, Pesarean, Cinangka, and Surabaya). The control area is defined as an area located at least 2.7 km away from the hot spot, which this distance is the average radius that elevated blood lead measures have been reported based on review of 11 studies measuring blood lead levels and point source exposures[30]. In this study, correspondingly, estimation of the human body burden of lead was done through measurement of concentration or levels of blood lead.

This book presented the description of blood lead levels (BLLs) among children between the ages 12 to 59 months living near lead hotspots (ULAB sites) on Java Island including the BLLs among children (12-59 months) based on lead exposure level and their anemia status, and growth and developmental status. This book also describe the correlation between children BLL and variable of lead exposures as risk factors (such as leaded paint, cookware, dust, water, food and parent exposure) and BLL in children. Furthermore, this book presented the association between children's BLL and their hemoglobin/anemia status and growth and development.

II.2 Children's Protection Against Lead Exposure

In order to accomplish the main objective of implementing the Protecting Every Child's Potential (PECP) project, targeting to reduce the risk of lead exposure in children, it is crucial to understand the lead exposure among Indonesian children through local and up-to-date data. Measurement and testing of BLL done in this study will inform the Government of Indonesia and related stakeholders of the prevalence and severity of lead poisoning among young children, the geographic variability in its occurrence, and illuminate the most significant sources of exposures. The data and information gained from this study will be essential for advocating future interventions, counting on building a lead surveillance system and developing policies and programs to protect the health of children and the nation's future.

III

CHAPTER

III.1 Identification of Lead Contaminated Area in Java Island

This is a cross-sectional study design for assessing BLL among children 12-59 months of age in the neighborhood of previous or present operations of ULAB sites that have been identified through Toxic Site Identification Program (TSIP) studies as hotspots for lead selected from Java, Indonesia. Referred to the results of the TSIP carried out by ITS on Java Island at the end of 2021, the selection criteria of areas based on the status of used battery recycling activities at that particular location, the results of measurements of lead concentration in soil, the number of at-risk populations and the presence or absence of support from the government at national and regional levels. The chosen areas for study at first were Cinangka Village in Bogor Regency, West Java Province; Surabaya Municipality in East Java Province; Manis Industrial Area, Tangerang Regency, Banten Province, and Pesarean Village in Tegal Regency, Central Java Province.

Cinangka is a village located at the foot of Mount Salak in the southwestern part of Bogor City. Cinangka is part of Ciampea District, Bogor Regency. The land use of Cinangka is mostly forest, agriculture and plantation areas with a hilly topography. Based on data from the Ciampea District website, from the 2019 population census, the population of Cinangka is 12,941 people with a distribution of 6,603 males and 6,338 females. The education level of the population is dominated by elementary school graduates and the equivalent and most population work as private employees and are self-employed. There are 14 elementary high school buildings, one public health center and one health clinic in the area.

Cinangka was previously known as a village where most of the population made a living as informal ULAB recyclers. These activities have caused almost the entire village area to be polluted with lead (plumbum/Pb). This pollution has an impact on public health, as indicated by the high levels of lead in the blood of school children. Further additional exposure from daily habits and environment, which have not been identified may increase the blood lead level.

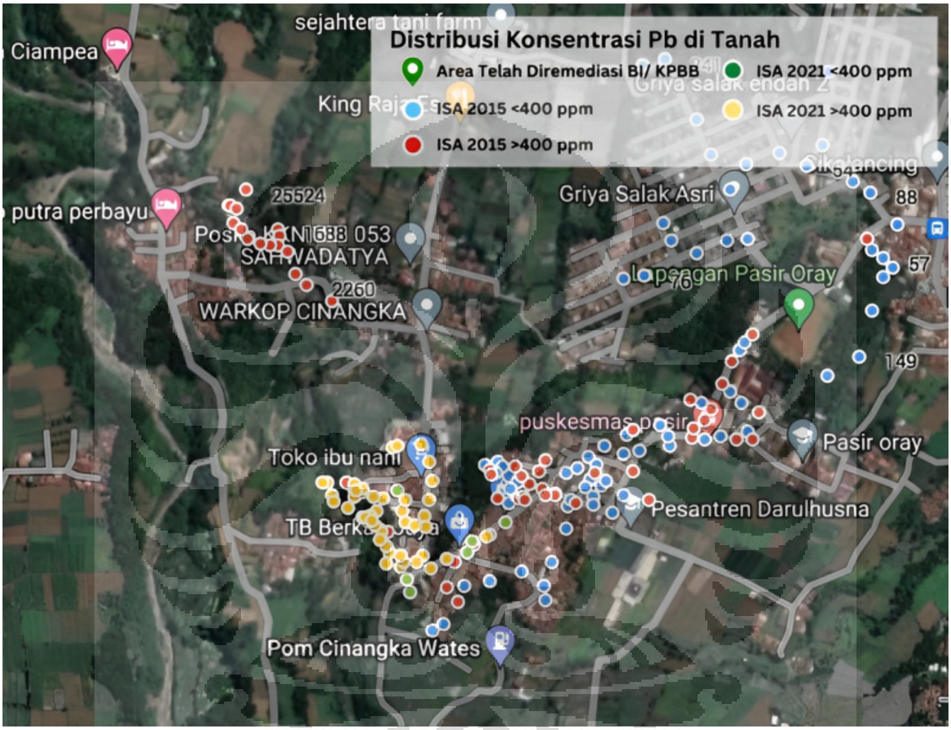

Figure 3: Distribution of lead concentration in soil in Cinangka

Demak Street is located in Dupak Village, Krembangan District, Surabaya Municipality, East Java Province. Dupak Village is the most populous village in Krembangan District, Surabaya Municipality, with an area of 0.48 km^2 and a population of 21,663 people. With the distribution of education levels dominated by the population who do not/have not attended school and have not/have not finished elementary school. With the distribution of livelihoods most are not/not yet working, private employees and self-employed. There are six school buildings located in the Dupak Village, starting from elementary to high school or equivalent. There are two clinics and one public health centre with inpatient facilities in Dupak Village.

Demak Street hosts a flea market that has been in operation since 1967, primarily serving as a hub for the sale of secondhand goods. This area was designated as a relocation spot for traders from other locations within the Surabaya Municipality. Its peak period was during the 1970s until shortly before the 1998 economic crisis. Presently, the Demak Street flea market primarily functions as a trading center for spare parts of motor-cycles, with a particular focus on two-wheelers. Furthermore, in various spots along Demak Street, several vendors are involved in transactions related to ULAB and battery reconditioning. Notably, ULAB storage is also observed within shop buildings or kiosks at various points along Demak Street.

The results of the TSIP conducted by ITS in 2021 show that there are several points showing very high lead concentrations in the Demak Street area. High levels of lead are generally found near locations where used batteries are traded, repaired, or stored. The highest lead contamination detected by the ITS team reached 111,500 ppm.

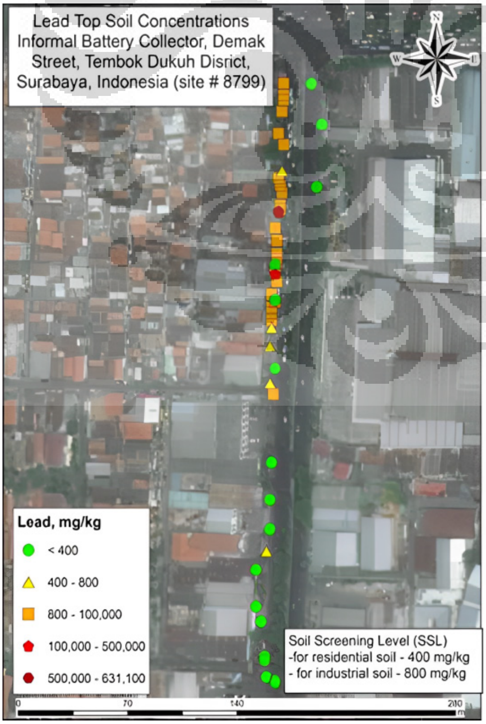

Figure 4: Distribution of lead concentration in soil on Demak Street, Surabaya

From a study conducted by Pure Earth and Leaded Gasoline Elimination Committee (*Komite Penghapusan Bensin Bertimbel/KPBB*) in 2012, there was suspected recycling facilities contributing to high lead contamination (above 300 ppm) around its facilities in Kadu Village. Lead contamination on the soil surface was found to be quite consistently high starting from the studies which was conducted in 2012 and 2014 by Pure Earth and KPBB, until 2021 in a study which was conducted by ITS.

In addition to lead contamination in the soil, Pure Earth and KPBB have also done BLL testing using LeadCareII on workers and residents living around recycle companies. The findings revealed that the blood samples collected from ULAB recycling workers (consisting of 16 respondents from the years 2020 to 2011) all measured at 65 μg/dL. This value coincides with the upper measurement limit of the LeadCareII tool, suggesting that the blood lead levels of the sampled workers are at a minimum of 65 μg/dL. As for the local community, blood samples were gathered from 41 school children in 2010, yielding results ranging from 12.10 μg/dL to 47.80 μg/dL.

In this study, we initially received no response from village officials of Kadu Jaya to conduct the study. Then, our study team approached and received a positive response from officials of Kadu Jaya Village to do the study. Kadu Jaya Village has similar society characteristics to Kadu Village and it's located in radius of 2.3 kilometers from the industrial area.

Pesarean has an area of 13.08 km^2 with a population of 12,398 people (Statistics Indonesia, 2019). The people of Pesarean have their main source of livelihood in services and industry. There are 67 metal industry groups that employ 265 workers from Pesarean. There are at least 10 schools in Pesarean, starting from kindergarten to high school. There is one public health center in Pesarean. Also known that low nutritional status for children under five in this village is relatively high compared to other villages in Adiwerna District.

Pesarean is a village that is famous for its people's skills in producing metal crafts. For more than 50 years this activity has been the main livelihood of the people of Pesarean, from the production of kitchen utensils to automotive accessories, all of which can be produced in this village in a relatively traditional way. The raw materials for these metal crafts come from used goods collected by the community from various places, to then be sorted based on the basic materials of these used goods. This activity of collecting used goods has made some residents find that some used goods have more economic value than others, one of which is ULAB. The community knows that the lead content in ULAB is large enough to be recycled and sold as a raw material that is ready for use/ready to sell.

In Pesarean, the ULAB smelting began to take place along with the smelting of aluminum and the production of metal crafts. With household scale management, these activities then create new problems. Among them are the smoke from smelting that most people complain about and the remaining smelting waste that is piled up in an open area in the middle of the Pesarean. It was this complaint from the community that in 2015 was followed up by the Government of Tegal Regency by relocating ULAB smelting in Pesarean Village to Kebasen Village where the government established a small industrial area. This relocation was a quick response from the Government of Tegal Regency to stop direct pollution to human health and the environment. However, the pollution resulting from the accumulation of ULAB smelting remains in the middle of the village and requires further handling. Before relocating, the Government of Tegal Regency measured lead levels in the blood of metal smelting workers in Pesarean village. The results showed that out of 50 samples 92% had lead levels >30 µg/dL.

The Central Government also responded to the problems in Pesarean through the Ministry of Environment and Forestry and in collaboration with Mer-C in 2011, by measuring the blood lead levels. Three hundred and sixty-five blood samples consisting of workers and people living in Pesarean Village were taken and showed 8,8% had lead levels >30 µg/dL. Four years later, in 2015, another health study was also conducted by the Blacksmith Institute by taking 46 samples of smelting workers who came from the same sample taken by Mer-C and the Ministry of Environment and Forestry and obtained the results that 60.9% had blood lead levels >30 µg/dL.

In light of the findings from environmental and health investigations, the Ministry of Environment and Forestry has undertaken a four-stages remediation process to address the site contaminated by hazardous waste. The plan is to finish this remediation in the current year, 2023, with a particular emphasis on the central dump site. Meanwhile, from a study conducted by Blacksmith Institute in 2016, there are relatively high levels of lead in the soil measured outside the central dump site which still has the potential to pollute health and the environment.

The results of measuring the concentration of lead in soil using XRF which was carried out by the ITS Team at TSIP in 2021, showed it was in the range of 0 ppm – 12,500 ppm.

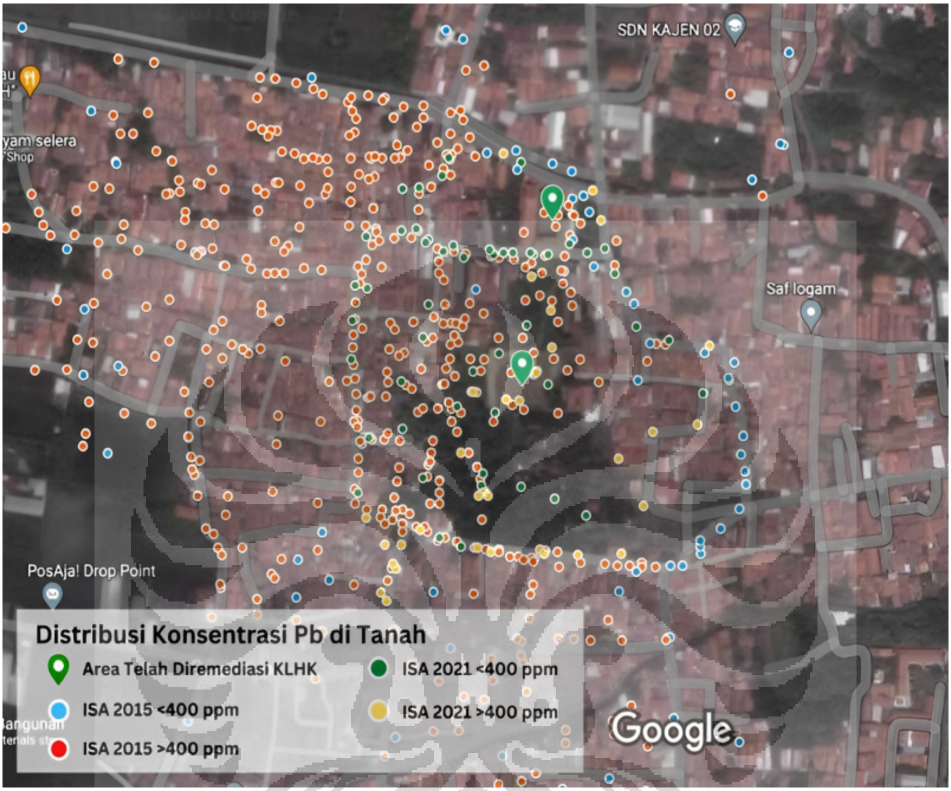

Figure 5: Distribution of lead concentration in soil in Pesarean

This study was also carried out in a control area with similar demographic characteristics to the study areas, but at minimum 2.7 km away from the hot spots. But, during the process, there was a change of control areas which at first were Cicadas, Cibadak, Cibatok, Bojong Jengkol suggested by the local health authorities, became Cinangneng Village. This dynamic was considered through a direct observation of those four areas (Cicadas, Cibadak, Cibatok, Bojong Jengkol) that geographically have lower altitude and transmission process of lead through air and soil water. After some considerations, the team decided to change the control areas into Cinangneng Village (which has a radius more than 2.7 km away from the hot spots), located in higher altitude than the hot spots, and also from previous measurements of the lead concentration in soil were not detected.

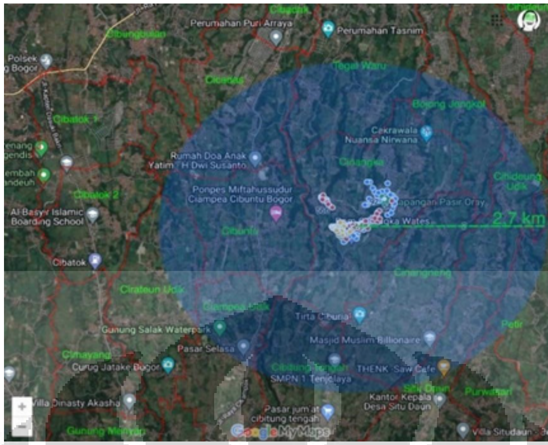

Figure 6: Areas within 2.7 km of Cinangka Village

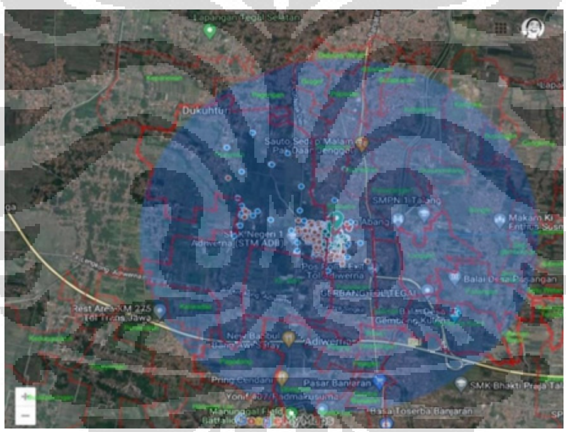

Figure 7: Areas within 2.7 km of Pesarean Village

III.2 Lead Level Assessment in Children and Environment

To determine the blood lead level, the capillary blood was analyzed using a mobile lead analyzer, LeadCare II which is a portable analyzer approved by the U.S Food and Drug Administration (FDA) and recommended by WHO. It has a comparable accuracy with laboratory-based methods for BLL between 3.5 and 65.0 µg/dL. Analysts and physicians from IMERI-FKUI are able to operate this analyzer. LeadCare II is comparatively cost effective, easy to operate, and can report instant results onsite using a small amount of sample (50 µL) that requires no preservation or special handling. Standardized procedures were followed during sample collection and analysis to create a clean environment and minimize sample contamination.

Minimum BLL (<3.5 µg/dL) defined as not detected, and maximum BLL (>65 µg/dL) defined as high. For levels > 65.0 µg/dL there is a protocol for dilution to be able to measure even above this limit the blood lead levels[32]. LeadCare II ® operates with specific "lead care" test strips. For one analysis one test strip was needed. For quality assurance purposes, we collected venous blood from a random subset of participants (10%) and analyzed using ICP-MS in a certified laboratory. Venous blood sampling was conducted by a certified nurse or phlebotomist following the procedure outlined in the WHO guidelines on drawing blood. To determine the hemoglobin level among children, this study uses HemoCue 201+. A capillary blood sample was introduced into the microcuvette by capillary action and, after reaction with the reagents, the absorbance was read in the HemoCue photometer at 565 and 880 nm. The hemoglobin concentration was then displayed as a digital reading, in g/dl in 15-45 seconds.

In this study, we used 2 units of LeadCare II Analyzer and LeadCare II Blood Lead Test Kit produced by Magellan and distributed by Meridian Biosciences. The serial numbers of LeadCare II Analyzer were WLC17060 and WLC17061. LeadCare II Blood Lead Test Kit as the reagent that consists of 17 boxes, 48 tests for each box with batch number LOT 2303 M. This reagent expired on 18 October 2023.

On October 13 th, 2023 Magellan sent the medical recall notice in the relation with the reagent we used. They noticed that LeadCare II Blood Lead Test Kit detail below:

Product name	: LeadCare II Blood Lead Test Kit
Producer	: Magellan
Distributor	: Meridian Biosciences
Number	: 7 boxes x 48 tests
Batch	: LOT 2303M
Exp date	: 10-18-2023

The concern of the recall notice is that Magellan discovered small percentage (<10%) the plastic caps used to close the treatment reagent tubes did not pass the dimensional specification of the cap's lip used to seal the tube may result the leakage of HCl or the evaporation of treatment reagent. The result of this might be a falsely elevated result. We did review the data by referring to the correlation coefficient and accuracy/recovery rate by comparing the BLL measured with the Lead Care II and BLL measured with the ICP-MS. In fact, during the study we found that there was no one of the measurement controls out of range of high result.

We calculated of 110 BLLs from Lead Care II and ICP-MS and the results showed BLL median (Q1-Q3) of LeadCare II was 5.50 (1.7-9.3) µg/dL which was lower than results of ICP-MS with BLL median 6.92 (5.17-14.23) µg/dL. Spearman correlation on 110 BLLs from LeadCare II and ICPMS from the same respondents was 0.89 and statistically significant ($p<0.001$). Using the accuracy/recovery rate x (in %) = [Pb Leadcare] / [Pb ICP-MS] * 100% with the tolerance 60 to 140% we found 9 BLL Lead Care results are too low and 5 results are too high. These results showed that the BLL measured with LeadCare II in this study are acceptable. The concern of LeadCare II BLL over measured was not indicated.

Pure Earth conducted a "Home-Based Assessment (HBA)" which consisted of sampling soil, dust, water, and other everyday household products to test for contamination and define any contributing factors in exposure levels. The home-based assessment was performed in 20% of all participating households. The environmental team performed the home-based assessment after the health team gave the result of the BLL test in the household. Then the environmental team visited and tested dust and other household items in selected households. The step-by-step for environmental sample collection laid out a suggested division of labor among team members. The environmental team applied a questionnaire and analyzed some samples immediately with an XRF. Other samples (drinking water, the dust wipes, and a subset of all samples assessed during HBA) were collected for quality control and transported to a laboratory which is certified for quality control.

About 20% of all children had a home-based assessment (HBA) was performed. There were two intentions in executing this home-based assessment:

- Identified potential individual sources of exposure for children with high blood lead levels (clinical perspective)
- Obtained an overview of potential lead exposure pathways a randomized sample (public health perspective)

For this study, the selection criteria were as follows:

- A HBA for every child with a blood lead level equal or greater than 20 µg/dL would be performed by PE's environmental team, based on BLL data.

To obtain a randomized sample, we tested 10% of all the remaining households (the ones below 20 µg/dL). The researcher randomly selected the participants, every 10th participant was approached by PE's environmental team for HBA. The study coordinator provided PE's environmental team with this list of "every 10th household".

The ethical clearance of this study was approved on 22nd May of 2023. Time spent collecting 564 samples of children and 146 samples of adults from four locations took about 11 weeks and 1 day, starting from 22nd May 2023 to 8th August 2023. For each participant, it took up to 60 minutes to complete analysis, and the team completed 10-15 samples per day and completed a visit to each site in 2 weeks.

The first thing we did in preparing the field activities was selecting the areas. Both study area and control area have similar demographic characteristics. As mentioned above control areas are in Cinangneng Village, located more than 2.7 km away from the hot spots and in higher altitude than surrounding villages and also from previous measurements of the lead concentration in soil which showed lead not detected in Cinangneng Village.

Pilot study was done by collecting data from an Indonesian version of questionnaire using 30 samples of the same population characteristics. The aim of the pilot study was to give an approximation of data collection time and to identify whether there was any confusion in answering the questions.

Three days workshop was held for everyone in the study team at the Department of Community Medicine, Faculty of Medicine, Universitas Indonesia. The aim of this workshop was to standardize the collecting data from the respondents. The training consists of sharing knowledge of intoxication, how to use the general questionnaires, health questionnaires including developmental questionnaires, how to use blood LeadCare analyzer, HemoCue, XRF, home-based assessment (HBA), sending the samples, data management and data protection, and occupational aspects regarding safety and health issues. Simultaneously with the implementation of the pilot study, preliminary survey of the selected areas, logistics arrangements were also held for field work.

While Pure Earth granted 2 Blood LeadCare analyzers to IMERI-FKUI, there were some purchases: Blood LeadCare II test kits, needles, syringes, containers, and other consumables for blood testing.

In order to obtain permission and support, we engaged with national authority (Ministry of Health), local authorities and stakeholders including provincial health offices *(Dinas Kesehatan),* Regional Public Hospital *(Rumah Sakit Umum Daerah),* Public Primary Health Center *(Puskesmas)*, district health offices, local social and political offices, village officers and cadres *(Posyandu)*. Usually, the process took two weeks for each level mentioned above. For Tangerang area, we were also collaborating with local university, that they previously already have community engagement in this area.

The study team developed a final time schedule for field work for the health and environmental team, according to the time-schedule of the local officers and cadres. The field work of this study was implemented in four areas: Manis Industrial Area in Tangerang Regency, Banten Province; Cinangka Village in Bogor Regency, West Java Province; Surabaya Municipality in East Java Province; and Pesarean Village, Tegal Regency, Central Java Province. Study team including Pure Earth Indonesian Foundation worked hand-in-hand with the /team, including recruited and enrolled participants/subjects, applied the questionnaire, took the blood sampling, performed home-based assessment.

To determine children's BLL, the approval for the study was obtained from the Health Research Ethic Committee of the Universitas Indonesia/ Cipto Mangunkusumo National Hospital on May 22nd 2023 with ethical approval number KET-622/UN2.F1/ETIK/PPM.00.02/2023. The ethical clearance process was performed in collaboration with the national and international partners. The ethical clearance itself was provided and submitted by the Indonesian Medical and Education Research Institute (IMERI) and Department of Community Medicine, Faculty of Medicine, Universitas Indonesia and by Prof. dr. Muchtaruddin Mansyur, MD, PhD as the principal investigator. We declared that the principles of the Declaration of Helsinki with its amendment of Fortaleza are taken into account in the currently valid versions of October 2013.

Informed consent for this study was obtained from the children's guardians/study and adult's subjects after providing an information sheet, explaining the aim of the study and also potential risk and benefits.

The members of the study team ensured that parents/children's guardians were provided all the essential information required at the household level to enable them to deliver a written informed consent before blood was taken.

In the data management and protection, all data of the study was treated absolutely confidentially and pseudonymized. The principal investigator in Indonesia distributed the ID number for each participant and stored the signed informed consent forms separately from other study documents. Those other study documents contained only the ID number and were used explicitly only for the scientific evaluation of the collected data.

The original records were stored, according to the regulations in Indonesia to store medical data, by IMERI, Faculty of Medicine, Universitas Indonesia which Prof. dr. Muchtaruddin Mansyur, MD, PhD was the principal researcher.

Access to data was only possible for the national principal along with his deputy (dr. Dewi Yunia Fitriani, Sp.Ok), the national study director Budi Susilorini, MBA (director of PE Indonesia Foundation), the international principal investigator Prof. Stephan Bose-O'Reilly MD, M.PH, (Pure Earth) and the research director Emily Nash (Pure Earth). No one outside this study team had access to the pseudonymized raw data/records. Only the summarized data used for publication.

The personal data as well as the blood samples were encrypted with number codes (pseudonymized) after the removal. Neither name, initials or the exact date of birth participants appeared in the encryption code. The description list as well as the original data were stored securely and were accessible solely by the principal researcher. The data and samples were secured against unauthorized access, the confidentiality of the personal data was guaranteed if results of the study were published. As mentioned above, the information and the consent form were given in written form.

In terms of the post pandemic era of Covid-19, all study activities were conducted in acceptable and environmentally safe manner, counted on establishing appropriate health and safety protocols, ensured that all protocols were adopted with particular attention to cross-contamination of fingers and sampling tools (The Decree of Minister of Health No. HK.01.07/MENKES/413/2020 concerning Coronavirus Disease 2019 (Covid-19).

Participation in this study included a general questionnaire, collection of capillary blood (50 µL) for children and for quality control venous blood (2-4 ml) taken from adults. Time spent for each participant was about 60 minutes for blood sample collection and the questionnaires. This blood sampling collection would be unpleasant and painful for the participant, especially children. Thus, the risk posed to the participants in this study consisted of the risks associated with sampling of blood (capillary sampling, venipuncture). During the study, there were no side event (nerve damage, vein rupture, infection) of blood sampling or prolonged pain after the puncture. There were no other envisaged potential risks, neither psychological, nor social / legal or ethical risks.

Alongside the risks, the potential benefit to the study subject in the blood lead survey was that legal guardians (parents) were informed of their children's blood lead levels as well as some recommendations to avoid lead exposures. Participants with elevated blood lead levels were offered a home inspection to identify potential sources and were provided with additional information on next steps related to accessing the treatment if needed.

Furthermore, participants received benefit instantly during the study through awareness they gained of their lead exposure levels, basic risk mitigation techniques, personal protective measures and feedback on child's anemia and growth and developmental status. Findings and results of the study would provide critical information on the current prevalence of BLLs among children in the regions and would inform future policy decisions. The aggregated survey data would be provided to the health authorities to be used in public health policy making.

From a preliminary survey for each area, we obtained the list of children ages 12-59 months and from this data, we chose 80 children, and 10 children for reserve respondents, by doing proportional cluster random sampling, according to their neighborhood. Most of the field works run smoothly, acceptance of the society was very good, local officers and cadres involved in the field works gave their best efforts. During data collection, not all of the respondents could come and we had to exclude 2 children from Cinangneng because one child had lived in the site less than 12 months and the other child was excluded due to blood clotting. The final number of children respondents for each locations were 80 children from Pesarean (Tegal), 84 children from Kadu Jaya (Tangerang), 81 children from Cinangka (Bogor), 79 children from Dupak (Surabaya), and 240 children from Cinangneng (Bogor).

Each child ran through capillary blood withdrawn for BLL and hemoglobin and had interviews with doctors for their developmental status and other risk factors for the data sampling. Then, the team communicated to parents presenting their growth and developmental status and children's hemoglobin level. Children, who have borderline or delayed development and or anemia, are referred to primary healthcare.

After all the children's BLL were gathered, the team shorted it from the highest to the lowest, to pick respondents with BLL above 20 µg/dL for home-based assessments and the parent/guardian examination. The adults (parents/guardians) that were chosen were only male since they brought potential exposure from their work environment outside the house.

The day after childrens' BLL and health questionnaires data sampling was collected, the study team did the home visit for each child in order to collect information about their home location, housing conditions, parent's/guardian's job, house activities and other risk factors related to lead exposure. And, while visiting the respondents' house, the team also asked for consent for home-based assessment and parents' examination for the chosen ones. One participant in Cinangka revoked his consent, since the child's father refused the home-based assessment. Thus, in this case the revocation of the consent was for home-based assessment only, whereas the consent of the child's BLL is valid. Home based assessment, parent/guardian's BLL test and health examination were done the day after home visit. One adult in Tegal had syncope during the blood test and also in Tangerang 3 adults who had syncope. All the subjects that had syncope were managed accordingly and they were excluded.

After gathering the data, we prepared individual reports for each child and parents or guardians. Each individual report consists of the results of children and parents as well as recommendations for further assessment and guidance to avoid lead exposure. We made recommendations to participants for referral to primary health care for those who needed it, and we provided a preliminary report of the child's BLL, hemoglobin level, growth status, and number of participants referred to primary health care to Provincial Health Offices *(Dinas Kesehatan)* and Public Health Center *(Puskesmas)*. Furthermore, for the children that had high BLL or any health disorders (with or without symptoms) we consulted with Indonesian Pediatric Society (*Ikatan Dokter Anak Indonesia/IDAI*) for developing the recommendations of lead intoxication management in children.

In this study, analysis was carried out to represent the characteristics of variables collected. The normality test of data distribution was performed on discrete and continuous data variables. Variables with normal data distribution were presented in mean and Standard Deviation (mean±SD). Variables which data were not normally distributed were presented in the median with quartiles 1 (Q1)and quartiles 3 (Q3) values (median (Q1-Q3)).

In this study data analysis, we categorized the child participants based on their age, using a cut-off point of 2 years old. Additionally, we established a cut-off point for blood lead levels at 20 µg/dL, as heme synthesis is known to be disrupted at this threshold. The assessment of socioeconomic status was determined by examining characteristics related to the respondents' homes, including the type of housing, the construction materials used (specifically, the type of flooring), and home ownership. Individuals living in non-permanent or semi-permanent housing with earthen floors and those residing in rented accommodations were categorized as having a low socioeconomic status.

We categorized activities at home and father's activities categorized into activities related to lead exposure if the respondents answered "yes" in any activity listed in the questionnaire. Cookware materials were categorized by its material. While food ware was categorized based on its materials and whether it's painted or not, which is usually done in aluminum/ceramic/clay/glass. The main drinking water source was categorized based on the source including river/pond/community well/house well/municipal/refill water. Spices that were categorized have red/yellow/other colours. About source and form spices, those were categorized as homemade or bought from the market. For the behavior on how respondents clean the house, it was categorized by their cleaning way including sweeping, mopping or vacuuming. Other behaviors were categorized the father bringing or washing their work clothes at home, and for children who habitually put things in their mouth and the location of their daily activities.

In the analysis of participant characteristics, univariate methods were employed to determine the proportion of each variable category. For continuous data variables, the results were presented as either the mean (mean ± SD) or the median (Q1 – Q3). To identify potential variables for inclusion in the multivariable analysis, a simple logistic regression was performed to assess their p-values.

Variables with p-values less than 0.3 were subsequently incorporated into the multiple logistic regression to identify the key determining factors. Correlation analysis was carried out using Pearson correlation for variables that normally distributed, whereas for variables that were not normally distributed using Spearman's Rho correlation.

IV

CHAPTER

IV.1 Characteristics of Children Exposed to Lead

The study generated estimates of BLL for the study population for the exposed population. Aiming to identify children with elevated BLLs and by using threshold level of 5 µg lead/dL blood, we used the study "Prevalence of Blood Lead among Children Living in Battery Recycling Communities in Greater Jakarta, Indonesia" to estimate the expected prevalence which in this study (2019) indicated that 47% of children 12-59 months age had BLLs above this threshold[16]. For the population at risk, a minimum sample size was calculated. For the expected prevalence of 47%, the required sample size would be 240 for the margin of error or absolute precision of ±7% in estimating the prevalence with 95% c onfidence and considering the potential loss of 18%. With this sample size, the anticipated 95% CI will be (40%-54%). This sample size was calculated using the Scalex SP calculator [31]. Therefore, for the calculation of sample size at were about 320 children from the exposed sites, and 240 children from control sites. With the estimation 20% of the children (12-59 months) had BLLs above this threshold[16], additionally we would test at least 130 of the BLL's parents and perform home-based analysis.

The study population within each study and control areas are children in the age group 12-59 months living within the defined study areas.

- The exposed group was defined as children living within 2.7 km of a ULAB recycling site in four target communities (Cinangka, Pesarean, Tangerang, and Surabaya).
- The control group was defined as children living in the same area, similar sociodemographic setting, but more distant from the ULAB site (more than 2.7 km)

Inclusion criteria for children consists of:

- Child aged between 12 to 59 months old.
- Child should have lived within the selected study and control areas within the last 12 months.
- The child should have lived in the area most of the time (spending not more than 4 weeks outside the area) during the last 6 months.
- Parents/guardians has granted informed consent for the child to participate in the study.
- Inclusion criteria for parents/guardians:
- Male aged between 18 to 65 years paired with the children BLL samples.

Exclusion criteria for children and parents are none.

The recruitment process in selecting children who could potentially participate in this study, was done in collaboration with Public Health Center *(Puskesmas*). *Puskesmas* held a monthly monitoring of children's health named *Posyandu* (Integrated Health Service Post) for children <5 years old. There were six participating *Puskesmas* in this study, and six *Posyandu* respectively. Through a database collected in each *Puskesmas*, the list of children 12-59 months was splitted into age groups (12-23, 24-35, 36-47, 48-59 months) and gender (male/female). The list of children was drawn up for each subgroup. A random generator was used to create a sequence proportionally for each group. Of the first 10 children in each order, the study team contacted children's caregivers for their children's participation. For some of the children contacted who rejected the participation, the study team contacted the next caregivers according to the lists until the desired number of participants was reached.

Characteristics of research subject in this study defined by children's demographic and residential characteristics. Children's demography consists of gender, age, study area. Residential characteristics consist of housing ownership and construction types including whether the construction is permanent or non-permanent, and type of floors used in the house.

The study included 295 boys and 269 girls as participating children. The average age of the children in the study was 35 months. In the exposed area, there were a total of 324 child respondents, while in the controlled area, there were 240 child respondents. Referring to the previously mentioned definition of socioeconomic status, the analysis indicated that 7.8% had a low economic status, while 92.2% fell into the middle economic category.

Housing construction types were classified into three categories: non-permanent, semi-permanent, and permanent. The majority of the children (87.4%) resided in their parents' permanent homes, with permanent housing being the most common type of construction (94.9%). A smaller percentage lived in semi-permanent housing (5%), and an even smaller fraction lived in non-permanent housing (0.2%). When considering the flooring of the respondents' houses, the majority had tile floors (83.3%), followed by concrete floors (12.4%), and a small minority (0.2%) lived in houses with wooden floors (table 2).

IV.2 Characteristics of Environmental Exposure

The assessment of environmental exposures involves an examination of the subject's residence to assess the potential for lead exposure within the household. This includes activities carried out at home over the past six months that may be related to lead exposure, the father's activities, the types of cookware and food ware materials used, the spices utilized for cooking (including their type, form, and source), the primary source of drinking water, smoking habits within the house, the methods employed by respondents for house cleaning, and how frequently adults bring and launder their work attire at home.

Results showed that in the last six months, 15.2% of respondents had renovation, followed by removing paint (5.7%), while few of them (1.2%) have been recycling batteries inside the house.

In similar manner, renovating house/building dominates the activities of father/children's guardian (9.2%), then removing paint including sandblasting (6.7%), and activity of demolishing (5.7%), whereas 1.2% of the respondents recycle batteries. The data also showed that 75.4% of the adults (father/guardian) were smoking inside their house (details see table 3).

Table 2. Characteristics of children demographic and residential (N = 564)

Characteristics of children demographic and residential	Frequency n (%)	Mean ± SD	Median (Q1- Q3)
Children Demography			
Gender			
Boys	295 (52.3)		
Girls	269 (47.7)		
Age (in months)		35 ± 13	35 (24 - 47)
Study Area			
Exposed Area	324 (57.4)		
Pesarean (Tegal)	80 (24.7)		
Kadu jaya (Tangerang)	84 (25.9)		
Cinangka (Bogor)	81 (25.0)		
Dupak (Surabaya)	79 (24.4)		
Controlled Area			
Cinangneng	240 (42.6)		
Residential Characteristics			
Ownerships			
Rented	71 (12.6)		
Owned	493 (87.4)		
House Type			
Non-permanent	1 (0.2)		
Semi permanent	28 (5.0)		
Permanent	535 (94.9)		
Type of floor			
Soil floor	3 (0.5)		
Soil and concrete floor	3 (0.5)		
Soil and tiles floor	11 (2.0)		
Concrete floor	70 (12.4)		
Concrete and tiles floor	5 (0.9)		
Concrete and woods floor	1 (0.2)		
Tiles floor	470 (83.3)		
Wood floor	1 (0.2)		

Analysis of cookware materials, aluminum was the most used one (46.5%), while plastic and glass were used the most among the food ware (35.8%). House well as source of drinking water dominates the others (48.2%), whereas one respondent gets their main drinking water from river (0.2%) and 3 participants get their drinking water from pond (0.5%).

Cooking used all three kinds of spices (yellow, red, white spices) were preferable for participants (31.2%) in the form of unpackaged/ground ones (92.6%). Those spices were obtained mostly from street vendors (80.9%) and only a few participants who self-planting the spices (2%) (see details in table 4).

Some household materials and soil around the participant's house were measured by XRF. We measured different numbers of the household samples from each house. The soil around the house had a median 113.80 ppm and soil outside the house had 123 ppm. We also measured the median for the cookware and food ware specifically made from ceramic, and the median was 190 ppm (see table 5).

Table 3. Characteristics of father's/guardian's behavior that potential to lead exposure (N = 564)

Father's/guardian's behaviours	Frequency n (%)
Activities at Home Relate to Lead Exposure on the last six months	
Renovating home	86 (15.2)
Removing paint at home	32 (5.7)
Removing vehicle's paint	5 (5.7)
Welding pipe at home	9 (1.6)
Mechanical repairing work at home	16 (2.8)
Soldering at home	12 (2.1)
Painting at home	9 (1.6)
Recycling battery at home	7 (1.2)
House-yard gardening	82 (14.5)
Other lead activity at home	17 (3.0)
Father's activities	
Removing paint, including sunblasting	38 (6.7)
Renovating house/building	52 (9.2)
Activity of demolishing	32 (5.7)
Activity fixing waterpipe	22 (3.9)
Repairing car/motor	25 (4.4)
Activity of smelting	25 (4.4)
Activity of welding	21 (3.7)
Activity of moulding	17 (3.0)
Activity of mixing paint	19 (3.4)
Activity of sorting waste	25 (4.4)
Activity of soldering	18 (3.2)
Activity in industry (chemical, glass, ceramic, jewel)	6 (1.8)
Activity recycling battery	7 (1.2)

Father's/guardian's behaviours	Frequency n (%)
Smoking habit	
Smoking inside the house	425 (75.4)
Not smoking	139 (24.6)

Percentage of participants who cleaned their house by sweeping and mopping was 91.5%, and 7.6% participants cleaned the house by sweeping. Many of the children's fathers/guardians always bring their work clothes to home (66.8%) and wash their work clothes every day at home (56%), whereas only few of them never wash the clothes at home (19.9%) (see table 6).

Table 4. Characteristics of household potential to lead exposures (N = 564)

Household Potential to Lead Exposure	Frequency n (%)
Cookware materials	
Aluminum	262 (46.5)
Enamel	106 (18.8)
Teflon or ceramic	9 (1.6)
Aluminum & enamel	34 (6.0)
Aluminum & teflon	91 (16.1)
Aluminum & combinations with enamel-teflon-glass-ceramic-clay	9 (1.7)
Enamel & teflon	46 (8.2)
Enamel & clay/glass	2 (0.4)
Teflon & ceramic/glass	4 (0.7)
No cookware at all	1 (0.2)
Food ware materials	
Aluminum	6 (1.1)
Plastic	20 (3.5)
Ceramic	41 (7.3)
Glass	160 (28.4)
Aluminum & plastic/glass	10 (1.7)
Ceramic & plastic/glass	54 (9.6)
Plastic & glass	202 (35.8)
Plastic-ceramic-glass	71 (12.6)
Main drinking water source at home	
River	1 (0.2)
Pond	3 (0.5)
Community well	13 (2.3)
House well	272 (48.2)
Refill water	139 (24.7)
Municipal waterwork	136 (24.1)

Household Potential to Lead Exposure	Frequency n (%)
Spices used for cooking	
Yellow spices (tumeric)	95 (16.8)
Red spices (chilli/pepper)	22 (3.9)
White spices (ginger/corriander)	80 (14.2)
Yellow & red	17 (3.0)
Yellow & white	148 (26.3)
Red & white	10 (1.8)
All spices	176 (31.2)
Not using spices	16 (2.8)
Form of spices	
Ground/unpackaged	522 (92.6)
Home-made	9 (1.6)
Branded packaging	26 (4.6)
Unbranded packaging	7 (1.2)
Source of spices	
Self-planting	11 (2.0)
Traditional market	95 (16.8)
Street vendors	456 (80.9)
Minimarket	2 (0.4)

Table 5. XRF measurements of household materials and soil around the participant's house

XRF Measurement	Median (Q1- Q3)
Soil around the house (N= 152)	113.80 (55.08 – 550.73)
Soil outside the house (N=14)	123 (57 – 210.5)
Toys (N=129)	0 (0 - 6.5)
Cookware (N=139)	190 (20 – 1827.5)
Plastic Food ware (N=82)	5.88 (0- 40)
Ceramic Food ware (N=60)	190 (30 – 2747.5)
Children's Clothes (N=96)	31.50 (0 – 185)
Adults' Clothes (N=28)	35.75 (8.25 – 260.13)
Matrass (N=147)	29.67 (8 – 131)

Table 6. Characteristics of household daily activities (N = 564)

Household Domestic Activities	Frequency n (%)
Cleaning the house	
Sweeping only	43 (7.6)
Mopping only	1 (0.2)
Sweeping & mopping	516 (91.5)
Sweeping - mopping - vacuuming	4 (0.7)
Bring their work clothes to home	
Always	377 (66.8)
Sometimes	42 (7.4)
Never	145 (25.7)
Washing their work clothes at home	
Every day	316 (56)
A few times a week	136 (24.1)
Never	112 (19.9)

IV.3 Characteristics of Exposed Children's Behavior

Among 564 child respondents, 86.9% of them had a breastfeeding at least 6 months. Moreover, we studied that 51.2% of the children have a good hand washing habit, while 16.5% never wash their hands before eating. Children who took current medical prescription drugs during the study were 14.9%, traditional herbs currently taken by 12.6% of the respondents. There was also cosmetic use in children such as baby powder by 72.7% of children and among them who use cosmetics, there was 1 child (0.2%) who wore lipstick.

Children are likely to have more hand-mouth activity than adults. Among 564 children, 20% of them inserted their hand to their mouth every day, and things they inserted in their mouth were toys (17.9%). About the places that children spend most of their time was inside the house (53.5%), followed by house-yard (37.4%), while few of them spend their time mostly in other villages (0.6%) (see details in table 7).

Table 7. Characteristics of children's behaviours potential to lead exposure (N – 564)

Children related to potential of lead exposures	Frequency n (%)
Breastfeeding milk	
Breastfeeding for 6 months or more	490 (86.9)
Breastfeeding <6 months	74 (13.1)
Prescription drugs	
Currently use	84 (14.9)
Currently not use	480 (85.1)
Traditional herbs	
Currently use	71 (12.6)
Currently not use	493 (87.4)
Cosmetics use	
Use cosmetics	410 (72.7)
Don't use cosmetics	154 (27.3)
Handwashing habit before eating	
Always	289 (51.2)
Sometimes	127 (22.5)
Seldom	55 (9.8)
Never	93 (16.5)
Frequency children inserted hand to mouth	
Everyday	113 (20)
Few times a week	140 (24.8)
Never	311 (55.1)
Children's habit inserting other things to mouth	
Yes	138 (24.5)
No	426 (75.5)
Type of things inserted in mouth	
Toys	101 (17.9)
Non-toys	37 (6.6)
None	426 (75.5)
Places for spending most of the time	
Inside the house	302 (53.5)
At house yard	211 (37.4)
At school area	6 (1.1)
At public spaces in neighbourhood	38 (6.7)
In nearby village	3 (0.6)
Others	4 (0.8)

Among 564 children, only 137 father/guardians from children's respondents were chosen for further assessment who were randomly selected based on the result of their children's BLL ≥20 µg/dL. The youngest age of the father/guardian respondents was 20 years old, the eldest was 80 years old, and mean age 39.5 years old, and 10.8% of them were between 31-40 age years old.

Their job was vary which freelancing (30.5%) was the highest percentage of adult's job in the study area (see table 8).

Table 8. Characteristics of sociodemographic of children's father/guardian (N = 137)

Characteristics of Sociodemography of Children's Father/Guardian	Frequency n (%)	Mean ± SD	Median (Q1- Q3)
Age (in years)		39.57 ± 9.8	39 (33 – 45)
≤30	18 (13.1)		
31-40	61 (44.5)		
41-50	42 (30.7)		
51-60	12 (8.8)		
>60	4 (2.9)		
Jobs			
Freelance	172 (30.5)		
Private Employee	144 (25.5)		
Private Businessman	133 (23.6)		
Farmer	24 (4.3)		
Professional	11 (2.0)		
Civil Servant	6 (1.1)		
Unemployed	3 (0.5)		
Others	71 (12.6)		

IV.4 Characteristics of Demographic and Socioeconomic Status among Exposed Children

Based on the gender difference, the data obtained that proportion of boys lived n exposed areas (58%) was higher than the proportion of boys lived in controlled area (51.7%) and proportion of girls lived in exposed area (47.2%) was lower than in controlled area (48.3%), thus the proportion difference was not statistically significant ($p = 0.79$).

By age, the proportion of children ≤24 months old lived in exposed areas (27.2%) was higher than children ≤24 months old (23.3%), and the proportion of children >24 months old lived in exposed areas (72.8%) was lower than children >24 months old (76.7%), thus not statistically significant ($p = 0.30$).

About children who came from families with low socioeconomic status lived in exposed areas, the proportion was (9.0%) higher than the proportion of children with low sosioeconomic status in controlled areas (6.3%).

Whereas the proportion of children from middle socioeconomic status lived in the exposed area was (91.0%) lower than the proportion of children from middle socioeconomic families (93.7%) in the controlled area. Thus, the proportion difference is not statistically significant ($p = 0.45$) (see table 9).

Table 9. The proportion comparison of children demographic and socioeconomic status (N = 564)

	Gender n (%)			**Age n (%)**			**Socioeconomic n (%)**		
	Boys	**Girls**	***p***	≤ 24 months old	> 24 months old	***p***	**Low**	Middle	***p***
Exposed area	171 (52.8)	153 (47.2)	0.79[CS]	88 (27.2)	236 (72.8)	0.30[CS]	29 (9.0)	295 (91.0)	0.45[CS]
Controlled area	124 (51.7)	116 (48.3)		56 (23.3)	184 (76.7)		15 (6.3)	225 (93.7)	

CS: Chi-Square Tests

V

CHAPTER

V.1 Blood Lead Level and The Future Indonesian Challenge

The proportion of blood lead level (BLL) from a different range of 564 children participants showed that children's lowest BLL, less than 3.5 µg/dL, was 4.1% whereas BLL 10 to <20 µg/dL dominates others (34.9%). Children whose BLL above the threshold which may require medical treatment (45 to ≥65 µg/dL) were 3.4% (see table 10).

Table 10. Children's BLL proportion in different levels (N = 564)

BLL proportion in different level	Frequency n (%)
Up to 3.5 µg/dL	23 (4.1)
>3.5 to <5 µg/dL	41 (7.3)
5 to <10 µg/dL	158 (28.0)
10 to <20 µg/dL	197 (34.9)
20 to <45 µg/dL	126 (22.3)
45 to <65 µg/dL	10 (1.8)
≥65 µg/dL	9 (1.6)

Furthermore, the comparison of proportions of BLL in different ranges showed that in exposed areas the biggest proportion of children's BLL was in range 10 to <20 µg/dL (40.4%) where Kadu Jaya had the highest number of children within this range compared to others in exposed areas (52.4%). Children's BLL above 45µg/dL indicates prompt treatment dominated by Pesarean (12.6%) followed by Cinangka (6.1%). Generally, children's BLL in Dupak were lower than Pesarean, Kadu Jaya, Cinangka in exposed areas which described by BLL less than 3.5 µg/dL were 7.6% and BLL greater than 45 µg/dL were only 1.3% and no children had BLL ≥65 µg/dL. Different from exposed area, the biggest proportion of children's BLL in controlled area was in range 5 to <10 µg/dL (40.0%) and children whose BLL lower than 3.5 µg/dL were 6.7% which were than exposed areas and only 1.3% proportion of BLL which above 45 µg/dL (see table 11).

Table 11. The proportion comparison of children's BLL group based on the study areas (N = 564)

Study Area	Up to 3.5µg/dL n (%)	>3.5 to <5µg/dL n (%)	5 to <10 µg/dL n (%)	10 to <20 µg/dL n (%)	20 to <45 µg/dL n (%)	45 to <65 µg/dL n (%)	≥65 µg/dL n (%)
Exposed Area	7 (2.2)	9 (2.8)	62 (19.1)	131 (40.4)	97 (29.9)	9 (2.8)	9 (2.8)
Pesarean	1 (1.3)	0 (0.0)	7 (8.8)	29 (36.3)	33 (41.3)	3(3.8)	7 (8.8)
Kadu jaya	0 (0.0)	1 (1.2)	13 (15.5)	44 (52.4)	24 (28.6)	1 (1.2)	1 (1.2)
Cinangka	0 (0.0)	1 (1.2)	18 (22.2)	32 (39.5)	25 (30.9)	4 (4.9)	1(1.2)
Dupak	6 (7.6)	7 (8.9)	24 (30.4)	26 (32.9)	15 (19.0)	1 (1.3)	0 (0.0)
Controlled Area							
Cinangneng	16 (6.7)	32 (13.3)	96 (40.0)	66 (27.5)	29 (12.1)	1 (0.4)	0 (0.0)

Blood lead levels among all children respondents had median (Q1-Q3) of 12.1 (7.5 – 20.1), whereas children lived near ULAB recycling sites who had BLL detected, with median (Q1-Q3) of 15.2 (10.3 – 22.6 µg/dL). In the controlled area there were 23 children who had BLL lower than 3.5 µg/dL, none of them live in controlled area had BLL higher than the upper level of detection, and the children with detected BLL had median (Q1-Q3) of 8.8 (5.9 – 15 µg/dL). This result was statistically significant lower than the BLL of those who live in the exposed area ($p<0.001$). Among children living in the exposed area, children in Dupak had the lowest BLL median (Q1-Q3) of 11.5 (6.4 – 17.3 µg/dL), compared to others (see table 12).

Table 12. Characteristics of children's BLL level in exposed and controlled areas

Children's BLL in study areas	n (%)		Median (Q1-Q3) µg/dL	*p*
Exposed Areas	309 (54.8)		15.2 (10.3 – 22.6)	<0,001^MW
Pesarean		72 (23.0)	19.60 (13.5 – 27.5)	
Kadu Jaya		83 (27.0)	15.2 (11.0 – 21.4)	
Cinangka		80 (26.0)	15.7 (10.0 – 23.7)	
Dupak		74 (24.0)	11.5 (6.4 – 17.3)	
ControlledArea	226 (45.2)		8.8 (5.9 – 15)	
Cinangneng				

Note MW: MannWhitney Test. Based on measurement detected by LeadCare II (N = 535)

This study also found that the proportion of the children whose BLL ≥20 µg/dL in the exposed areas were higher than the proportion of the children in controlled area ($p < 0.001$). The children who lived in the exposed areas have 3.9 times odds to have BLL ≥20 µg/dL (OR = 3.9 : CI 95% = 2.5-6.0). Blood lead level in father/guardian showed median (Q1 – Q3) of 6.63 (4.71 – 12.23 g/dL). Among father's whose BLL ≥20µg/dL, 90% of their children also has BLL ≥20µg/dL. Children whose parents BLL ≥20µg/dL, they were 6 times in higher risk of having high BLL, compared to children whose parent's BLL lower than 20 µg/dL. Thus, statistically significant (see table13).

Table 13. The proportion comparison of children's BLL level based on exposure areas group and father's BLL group

	Children's BLL ≥20 µg/dL n (%)	Children's BLL <20 µg/dL n (%)	OR (CI 95%)	*p*
Study Areas				
Exposed Areas	115 (35.5)	209 (64.5)	3.9 (2.5 – 6.0)	<0.001^CS
Controlled Area	30 (12.5)	210 (87.5)		
Fathers' BLL				
BLL ≥20µg/dL	18 (90)	2 (10)	6.0 (1.3 – 27.3)	0.009^CS
BLL<20µg/dL	70 (59.8)	47 (40.2)		

Note: N = 564 for study areas, N = 137 for father's BLL. CS: Chi-Square Tests

The mean of hemoglobin level among child respondents was 11.2 ± 1.27, whereas from the exposed area showed that hemoglobin level was 11.15 ± 1.24 and controlled area 11.2 ± 1.32 (see details in table 14).

Table 14. Hemoglobin level in exposed and controlled areas (N = 564)

Hemoglobin Level (in g/dL)	**n**	**Mean ± SD**
All children respondents	564	11.2 ± 1.27
Exposed Area	324	11.1 ± 1.24
Controlled Area	240	11.2 ± 1.32

Based on the anemia status of children in the exposed area showed 39.5% of children had anemia, whereas in the controlled area, there were 36.7% respondents with anemia. There was no statistical significant difference of anemic children proportion between two studies area (*p* = 0.89). There was also no statistical significant difference of anemic children proportion based on BLL categories between two study areas (see table 15– 16).

Table 15. The frequency distribution of anemia status in exposed and controlled areas (N = 564)

Study Area	**Anemia n (%)**	**Not Anemia n (%)**	***p***
Exposed Area	128 (39.5)	196 (60.5)	0.89[CS]
Pesarean	33 (41.3)	47 (58.8)	
Kadu Jaya	31 (36.9)	53 (63.1)	
Cinangka	34 (42.0)	47 (58.0)	
Dupak	30 (38.0)	49 (62.0)	
Controlled Area (Cinangneng)	88 (36.7)	152 (63.3)	

CS: Chi-Square Tests

Table 16. The proportion comparison of anemia status between BLL in exposed and controlled areas (N = 564)

Characteristics of Anemia Status	Anemia n (%)	Not Anemia n (%)	*p*
Exposed Area			
BLL ≥20 μg/dL	38 (33.0)	77 (67.0)	0.08[CS]
BLL <20 μg/dL	90 (43.1)	119 (56.9)	
Controlled Area			
BLL ≥20 μg/dL	11 (36.7)	19 (63.3)	1.0[CS]
BLL <20 μg/dL	77 (36.7)	133 (63.3)	

CS: Chi-Square Tests

All children respondents' median (Q1 -Q3) of the growth and developmental score was 9 (8-10). The proportion of children who had delayed growth and development status lived in the exposed area was (50%) in the same proportion of the controlled area. Among children living in exposed areas, the highest proportion of children with delayed developmental status (48%) was found in Kadu Jaya village.

Children who had borderline growth and developmental status lived in exposed areas, the proportion difference was (60%) higher than in controlled area (40%). The proportion of children with growth and developmental status that was appropriate to their age, lived in exposed areas was (57.3%) higher than controlled area (42.7%). Thus, the children's growth and development status between exposed and controlled areas were not statistically significant ($p = 0.45$). There was also no statistical significant difference of growth and developmental categories proportion between two study areas based on the BLL category (see details in table 17-18).

Results showed that children whose BLL ≥20ug/dL and who had anemia almost four times had delayed development compared to those who did not have anemia. Thus, growth and developmental status in relation with anemia status among respondents with high BLL was statistically significant (*p*-value 0.044) (see table 19).

Table 17. The comparison of growth and developmental status in exposed and controlled areas (N = 564)

	Delayed n (%)	Borderline n (%)	Appropriate to Age n (%)	*p*
Exposed area	25 (50.0)	102 (60.0)	197 (57.3)	0.45[CS]
Pesarean	4 (16)			
Kadu Jaya	12 (48)	25 (24.5)	51 (25.9)	
Cinangka	6 (24)	32 (31.4)	40 (20.3)	
Dupak	3 (12)	17 (16.7)	58 (29.4)	
		28 (27.5)	48 (24.6)	
Controlled area (Cinangneng)	25 (50.0)	68 (40.0)	147 (42.7)	

CS: Chi-Square Tests

Table 18. The proportion comparison of children's growth and developmental status based on their BLL in exposed and controlled areas (N = 564)

Characteristics of Growth and Developmental Status	Delayed n (%)	Borderline n (%)	Appropriate to age n (%)	*p*
Exposed Area				
BLL ≥20 µg/dL	7 (6.1)	40 (38.4)	68 (59.1)	0.52[CS]
BLL <20 µg/dL	18 (8.6)	62 (29.7)	129 (61.7)	
Controlled Area				
BLL ≥20 µg/dL	4 (13.3)	5 (16.7)	21 (70.0)	0.31[CS]
BLL <20 µg/dL	21 (10.0)	63 (30.0)	126 (60.0)	

CS: Chi-Square Tests

Table 19. The proportion comparison of children's growth and developmental status, anemia status and BLL in study areas (N = 564)

Children's BLL	Anemia Status	Delayed n (%)	Borderline/ Appropriate to age n (%)	OR (CI 95%)	*p*
BLL ≥20ug/dL	Anemia	7 (14.3)	42 (85.7)	3.83 (1.06 – 13.80)	0.044[F]
	Not Anemia	4 (4.2)	92 (95.8)		
BLL <20ug/dL	Anemia	18 (10.8)	149 (89.2)	1.33 (0.68 – 2.58)	0.399[CS]
	Not Anemia	21 (8.3)	231 (91.7)		

F: Fisher's Exact Test, CS: Chi-Square Tests

V.2 Determinant Factors of Blood Lead Level in Children

Based on the gender difference, the data obtained the proportion of girls who had BLL ≥20 µg/dL (27.1%) which was higher than the proportion of high BLL boys (24.4%). This proportion difference was not statistically significant ($p = 0.46$). By age, the proportion of children ≤24 months old who had BLL ≥20 µg/dL was (28.5%) higher than children >24 months old with high BLL (24.8%), this proportion difference was not statistically significant ($p = 0.38$).

Children who were in low economic status and lived in an exposed area with BLL ≥20 µg/dL had proportion difference (50.0%) higher than the proportion of middle socioeconomic children (23.7%). The proportion of children living in exposed areas who had BLL ≥20 µg/dL was (35.3%) higher than the proportion in children with high BLL lived in the controlled area. Variables of socioeconomic and study areas had proportions that were statistically significant associated with BLL (p <0.001).

Based on the p-value < 0.3 obtained from the bivariate analysis, the variables included in the multivariate analysis were socioeconomic status and study areas. Multivariate logistic regression found that children living in low socioeconomic status were three times in higher odd (aOR = 3.11 : 95% CI = 1.6 - 6.1) having high BLL ≥20 µg/dL than those who had better socioeconomic status. Similar with children lived in exposed areas were in higher odd (aOR = 3.83 : 95% CI = 2.4 – 6.0) almost four times having BLL ≥20 µg/dL compared to children living in controlled area (see table 20 - 21).

Table 20. Characteristics of demographic and socioeconomic status (N = 564)

Characteristics of children demographic and socioeconomic status	Children's BLL ≥20 µg/dL n(%)	Children's BLL <20 µg/dL n(%)	*p*
Gender			
Boys	72 (24.4)	223 (75.6)	0.46[CS]
Girls	73 (27.1)	196 (72.9)	
Age			
≤ 24 months old	41 (28.5)	103 (71.5)	0.38[CS]
> 24 months old	104 (24.8)	316 (75.2)	
Socioeconomic			
Low	22 (50.0)	22 (50.0)	<0.001[CS]
Middle	123 (23.7)	397 (76.3)	
Study Area			
Exposed areas	115 (35.5)	209 (64.5)	<0.001[CS]
Controlled area	30 (12.5)	210 (87.5)	

CS: Chi-Square Tests

Table 21. Multivariate analysis of demographic and socioeconomic status (N = 564)

Characteristics of children demographic and socioeconomic status	Children's BLL ≥20 µg/dL n(%)	Children's BLL <20 µg/dL n (%)	cOR (95% CI)	aOR (95% CI)
Socioeconomic				
Low	22 (50.0)	22 (50.0)	3.2 (1.7 – 6.0)	3.11 (1.6 - 6.1)
Middle	123 (23.7)	397 (76.3)		
Study Area				
Exposed area	115 (35.5)	209 (64.5)	3.8 (2.5 – 6.0)	3.83 (2.4 – 6.0)
Controlled area	30 (12.5)	210 (87.5)		

Note: Adjusted OR by each other variables.

Environmental exposures consist of variables activities related to lead exposure last 6 months, father's activities, smoking habit, cookware and food ware materials, main drinking water source at home, types, form and sources of spices used for cooking, way of cleaning the house, and activity of bring or wash work clothes at home. Among those variables, the proportion differences of cookware materials, food ware materials and type of spices were statistically significant associated with high BLL ≥20 µg/dL (p<0.001) (see details in table 22).

The proportion difference of children with high BLL ≥20 µg/dL who used aluminum as cookware materials was (33.3%) higher than the proportion of children with high BLL that used other cookware materials (7.7%). Similarly, the proportion difference of children with high BLL ≥20 µg/dL who used aluminum as food ware materials was (33.8%) higher than the proportion of children with high BLL that used other food ware materials (19.8%). Type of spices used for cooking showed that the proportion difference of children with high BLL ≥20 µg/dL (47.9%) was higher in spices other than yellow/red ones, compared to the proportion of children with high BLL ≥20 µg/dL who used red/yellow spices (21.2%) (see details in table 22).

Bivariate analysis was carried out to identify variable candidates based on the results of *p*-value <0.3. Thus the data showed that variables with p<0.3 were activities related to lead exposure on the last six months, father's activities, cookware and food ware materials, main drinking water source, type and form of spices, way of cleaning house, and about how the father or guardian bring or wash their work clothes at home. Then further analysis on multivariate showed that determinant environmental factors were cookware (*a*OR = 1.4 95% CI : 1.2 – 1.6), food ware materials (*a*OR = 1.15 95% CI: 1.0– 1.3), type of spices (*a*OR = 2.7 95% CI : 1.7 – 48.0) and the way of cleaning house (*a*OR = 2.9 95% CI : 1.2 – 7.1) (see details in table 22-23).

The proportion of those who use aluminum cookware in low socioeconomic with BLL ≥20 µg/dL was 61.1%, whereas low socioeconomic and not using aluminum with BLL ≥20 µg/dL was 0%. Participants living in low socioeconomic levels and using aluminum may have probabilities of having BLL ≥20 µg/dL were almost 18 times higher than those who did not use aluminum (OR 17.8 with 95% CI 7.4 – 42.8 with Mantel-Haenszel analysis). Then comparing those in middle socioeconomic level and using aluminum were still having risk of BLL ≥20 µg/dL about 3.6 times (OR 3.6 95% CI: 1.8 – 7.2 with Mantel-Haenszel analysis) (see table 24).

Analysis of correlation results between child's BLL and variables of potential lead exposures from environment (father's BLL, soil, dust, clean water, drinking water, air, door paint and wall paint), the correlation of soil lead level and child's BLL was the strongest among others that had moderate positive correlation and statistically significant ($r = 0.55^{S}$; p<0.001) (see table 25).

We also found that father's BLL, dust lead level, drinking water lead level, and wall paint lead level were also statistically significant although the coefficient correlation were categorized as weak positive (father's BLL r = 0.24^S, *p* = 0.006; dust lead level r = 0.38^S, *p*<0.001; drinking water lead level r 0.35^P, *p* = 0.013 wall paint lead level r = 0.22^S, *p* = 0.010 respectively). Clean water lead level had very weak positive correlation with child's BLL but statistically not significant (r = 0.15^S, *p* = 0.077). Similar to clean water, door paint lead level also had very weak correlation with child's BLL but statistically not significant (r = 0.04^S, *p* = 0.753). Interestingly, air lead level was statistically significant with moderate negative correlation with child's BLL (r = -0.45^S, *p*<0.001) (see table 25).

Table 22. Children's BLL and environmental exposure analysis (N = 564)

Characteristics of Environmental Exposure	Children's BLL ≥20 µg/dL n(%)	Children's BLL <20 µg/dL n(%)	*p*
Activities related to lead exposure last 6 months			
Yes	48 (22.6)	164 (77.4)	0.19^{CS}
No	97 (27.6)	255 (72.4)	
Father's activities			
Yes	53 (28.8)	131 (71.2)	0.24^{CS}
No	92 (24.2)	288 (74.3)	
Smoking habit			
Yes	109 (25.6)	316 (74.4)	0.953^{CS}
No	36 (25.9)	103 (74.15)	
Cookware materials			
Aluminum	132 (33.3)	264 (66.7)	$<0.001^{CS}$
Enamel/teflon/ceramic/clay/ glass	13 (7.7)	155 (92.3)	
Food ware materials			
Alumunium/ceramic/clay/ glass	81 (33.8)	159 (66)	$<0.001^{CS}$
Plastic	64 (19.8)	260 (80.2)	

Characteristics of Environmental Exposure	Children's BLL ≥20 µg/dL n(%)	Children's BLL <20 µg/dL n(%)	*p*
Main drinking water source at home			
River/Pond/Community Well/House Well	66 (22.8)	223 (77.2)	0.11 CS
Municipal Water/Refill Water	79 (28.7)	196 (71.3)	
Types of spices used for cooking			
Other than Yellow/Red Spices	46 (47.9)	50 (52.1)	<0.001 CS
Yellow/Red Spices	99 (21.2)	369 (78.8)	
Form of spices			
Homemade	5 (55.6)	4 (44.4)	0.053 CS
Bought from market	140 (25.2)	415 (74.8)	
Sources of spices			
Self – planting	4 (36.4)	7 (63.6)	0.41 CS
Traditional/minimarket/ vendors	141 (25.5)	412 (74.5)	
Cleaning the house			
Sweeping Only (daily)	7 (16.3)	36 (83.7)	0.14 CS
Sweeping and mopping/ vacuuming (not daily)	138 (26.5)	383 (73.5)	
Bring/wash work clothes at home			
Bring and/or wash at home	114 (24.7)	347 (75.3)	0.26 CS
Don't bring and wash at home	31 (30.1)	72 (69.9)	

CS: Chi-Square Tests

Table 23. Multivariate analysis of environmental exposure (N = 564)

Characteristics of Environmental Exposure	**Children's BLL ≥20 µg/dL n (%)**	**Children's BLL <20 µg/dL n (%)**	***c*OR (95% CI)**	***a*OR (95% CI)**
Cookware materials				
Aluminum	132 (33.3%)	264 (66.7%)	6.0 (3.3-10.9)	1.4 (1.2 -1.6)
Enamel/teflon/ ceramic/clay/glass	13 (7.7%)	155 (92.3%)		
Food ware materials				
Alumunum/ceramic/ clay/glass	81 (33.8%)	159 (66%)	2.1 (1.4-3.0)	1.15 (1.0– 1.3)
Plastic	64 (19.8%)	260 (80.2%)		
Types of spices used for cooking				
Other than yellow/ red spices	46 (31.7)	50 (11.9)	3.4 (2.2 – 5.4)	2.7 (1.7 – 48.0)
Yellow/red spices	99 (68.3)	369 (88.1)		
Cleaning the house				
Sweep and mop/ vacuum (not daily)	138 (26.5%)	383 (73.5%)	1.8 (0.8 – 4.2)	2.9 (1.2 – 7.1)
Sweeping only (daily)	7 (16.3%)	36 (83.7%)		

Note: Adjusted OR by house activities related to lead, father's activities related to lead, main drinking water source at home, form of spices, and bring/wash work clothes at home.

Table 24. Children's BLL with socioeconomic level and cookware usage analysis (N = 564)

Socioeconomic and cookware usage	Children's BLL ≥20 µg/dL n (%)	Children's BLL <20 µg/dL n (%)	*cOR (95% CI)*
Low Socioeconomic			
Using aluminum	22 (61.1)	14 (38.9)	17.8 (7.4 – 42.8)
Using other materials/ not aluminum	0 (0.0)	8 (100.0)	
Middle Socioeconomic			
Using aluminum	110 (30.6)	250 (69.4)	3.6 (1.8 – 7.2)
Using other materials/ not aluminum	13 (8.1)	147 (91.9)	

Table 25. The potential lead exposure from environment

n Children's BLL		r	*p*
125	Adult's (Father/Guardian) blood lead level	0.24^{S}	0.006
101	Soil Lead Level	0.55^{S}	<0.001
131	Dust lead level	0.38^{S}	<0.001
136	Clean water lead level	0.15^{S}	0.077
50	Drinking water lead level	0.35^{P}	0.013
138	Air lead level	-0.45^{S}	<0.001
79	Door paint lead level	0.04^{P}	0.753
133	Wall paint lead level	0.22^{S}	0.010

P: Pearson Correlation; S: Spearman's Rho Correlation

Based on location of lead measurement from environment defined by ordinate, the correlation between BLL among children and the potential exposure of lead in soil and air ambience can be seen in maps no. 8 – 12 below.

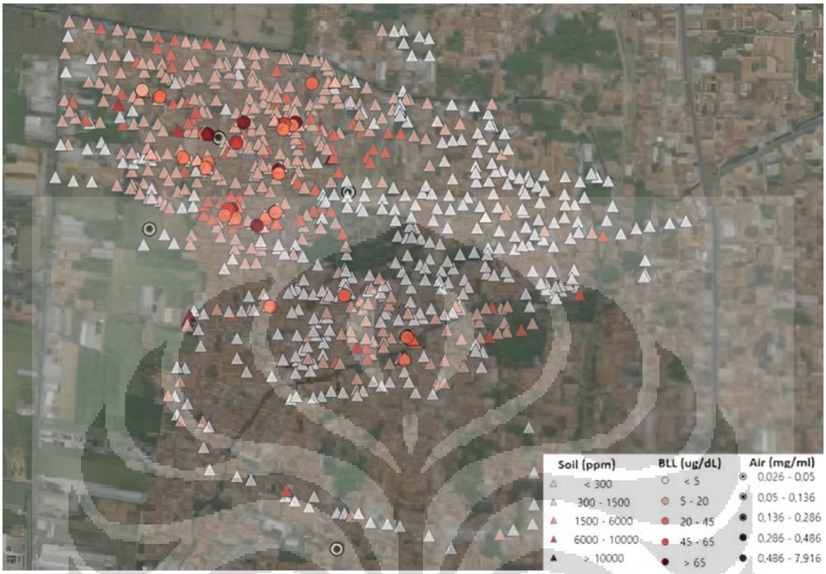

Figure 8. Maps distribution of concentration of soil lead level, air lead level and children's BLL in Pesarean (Tegal)

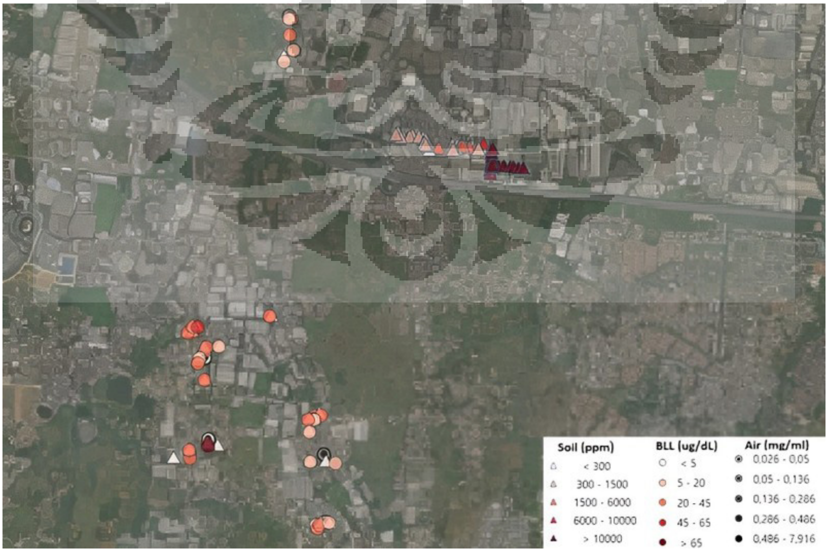

Figure 9. Maps distribution of concentration of soil lead level, air lead level and children's BLL in Kadu Jaya (Tangerang)

Figure 10. Maps distribution of concentration of soil lead level, air lead level and children's BLL in Cinangka (Bogor)

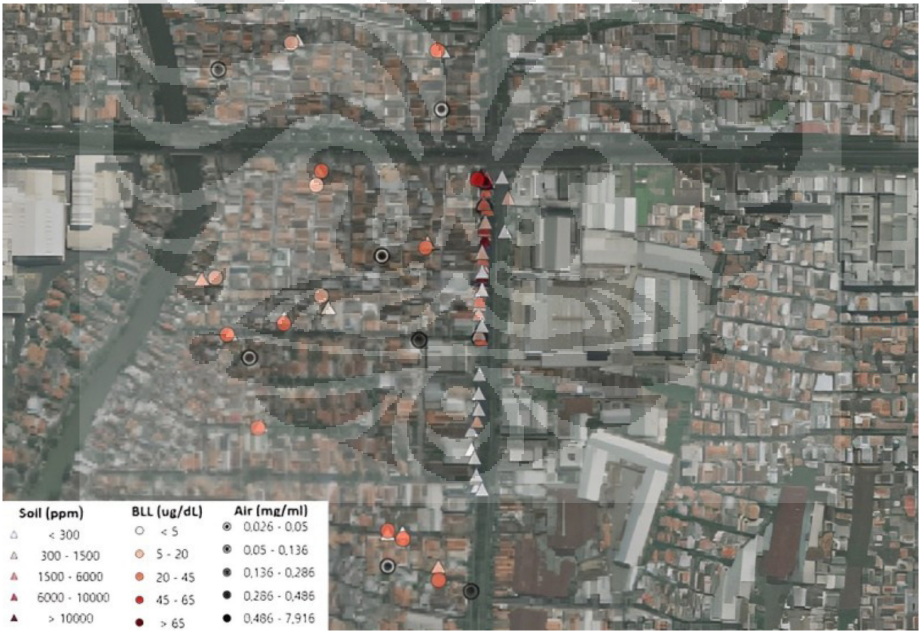

Figure 11. Maps distribution of concentration of soil lead level, air lead level and children's BLL in Dupak (Surabaya)

Figure 12. Maps distribution of concentration of soil lead level, air lead level and children's BLL in Cinangneng (Bogor)

Children's behaviors as risk factors consist of variables such as breastfeeding duration, taking regular/traditional medicines, cosmetic use, handwashing habit before eating, children's habit inserting hand to mouth, frequency of inserting hand to mouth, type of things inserted to mouth and places where children spend most of their time. Among those variables, the proportion differences of breastfeeding duration were statistically significant associated with high BLL ≥20 µg/dL (p = 0.04). Based on the analysis, children who experienced breastfeeding <6 months with BLL ≥20µg/dL was (39.2%) higher than children who were breastfed ≥6 months with high BLL (23.7%) (see details in table 26).

Bivariate analysis was carried out to identify variable candidates based on the results of p <0.3. Thus, the data showed that variables with p<0.3 were breastfeeding duration variables, taking regular/traditional medicines, frequency and type of things that children inserted in the mouth, and places where children spent most of their time. Further analysis on multivariate also carried out and we found that determinant factors were breastfeeding duration (*a*OR = 2.0 (see table 26-27).

Table 26. Characteristics of children's behavioral risk factors (N = 564)

Characteristics of Children's Behavior/ Activities Related to Lead Exposure	BLL ≥20 µg/dL	BLL <20 µg/dL	*p*
Breastfeeding duration			
<6 months	29 (39.2%)	45 (60.8%)	0.04[P]
≥6 months	116 (23.7%)	374 (76.3%)	
Taking regular/traditional medicines			
Yes	41 (29.7%)	97 (70.3)	0.2[P]
No	104 (24.4%)	322 (75.6%)	
Cosmetics use			
Yes	107 (26.1%)	303 (73.9%)	0.7[P]
No	38 (24.7%)	116 (75.3%)	
Handwashing habit before eating			
Seldom/Never	38 (25.7%)	110 (74.3%)	0.9[P]
Sometimes/always	107 (25.7%)	309 (74.3%)	
Children's habit inserting hand to mouth			
Yes	65 (25.7%)	188 (74.3%)	0.9[CS]
No	80 (25.7)	231 (74.3)	
Frequency of inserting hand to mouth			
Everyday	23 (20.4)	90 (79.6)	0.2[CS]
Few times a week	42 (30.0)	98 (70.0)	0.3[CS]
Never	80 (25.7)	231 (74.3)	Ref
Type of things inserted to mouth			
Toys	25 (24.8%)	76 (75.2%)	1.0[CS]
Non Toys	14 (37.8%)	23 (62.2%)	0.1[CS]
Not inserting things to mouth	106 (24.9%)	320 (75.1%)	Ref
Places for spending most of the time			
Outside the house	76 (29%)	186 (71%)	0.1[CS]
Inside the house	69 (22.8%)	233 (77.2%)	

CS: Chi-Square Tests

Table 27. Multivariate analysis of children's behavior risk factors

Characteristics of Children's Behavior Related to Lead Exposure	BLL ≥20 μg/dL	BLL <20 μg/dL	*cOR* (95% CI)	*aOR* (95% CI)
Breastfeeding duration				
<6 months	29 (39.2%)	45 (60.8%)	1.1 (0.7-1.8)	2.0 (1.2 – 3.4)
≥6 months	116 (23.7%)	374 (76.3%)		
Taking regular/traditional medicines				
Yes	41 (29.7%)	97 (70.3)	1.3 (0.8-2.00)	1.2 (0.8 – 1.9)
No	104 (24.4%)	322 (75.6%)		
Frequency of inserting hand to mouth				
Everyday	23 (20.4)	90 (79.6)	1.3 (0.8 – 2.3)	1.4 (0.9 – 2.5)
Few times a week	42 (30.0)	98 (70.0)	0.8 (0.5 – 1.3)	0.8 (0.5 – 1.3)
Never	80 (25.7)	231 (74.3)	Ref	
Type of things inserted in mouth				
Toys	25 (24.8%)	76 (75.2%)	1.0 (0.6 – 1.7)	1.0 (0.6 – 1.7)
Non Toys	14 (37.8%)	23 (62.2%)	0.5 (0.3 – 1.1)	0.6 (0.3 – 1.3)
Not inserting things to mouth	106 (24.9%)	320 (75.1%)	Ref	
Places for spending most of the time				
Outside the house	75 (29%)	186 (71%)	1.4 (0.9-2.0)	1.4 (0.9 – 2.0)
Inside the house	69 (22.8%)	233 (77.2%)		

Note: This multivariate analysis was adjusted by breastfeeding, handwashing habits before eating, children's habit inserting hand to mouth, frequency of inserting hand to mouth, type of things inserted to mouth and places for spending most of the time.

This study measured lead level from the environment including air, soil, drinking water, clean water, dust, to explore the potential lead exposure sources.

The measurements of lead level in the exposed and controlled areas which were statistically significant were air, soil, clean water, dust, wall paint, and mattress. Among those materials measured, soil had the most difference between exposed and controlled areas which in exposed areas had median (Q1-Q3) of 6581.7 (2432.6-16647.1) mg/kg and in controlled areas had median (Q1-Q3) of 253.5 (158.8 – 417.1) mg/kg (p<0.001). Mattress had median in exposed areas almost 3 times higher than in controlled area which median (Q1-Q3) of 37.3 (14.0 – 199.1), and 13.0 (0.0 – 36.0) respectively (p = 0.001)(see table 28).

Lead level found in dust whose median (Q1-Q3) of 0.15 (0.1 – 0.3) µg/cm^2 was higher in exposed areas than in controlled area 0.5 (0.1 – 2.0) µg/cm^2 (p<0.001). Also, the median (Q1-Q3) of adult's clothes in controlled areas was 959.3 (73.5 – 1845.0) which was higher than the median in exposed areas 32.8 (7.0 – 233.4). of The total sample of adults' clothes in the controlled area were only 2 samples and these clothes might be highly contaminated by lead. Thus, children in controlled areas might have higher potential lead exposure at home from his father's clothes (see table 28).

Table 28. Lead level from environmental measurements in exposed and controlled areas

Environmental Measurement of Lead Level	Exposed Areas Median (Q1-Q3)	Controlled Area Median (Q1-Q3)	*p*
Air (mg/m^3)	0.07 (0.05 – 0.1)	0.4 (0.4 – 0.8)	<0.001
Soil (mg/kg)	6581.7 (2432.6-16647.1)	253.5 (158.8-417.1)	<0001
Drinking water (ppm)	0.0002 (0.00003 – 0.00185)	0.0001 (0.00000- 0.00035)	0.060
Clean water (ppm)	0.0002 (0.0001 – 0.00075)	0.0001 (0.00000-0.00010)	<0.001
Dust (µg/cm^2)	0.5 (0.1 – 2.0)	0.15 (0.1 – 0.3)	<0.001
Wall paint (mg/cm^2)	0.8 (0.0 – 3.1)	0.0 (0.0 – 0.3)	<0.001
Door paint (mg/cm^2)	44.2 (1.24 – 153.8)	41.3 (18.3 – 132.9)	0.567
Toys	0.0 (0.0 - 8.8)	0.0 (0.0 – 0.0)	0.177
Cookware	130.0 (15.0 - 1643.3)	892.5 (22.5 – 2080.0)	0.289
Food ware (plastic)	10.0 (0.00 – 41.5)	0.0 (0.0 – 37.8)	0.381
Food ware (non-plastic)	340.0 (47.5 – 3030.0)	170.0 (15.0 – 1845.0)	0.454
Children's clothes	30.5 (0.0 – 150.0)	55.0 (4.5 – 308.75)	0.360
Adult's clothes	32.8 (7.0 – 233.4)	959.3 (73.5 – 1845.0)*	0.180
Matrass	37.3 (14.0 – 199.1)	13.0 (0.0 – 36.0)	0.001

*) minimum and maximum from 2 measurements

VI

CHAPTER

VI.1 Preventive Measures in Lead Exposure

Based on sociodemographic analysis and economic status, it was found that this study community has a socio-demographic picture of the sub-urban population in Indonesia. This can be seen at least from the distribution of types of work and economic status of research participants. Aligned with the data of parent's monthly income that is less than regional minimum wages in Bogor (IDR 4.600.000), Tegal (IDR 2.145.000), Surabaya (IDR 4.525.000) and Tangerang (IDR 4.584.519). Most of the participants have monthly income less than regional minimum wages in all study areas were 86.1%, 93.6%, 72.8%, 88% in Bogor, Tegal, Surabaya, Tangerang respectively. Among those participants, participants who do not have memberships in Social Health Insurance Administration Body *(Badan Penyelenggara Jaminan Sosial Kesehatan/BPJS Kesehatan)* were 70.8% children in Cinangka, 37.6% in Tangerang, 42.3% in Tegal, 25.4% in Surabaya and 47.9% in Cinangneng.

This research data shows that the occupation of the respondents' parents was mostly temporary workers (30.5%), the second most were private workers (25.5%), followed by working in their own business (23.6%). Based on socio-economic status, we found that low economic status (poverty) in this study area was 7.8% while the economy level nationally was 9.36%[33]. Both economic status in our study were below 10% as a national target.

Analysis of this study showed that children living in poor condition were statistically significant associated with high BLL in a threefold higher odd. Moreover, children lived in an exposed area of lead almost fourfold having higher odd of high BLL compared to the ones living in controlled area. The results here were relevant to the previous studies of EPA and Aelion CM, et al[34,35], that children between 1 to 5 years old with high BLL has been associated with poverty. Beside that, many previous studies conducted showed that children living in socioeconomic disadvantages, household conditions, and living in rural areas near lead-acid battery recycling and smelting, malnourishment are more vulnerable to environmental lead exposure[5,36,37].

From the environmental measurements and analysis, we found that sources of potential lead exposure to children living in exposed areas were from father's BLL, soil, wall paint, cookware, non plastic food ware, children's clothes, adults' (fathers/guardians) clothes and mattress. This study found that, the BLL of adults (fathers/guardians of children) were more than 20µg/dL making the children's BLL posed sixfold higher odd. This could be due to adult clothing and adults' personal hygiene has a significant impact on the children's BLL.

Furthermore, a relationship was identified between the blood lead levels (BLL) of fathers and those of their children. This study reveals that the high BLL of adults (fathers/guardians) by ≥20 µg results in a 6 folds crease in the risk of high BLL in children. Additionally, a statistically significant correlation was observed through correlation analysis, suggesting that the transfer of lead from the father's workplace to the home may be a contributing factor. This transfer could be facilitated by the contamination of adult clothing and a lack of personal hygiene practices after work, allowing lead to infiltrate the living environment and affect children.

To mitigate the risk of lead exposure brought home by working fathers, there is a need for educational interventions focusing on personal hygiene and healthy living behaviors among workers. The Ministry of Manpower can contribute to this effort by integrating Occupational Safety and Health programs that emphasize the importance of clean and healthy practices in the workplace. Strengthening the promotion of safe and healthy behaviors at work should align with the messaging on clean and healthy practices introduced by the Ministry of Health.

Lead level from soil measurement showed the highest median among others in exposed areas and statistically significant in the analysis of both areas. As mentioned before, the threshold for soil set by US-EPA and WHO are 400 pm; while the standard in Indonesia is 300 ppm (the Government Regulation No. 22 Year 2021 and the Regulation of Minister of Environment and Forestry No. 101 Year 2018). Thus, in exposed areas the median of lead level in soil was 22 folds higher than the lead level standard set by the Government.

Previous study by Haryanto B[21], that the lead related activities (ULABs recycling, smelting) deposited in the soil and accumulated on the surface. The deposition of lead in the soil occurred over decades because lead moves slowly through the soil due to its strong tendency to be absorbed by organic matter and clay particles, making it immobile and biologically inert[35,38]. The mobility of lead in soil depends on several factors, including soil type, pH, soil moisture content, and water infiltration[39].

Toddlers may be exposed to more contaminated soils and dust as a result of hand-to-mouth behaviors and increased time spent close to the ground through crawling and play activities[35,38]. Moreover children played barefoot, frequently put their hands or toys in their mouths, and lived in poor sanitary conditions at home were at high risk for elevated BLL levels. Kwong L, et al.[40], analysed that direct soil ingestion accounted for nearly 40% of soil consumed by children age 6 to 23 months.

Preventing exposure to soil and dust contaminated with Pb is important. The Ministry of Environment and Forestry needs to take a role primarily in controlling contaminated land. Soil remediation efforts need to continue to improve their effectiveness and expand their reach. Apart from that, control of pollution sources from industry needs to continue to be strengthened. Collaboration with the Ministry of Cooperatives for Small and Medium Enterprises to provide guidance to micro, small and medium enterprise groups needs to be carried out. However, building habits on good hygiene particularly on personal hygiene, washing toys and things surrounding the children play an important role in reducing exposure to lead.

In addition, children could be poisoned also by dust and interior surfaces of home with paint containing lead[41]. Ingestion and inhalation of lead were the main routes of lead contamination[40,42]. Both the wall paint and dust measurements were also statistically significant from the lead measurements. A National Report of Lead in Solvent-Based Paints in Indonesia in October 2021[13] showed that solvent-based paints containing high lead concentrations are sold for home use, available in Indonesia and among those paints only 23% of paints contained lead concentrations below the threshold (90 ppm). Furthermore, prior studies by Swaringen B, et al.[43]; Shi T, et.al[44]; Lanzerstorfer C[45], explained that the use of leaded paint in the renovation of old houses creates hazardous environments. When paint is removed or disturbed, lead from dust particles can become airborne, causing dust to accumulate around the house and on workers, exposing others to the metal. In fact, lead in dust can be found in a wide range of small particles ranging in size from tens of microns to one millimeter, which can accumulate both outdoors and indoors depending on their sources and are easily absorbed.

Interesting finding was on air lead level that had negative correlation with child's BLL. The negative correlation between children's blood lead levels and air lead level may be due to the fact that children are more likely to be at home than outside. The measurement air lead levels are more representative of the air lead levels at the macro environmental level and do not describe the air lead levels in the house.

The cookware and food ware made from aluminum that participants use on a daily basis. The use of aluminum for cookware and food ware is popular with consumers because it is inexpensive, lightweight, and conductive to heat. Our study showed that the use of aluminum for cooking resulted in 18 times higher BLL to participants living in low socioeconomic status and used aluminum, than in participants who lived in middle socioeconomic status and did not use aluminum. Participants with low economic status may purchase alumiium food ware/cookware produced and distributed by the informal industrial sector that does not meet the Indonesian National Standard (*Standar Nasional Indonesia/SNI*) as there may be a lack of strict monitoring of food ware manufacturers or the industry, such as standard for heavy metal contained in products especially lead. So, that the permissible limits for aluminum are not met.

Because aluminum easily conducts heat, the lead contamination process accelerates as the temperature rises. Aluminum leachability increases with temperature, heating cookware for 2 hours or more releases significantly more lead into food. Moreover, the age and useful life of aluminum cookware can also affect the migration of metals into food[46]. The older or more frequently used cookware or food ware made from aluminum, the more lead is released and seeps into the food. A previous study in Cameroon showed that the pots and utensils tested contain a moderate amount of lead as a contaminant, ranging from <15 to 850 ppm, which is consistent with another study that examined aluminum cookware manufactured in China, Saudi Arabia and Syria[47].

In our measurements on cookware, the median was 130 ppm in exposed areas and 892.5 ppm in controlled area.

Children's behavior and duration of breastfeeding were considered also as the risk factors on elevated BLL. Children with high BLL were the ones who had breastfeeding duration less than 6 months. Higher BLL occurred in children who were breastfed for less than 6 months, which may indicate that the children were weaned early and the diet may have been contaminated with lead.

Studies on the effects of lead and other heavy metals on health have been conducted in the past. Jarup L[48] studied that children may absorb up to 50% of lead through their gastrointestinal tracts, while adults only absorb 10-15% of lead from meals. Because children's blood-brain barriers are less established than adults', children's neurological systems are more susceptible to lead exposure. Children are more vulnerable to lead exposure and brain damage due to the porous blood-brain barrier and the high absorption of lead in the gastrointestinal tract, especially in newborns and infants[48] In childhood, every 10 g/dL of lead increase in blood results in a loss of five points on language tests[49]. According to the Indonesian Health Ministry, the correlation between dietary exposure and intelligence decrease is that every 12 g/day exposure reduces one IQ point[50–52]. Also, lead builds up in the skeleton and is gradually eliminated from the body through urination. Lead has a half-life of one month in blood and with about 90% of the total body of lead deposits in the skeleton for twenty to thirty years[53]. Thus, the effect of lead exposure in children may exist for a long time and along their growth periods.

Analysis of the health effects of lead exposure in this study showed that high BLL in children was not statistically significant related to anemia and growth and developmental status in the study areas. Several factors cause anemia in children. Low socioeconomic status was the most plausible reason that children were not adequately nourished and had poor hygiene, leading to a higher risk of frequent infections that caused anemia and impaired growth and development. Furthermore, their physical, social, emotional, and cognitive development may suffer as a result. Though, statistically our study showed that lead may not be the main factor causing anemia in children, many studies have shown that children with iron deficiency have elevated BLLs, possibly due to increased lead intake[52]. Therefore, it is a caution for children with high BLL to be monitored closely to prevent anemia.

Children's developmental status was also statistically significant associated with anemia status. Lead poisoning cause anemia because it reduces haemoglobin production and shortens the life of erythrocytes through hemolysis and inhibition of the enzyme's coproporphyrino-gen, δ-aminolevulinic acid dehydratase (ALAD), and ferrochelatase which reduces hemoglobin (Hb) levels in the blood[26,54]. Furthermore, a study by Kim H, Jang T, et al.[55], explained that only lead exposure levels above 50 g/dL in adults and 25-40 g/dL in children can cause basophilic stippling and microcytic or normocytic anemia.

This study revealed significant risk factors influencing children's BLL. In exposed areas, lead-contaminated soil needs to be remediated using the most appropriate methods and strategies, and the process needs to be continuously evaluated. Children who live in exposed areas require immediate access to appropriate treatment and close monitoring of their health, especially if they are developing symptoms and already experience delayed in their growth and developmental status.

Aluminum and lead-based paint manufacturers and local entrepreneurs must be educated and supervised in manufacturing and distributing their products. Therefore, regulation, policies and guidelines need to be developed and implemented as soon as possible. Government should intervene to formalize, localize, and provide necessary supports (including facilites, access to capital and market and coaching) to small and medium enterprises and strict enforcement to whom continue doing their business not in compliance with the prevailing laws and regulations.

The use of lead-based paint in the construction of homes and schools must be prohibited. Collaborating with the Indonesian Pediatric Society (IDAI), provincial health offices *(Dinas Kesehatan),* Public Health Center *(Puskesmas)*, district health offices, local social and political offices, village officers and cadres *(Posyandu)* to conduct comprehensive management and treatment of lead poisoning. Compatible with the best toxicology labs and tools. Align with improving the lead intoxication testing facilities and equipment.

This study represents the pioneering effort in Indonesia to uncover the association between variables indicative of potential lead exposure and their correlation with the lead levels observed in children. Furthermore, it is the first investigation to scrutinize the interplay between lead levels, anemia, and the growth and development of children.

Nevertheless, it is essential to acknowledge the constraints inherent in this research. The findings primarily center around the analysis of the relationship between potential lead exposure variables and children's blood lead levels. However, the results of this study are not intended to provide an overview of the contribution of each variable to BLL and they do not elucidate the specific pathways through which lead exposure occurs. Additionally, it is crucial to recognize that the outcomes of this study may not offer a comprehensive depiction of lead exposure in Indonesia. This limitation is noteworthy, particularly considering that the research focuses on an area characterized by high population density, constituting almost half of the country's total population.

VI.2 Future Directions

There is no sociodemographics characteristics differences (p>0.05) between the children living in the lead exposed areas and the children living at the control area. The BLLs among the exposed areas children (12-59 months) living near ULAB recycling sites (within 2.7 km) in four communities (Cinangka-Bogor, Pesarean-Tegal, Kadu Jaya-Tangerang, and Dupak-Surabaya) was statistically significant higher than BLLs among children (12-59 months) from the control area (>2.7 km). The median (Qi-Q3) BLL of exposed area children and the control area children were 15,2 (10.3 – 22.6 µg/dL) and 8.8 (5.9 – 15 µg/dL) respectively. The exposed area children have 3.9 times more odds than the control area for having high BLL ≥20 µg/dL.

There were no anemia proportion differences based on the study area with p = 0.89. Determining the anemia status of the children living near ULAB recycling sites (within 2.7 km) and children from the control area (> 2.7 km), we found that the proportion of children with anemia was 39.5% in exposed areas and 36.7% in controlled area. For growth and developmental status, the same proportion of 50% children had delayed development in both study areas. The children who had high BLL and anemic tended to have delayed growth and development statistically significant with p = 0.044 that children who have anemia almost four times have delayed development compared to those who don't not have anemia.

The children BLL have a medium correlation with their fathers/guardians BLL (r = 0.24, $p = 0.006$). Children who has the fathers' BLL ≥20 µg/dL have six more times to experience high BLL (≥20 µg/dL). Some environmental lead exposure sources have the association with the high BLL children which are father's BLL, soil, dust, clean water, drinking water, air, door paint and wall paint. There were some behavioural variables associated with the high BLL children including breastfeeding duration less than 6 months, taking regular/traditional medicines, how often and type of things that children inserted on mouth, and places where children spent most of their time.

As part of the research outcome, a policy brief was created, referring to various Government regulations, laws, policies, and programs. The policy brief contains recommendations aimed at Indonesian ministries (The Ministry of Health; The Ministry of Environment and Forestry; The Ministry of Education, Culture, Research and Technology; The Ministry of Social Affairs; The Ministry of Industry; The Ministry of Trade; The Ministry of Cooperatives and Small and Medium Enterprises (SMEs); The Ministry of Labour) and stakeholders (The Local Government; Professional Organizations; Non-Governmental Organization).

In summary, this policy brief has three main components: public education to raise awareness, improving public services and it is capacities to overcome health impacts of lead exposure, and monitoring and implementation of legal regulations for the entire community.

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CONTRIBUTORS

Contributor consists of the following partners and their key staffs:

- Universitas Indonesia (Jakarta):
  - Prof. dr. Muchtaruddin Mansyur, MS, Sp Ok, PhD – Professor of Occupational Medicine, national principal investigator
  - dr. Dewi Yunia Fitriani, Sp Ok – Head of Occupational and Environmental Research Centre, IMERI - Faculty of Medicine, Universitas Indonesia
  - dr. Ari Prayogo, Sp A – Pediatrician
  - dr. Ade Mutiara, MKK, Sp Ok – Occupational Medicine Specialist
  - Health teams: dr. Rifka Aini, dr. Widya Widyaning, dr. Asep, dr. Ratih Fadhillah, Sarah Edna FR, MD

- Health Polytechnic of Ministy of Health of Yogyakarta:
  - Sardjito Eko Windarso, SKM, MP - Department of Environmental Engineering, environmental team coordinator
  - Environmetal team: Dr. Bambang Suwerda, SST, M.Si., Dr. Agus Karmayana Rubaya, SKM, MPH, Dr. Herman Santjoko, SKM, M.Kes., Dr. Choiril Amri, Haryono SKM, M.Kes., Sigid Soedaryanto, SKM, M.Kes, Wahyu WS, M.Si.

- Pure Earth Indonesia Foundation:
  - Budi Susilorini, S.Sos., MBA, director of Pure Earth Indonesia Foundation, national study director
  - Nickolaus Hariojati, S.Hut., program officer of Pure Earth Indonesia Foundation
  - Vedila Rahmi Anantisa, field assistant

- Pure Earth Headquarter:
  - Gabriel Sanchez Ibarra - Vice president of programs PE, international study director
  - Emily Nash – Research director PE, scientific director

- Lori Fried – Director monitoring and evaluation PE, project management leader
- Prof. Stephan Böse-O'Reilly – Professor of Environmental and Public Health, Sr. technical director PE, medical team leader, international principal investigator
- Alfonso Rodriguez – Technical expert PE, environmental team leader

The local team which conducted field work consisted of a trained public health professional to administer the questionnaire, a certified nurse to collect blood samples, and trained technicians to analyze blood samples using the decided analyzer.

Public health nurses with prior experience in field data collection and research assistants with a minimum of a Bachelors' Degree with prior experience in field data collection were contracted to do the information provision, and explanations, screening interview, informed consent, and administration of demographic questionnaires.

Laboratory technicians went through orientation in obtaining the venous blood samples in children 12-59 months of age.

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