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Research Article

# Risk Potency of Lead Exposure to Decrease Cognitive Ability of Productive Age Community in Indonesia Emas 2045

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**Abstract:** Lead (Pb) can decrease children's intelligence quotient (IQ) and cognitive abilities. This study aims to analyze the risk characteristics of lead exposure in children aged 4-5 years related to the risk of low IQ as an obstacle in realizing "Indonesia Emas" of 2045 and to analyze the role of medical intelligence in anticipating these potential risks. This study was conducted in the Tangerang Industrial Area. The Pb concentrations in food, urine, water, and rice were tested using Atomic Absorption Spectrometry (AAS). The results showed that Pb levels in food were lower than the Limit of the Quantification (LOQ) method, thus, a censored data rule was used for data processing. Overall results indicate a risk of causing long-term cognitive impairment. However, The results of the calculation of exposure and Margin of Exposure (MOE) are based on the assumption of 50% and 100% of LOQ value. The obtained exposure and MOE values can not be used to say that the status of Pb exposure occurs. The resulting data is still useful as a basis for further research.

**Keywords**: Lead Exposure, Demographic Bonus, Cognitive Power.

## Introduction

In Indonesia, according to the previous research between the National Nuclear Energy Agency of Indonesia and the Ministry of the Environment from 2009 to 2016, Tangerang is the city with the highest Pb content of PM2.5 in the air after Surabaya [1]. Meanwhile, children are very susceptible to lead exposure since children are generally able to absorb ingested Pb about 4-5 times higher than adults. Furthermore, the adsorbed Pb can accumulate and affect various important organs, including the brain, causing health and developmental problems in children with fatal consequences [2].

Children are also potentially exposed to Pb through various routes, especially food consumed daily. On July 30, 2020, UNICEF and Pure Earth published an article on reports of poisoning affecting children on a large and previously unknown scale. The report suggests that about 1 in 3 children up to 800 million globally have detectable levels of lead in their blood >5 mcg/dL, a level at which WHO has declared this requires intervention. While at its 53rd meeting, JECFA specifically evaluated the impact of lead exposure through food sources on children's Intelligence Quotient (IQ). Even WHO has determined an exposure dose of 0.6 mcg/kg BW/day which causes a decrease of 1 point on the IQ scale in children as a Point of departure (POD) in carrying out the characterization of health risks related to exposure to this metal [3].

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Concerning the first pillar of the vision of "Indonesia Emas" 2045, namely the development of human resources and the ability to control science and technology. If the children of a young generation are exposed to lead, it will cause a decrement in their intelligence. As a result, the lack of intelligence will result in the non-optimal mastery of science and technology and Indonesia will not be able to compete globally. Therefore, lead exposure in children is a factor that must be taken into consideration to achieve the government's vision in 2045 [4].

The status of lead exposure in children needs to be detected early to avoid the high level of risk of cognitive and intelligence disorders in children. Budiyono, et al (2016) showed that children living around battery recycling plants contained a high level of lead in their blood, leading to a high-risk low intelligence compound level 3.5 times compared to those who have low lead levels in their blood. In this case, intelligence personnel are expected to be able to carry out early detection so that appropriate efforts can be made in accordance with Article 4 of Law No. 17 of 2011 which reads: "State intelligence plays a role in carrying out efforts, work, activities, and actions for early detection and early warning in the context of prevention, deterrence, and countermeasures against any nature of threats that may arise and threaten national interests and security." The government can immediately make anticipatory and solution efforts so that the first pillar of the vision of "Indonesia Emas" 2045 is still can be implemented optimally.

## Materials and Methods

The sample was collected from 32 children aged 4 – 5 years in 3 preschool schools that were randomly selected by taking into account the maximum radius of the school from the industrial area, which is a maximum of 15 km east of the Cikupa industrial area. The location was selected since the dominant cardinal direction at that moment was blowing eastward. The samples used in this study were food samples eaten daily by children, urine samples from these children, samples of water used for cooking, and samples of rice sold in the Tangerang industrial area market The food samples taken by the researcher were food supplies brought by the students including rice, vegetables and side dishes which are considered to represent the food they usually consume every day. These ready-to-eat foods are then taken with a minimum weight of 50 grams each for further analysis in the laboratory using the Atomic Absorption Spectrometry (AAS) method. Meanwhile, urine samples were taken from students' urine randomly when the researchers visited the schools. The urine was taken at least 50ml and stored in a special tube and container before further analysis. For the rice, it tested for two types of rice samples at random from students' parents. The rice is cooked daily for their children's consumption. All samples were analyzed by using the Atomic Absorption Spectrometry (AAS) method.

The AAS analysis is divided into 3 steps, including standard and sample preparation. The Pb standard solution was diluted into HCl 1 N solution. Then, 10 g of the sample was gradually heated to the temperature of 450°C. The resulting ash was dissolved into 5 mL HCl 6 N by heating in a hotplate, followed by dissolving in $HNO_3$ 0.1 N for 3 minutes. The resulting solution was filtered and diluted before further analysis using AAS. The blank solution was carried out by a similar procedure to the sample. The dissolved Pb was calculated using the AAS at a maximum wavelength of 283.3 nm.

The obtained data was processed by parametric descriptive statistics. Data on the type of food consumed and its quantity as well as the lead content in each sample were processed manually statistics and shown as daily lead exposure levels in mcg/kg BB/day considering the child's body weight based on the available anthropometric data. Furthermore, by using the point of departure (POD) according to WHO of 0.6 mcg/kg BW/day for a 1-point decrease in IQ scale in children as the numerator and daily exposure level of lead in mcg/kg BW/day as the denominator. The margin of exposure (MOE) of lead can be calculated as sourced from food. The greater the MOE value obtained, the lower the risk of exposure that can cause health problems in the exposed population and vice versa. An approach using MOE value is a useful option and pragmatic to use as a parameter for assessing the risk of genotoxic and carcinogenic substances or compounds for humans as well as has the potential to be able to provide improvements in the efforts of advice and input provided to the management responsible for performing risk management.

## Results and Discussions

In this study, the lead concentration is known to be less than the limit of quantification (LOQ) tool from the AAS used, so the rule of left-censored data is used in conducting the calculation of lead exposure and MOE. In statistics, censoring is a condition, in which a value measurement or observation is only partially known. Censoring is also carried out when a known value is out of range of the measuring instrument. Since the data point of the Pb level is below a certain value, but it is not known the magnitude, then the rule of left-censored data is used. Left censored data is data for items that failed before the start of

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the test. Left-censored data is the same as interval-censored data, however, the lower interval is 0 [5]. If the lower data bound is less than LOQ, the value is considered equal to zero. If the middle bound data is less than LOQ, the value is considered equal to half of the LOQ. If the upper bound data is less than LOQ, the value is considered the same as the LOQ value. The Pb level of LOQ on the AAS tool used in this study is 0.165 mg/kg.

Table 1 shows the lead concentration in food and the prediction of lead exposure in children. At the lower bound, since the data is less than LOQ and considered equal to zero, the MOE cannot be calculated. In the middle bound data, the lead content of all food is considered half of the LOQ with the value of 0.0825 mg/kg. From these results, it is possible to calculate the exposure per child's body weight per day and calculate the MOE to determine the risk characteristics. In the upper bound data, the lead concentrations for all food are considered to be at the LOQ of 0.165 mg/kg. The calculation results are shown in Table 1 and Table 2 for middle-bound and upper-bound data.

The average Pb exposure for the middle bound data is 6.98 mcg/kg BW/day with an average MOE of 0.0871. While the average lead exposure for children according to WHO data (2021) is in the range of 0.03-9 mcg/kg BW/day [3]. Thus, we can conclude that the average exposure in the middle bound data is still in the range's value reported by WHO. It means the exposure that happened at the median limit is also experienced by other countries globally. However, the average exposure in the upper bound data is greater than the exposure rate reported by WHO, which is 13.96 mcg/kg BW/day with an average MOE of 0.0435.

**Table 1. Middle Bound Data for Food**

| Correspondent code | weight (kg) | Total food consumption (kg) | Pb level in composite (mg/kg) | Total Pb Intake (mcg/ person/ day) | Pb exposure (mcg/kg BW/day) | POD WHO (mcg/kg BW/day) | MOE |
|---|---|---|---|---|---|---|---|
| 1 | 12.5 | 1.10 | 0.0825 | 90.92 | 7.27 | 0.6 | 0.0825 |
| 2 | 14 | 1.31 | 0.0825 | 108.08 | 7.72 | 0.6 | 0.0777 |
| 3 | 13 | 1.31 | 0.0825 | 108.08 | 8.31 | 0.6 | 0.0722 |
| 4 | 15 | 1.31 | 0.0825 | 107.66 | 7.18 | 0.6 | 0.0836 |
| 5 | 12 | 1.16 | 0.0825 | 95.45 | 7.95 | 0.6 | 0.0754 |
| 6 | 17 | 1.39 | 0.0825 | 114.26 | 6.72 | 0.6 | 0.0893 |
| 7 | 13 | 1.21 | 0.0825 | 100.07 | 7.70 | 0.6 | 0.0779 |
| 8 | 15 | 1.37 | 0.0825 | 112.86 | 7.52 | 0.6 | 0.0797 |
| 9 | 15 | 1.21 | 0.0825 | 99.83 | 6.66 | 0.6 | 0.0902 |
| 10 | 17 | 1.37 | 0.0825 | 112.61 | 6.62 | 0.6 | 0.0906 |
| 11 | 14 | 1.33 | 0.0825 | 109.31 | 7.81 | 0.6 | 0.0768 |
| 12 | 10 | 1.24 | 0.0825 | 102.47 | 10.25 | 0.6 | 0.0586 |
| 13 | 16 | 1.38 | 0.0825 | 113.69 | 7.11 | 0.6 | 0.0844 |
| 14 | 17 | 1.47 | 0.0825 | 120.86 | 7.11 | 0.6 | 0.0844 |
| 15 | 13 | 1.16 | 0.0825 | 95.45 | 7.34 | 0.6 | 0.0817 |
| 16 | 19.5 | 1.39 | 0.0825 | 114.26 | 5.86 | 0.6 | 0.1024 |
| 17 | 17 | 1.37 | 0.0825 | 112.86 | 6.64 | 0.6 | 0.0904 |
| 18 | 16.5 | 1.21 | 0.0825 | 99.83 | 6.05 | 0.6 | 0.0992 |
| 19 | 17.5 | 1.37 | 0.0825 | 112.61 | 6.44 | 0.6 | 0.0932 |
| 20 | 14 | 1.21 | 0.0825 | 99.83 | 7.13 | 0.6 | 0.0841 |
| 21 | 18 | 1.37 | 0.0825 | 112.61 | 6.26 | 0.6 | 0.0959 |
| 22 | 16 | 1.37 | 0.0825 | 112.86 | 7.05 | 0.6 | 0.0851 |
| 23 | 16 | 1.21 | 0.0825 | 99.83 | 6.24 | 0.6 | 0.0962 |
| 24 | 15 | 1.21 | 0.0825 | 99.83 | 6.66 | 0.6 | 0.0902 |
| 25 | 14.5 | 1.21 | 0.0825 | 100.07 | 6.90 | 0.6 | 0.0869 |
| 26 | 14 | 1.21 | 0.0825 | 100.07 | 7.15 | 0.6 | 0.0839 |

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| Correspondent code | weight (kg) | Total food consumption (kg) | Pb level in composite (mg/kg) | Total Pb Intake (mcg/ person/ day) | Pb exposure (mcg/kg BW/day) | POD WHO (mcg/kg BW/day) | MOE |
|---|---|---|---|---|---|---|---|
| 27 | 15 | 1.21 | 0.0825 | 99.83 | 6.66 | 0.6 | 0.0902 |
| 28 | 17.5 | 1.37 | 0.0825 | 112.86 | 6.45 | 0.6 | 0.0930 |
| 29 | 18 | 1.37 | 0.0825 | 112.61 | 6.26 | 0.6 | 0.0959 |
| 30 | 17 | 1.21 | 0.0825 | 99.83 | 5.87 | 0.6 | 0.1022 |
| 31 | 17.5 | 1.37 | 0.0825 | 112.61 | 6.44 | 0.6 | 0.0932 |
| 32 | 16.5 | 1.21 | 0.0825 | 99.83 | 6.05 | 0.6 | 0.0992 |

**Table 2. Upper Bound Data for Food**

| Correspondent code | weight (kg) | Total food consumption (kg) | Pb level in composite (mg/kg) | Total Pb Intake (mcg/ person/ day) | Pb exposure (mcg/kg BW/day) | POD WHO (mcg/kg BW/day) | MOE |
|---|---|---|---|---|---|---|---|
| 1 | 12.5 | 1.10 | 0.165 | 181.83 | 14.55 | 0.6 | 0.0412 |
| 2 | 14.0 | 1.31 | 0.165 | 216.15 | 15.44 | 0.6 | 0.0389 |
| 3 | 13.0 | 1.31 | 0.165 | 216.15 | 16.63 | 0.6 | 0.0361 |
| 4 | 15.0 | 1.31 | 0.165 | 215.33 | 14.36 | 0.6 | 0.0418 |
| 5 | 12.0 | 1.16 | 0.165 | 190.91 | 15.91 | 0.6 | 0.0377 |
| 6 | 17.0 | 1.39 | 0.165 | 228.53 | 13.44 | 0.6 | 0.0446 |
| 7 | 13.0 | 1.21 | 0.165 | 200.15 | 15.40 | 0.6 | 0.0390 |
| 8 | 15.0 | 1.37 | 0.165 | 225.72 | 15.05 | 0.6 | 0.0399 |
| 9 | 15.0 | 1.21 | 0.165 | 199.65 | 13.31 | 0.6 | 0.0451 |
| 10 | 17.0 | 1.37 | 0.165 | 225.23 | 13.25 | 0.6 | 0.0453 |
| 11 | 14.0 | 1.33 | 0.165 | 218.63 | 15.62 | 0.6 | 0.0384 |
| 12 | 10.0 | 1.24 | 0.165 | 204.93 | 20.49 | 0.6 | 0.0293 |
| 13 | 16.0 | 1.38 | 0.165 | 227.37 | 14.21 | 0.6 | 0.0422 |
| 14 | 17.0 | 1.47 | 0.165 | 241.73 | 14.22 | 0.6 | 0.0422 |
| 15 | 13.0 | 1.16 | 0.165 | 190.91 | 14.69 | 0.6 | 0.0409 |
| 16 | 19.5 | 1.39 | 0.165 | 228.53 | 11.72 | 0.6 | 0.0512 |
| 17 | 17.0 | 1.37 | 0.165 | 225.72 | 13.28 | 0.6 | 0.0452 |
| 18 | 16.5 | 1.21 | 0.165 | 199.65 | 12.10 | 0.6 | 0.0496 |
| 19 | 17.5 | 1.37 | 0.165 | 225.23 | 12.87 | 0.6 | 0.0466 |
| 20 | 14.0 | 1.21 | 0.165 | 199.65 | 14.26 | 0.6 | 0.0421 |
| 21 | 18.0 | 1.37 | 0.165 | 225.23 | 12.51 | 0.6 | 0.0480 |
| 22 | 16.0 | 1.37 | 0.165 | 225.72 | 14.11 | 0.6 | 0.0425 |
| 23 | 16.0 | 1.21 | 0.165 | 199.65 | 12.48 | 0.6 | 0.0481 |
| 24 | 15.0 | 1.21 | 0.165 | 199.65 | 13.31 | 0.6 | 0.0451 |
| 25 | 14.5 | 1.21 | 0.165 | 200.15 | 13.80 | 0.6 | 0.0435 |
| 26 | 14.0 | 1.21 | 0.165 | 200.15 | 14.30 | 0.6 | 0.0420 |
| 27 | 15.0 | 1.21 | 0.165 | 199.65 | 13.31 | 0.6 | 0.0451 |
| 28 | 17.5 | 1.37 | 0.165 | 225.72 | 12.90 | 0.6 | 0.0465 |
| 29 | 18.0 | 1.37 | 0.165 | 225.23 | 12.51 | 0.6 | 0.0480 |

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| Correspondent code | weight (kg) | Total food consumption (kg) | Pb level in composite (mg/kg) | Total Pb Intake (mcg/ person/ day) | Pb exposure (mcg/kg BW/day) | POD WHO (mcg/kg BW/day) | MOE |
|---|---|---|---|---|---|---|---|
| 30 | 17.0 | 1.21 | 0.165 | 199.65 | 11.74 | 0.6 | 0.0511 |
| 31 | 17.5 | 1.37 | 0.165 | 225.23 | 12.87 | 0.6 | 0.0466 |
| 32 | 16.5 | 1.21 | 0.165 | 199.65 | 12.10 | 0.6 | 0.0496 |

The exposure and MOE calculations are not definitive levels for each sample, thus it cannot be used to conclude the status of the Pb exposure level. However, the resulting data are still useful for further research using more sensitive instruments, so that they can achieve LOQ at lower concentrations and allow Pb quantization at lower concentrations as well.

In this study, the concentration of lead was also conducted for the urine of children. It means that if a certain concentration of Pb is found in a urine sample, the children have a potential risk of lead accumulation in their bodies in the future. This accumulation has an impact on the Pb level increment in the body, thus increasing the potential risks for these children. in terms of health and intelligence.

Of the total respondents of 32 children in the three Nursery Schools studied, researchers were only able to take urine samples of 17 samples (53.13% of the total respondents). This is because it is difficult to get the child's consent as the subject is under study for a urine sample to be taken. Based on the urine sample tested, it was known that all of them had lead levels in urine <LOQ where the LOQ for urine in the AAS method used was 8.10 mcg/L.

The very low concentration of lead in the urine of the children is due to the release of lead through the urine. which is the primary excretion from the body, so the lead in urine is lower than blood lead, which has a survival time of up to 30 days according to the EFSA [6]. Most of the lead is excreted mainly through urine as well as feces, whereas sweat, saliva, hair, nails, and breast milk are minor excretion routes of lead in the body [7]. According to the EFSA (2017), lead in urine describes lead levels in children's urine that have just been received at the time of urine sampling.

The rice sample consumed by the surrounding community was also tested in this study. Rice A and B are rice samples obtained from the parents of students who were randomly selected. Meanwhile, the water widely used by the respondent's parents for cooking was also tested. It was found that the concentrations of lead for rice A and B were 3.18 mg/kg and 0.83 mg/kg, respectively. The tap water sample used for cooking has lead levels less than 0.0033 mg/L (LOQ), thus the lead exposure is considered zero.

**Table 3. Pb Levels in Rice and Water**

| No. | Sample | Pb level |
|---|---|---|
| 1 | Rice A | 3.18 mg/kg |
| 2 | Rice B | 0.83 mg/kg |
| 3 | Tap water | <0.0033 mg/L |

**Risk Characteristics of Pb Exposure**

Pb contamination through various routes has made many problems. For both adults and children who have a higher risk, Pb has several serious long-term impacts. According to WHO (2022), Young children are particularly vulnerable to the toxic effects of lead and can suffer profound and permanent adverse health impacts, particularly on the development of the brain and nervous system. Lead also causes long-term harm in adults, including increased risk of high blood pressure and kidney damage. Exposure of pregnant women to high levels of lead can cause miscarriage, stillbirth, premature birth, and low birth weight [3]. In this case, medical intelligence is needed to carry out early detection and prevention so that the impact can be minimized.

The risk characteristics of lead exposure through food intake in children aged 4-5 years against the potential risk of low cognitive power as an obstacle to realizing Indonesia Emas 2045 around the Tangerang industrial area were initially expected to be illustrated from the results of this study. Considering that the analytical method used has not been able to determine the level of Pb in the food consumed by respondents

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at low levels, quantitative exposure data and MOE calculations cannot be carried out conclusively. However, as supporting data, the authors found that at least two types of rice which are used as staple foods in daily life contain high levels of lead. In addition, some of the food samples tested have also been exposed to lead, although at relatively low concentrations. However, no matter how low Pb levels are exposed to children, it is considered that they can potentially pose a threat of decreased intelligence.

The decline in full-scale IQ scores is thought to reflect changes in cognitive function in children aged 4 years and over. This is because IQ scores are the most consistent endpoint of cognitive ability to be assessed in studies and are used as a reference for assessing neurodevelopmental effects [8]. This is one of the references for the impact of the decline in people's cognitive power as a result of exposure to lead, where WHO (2020) has set a POD of 0.6 mcg/kg BW/day capable of reducing at least one IQ score in children.

The MOE approach is used to assess health risks from exposure to lead in food because there is no health-based guideline value for lead. MOE is defined as the ratio of the observed level of effect (e.g., no observed adverse effect rate (NOAEL) or lower limit of the benchmark dose (BMDL) on the dose-response curve to the critical effect and exposure level of the population). The European Food Safety Authority (EFSA) recommends the use of benchmark dose (BMD) to obtain MOE, i.e., MOE=BMDL/exposure [9].

According to EFSA (2020), the approach using the MOE value is a useful and pragmatic option as a parameter for assessing the risk of substances or compounds that have genotoxic and carcinogenic properties and has the potential to provide increased efforts to advice and input given to responsible managers. to carry out risk management. The greater the MOE value obtained, the lower the risk of exposure that can cause health problems in the exposed population and vice versa. A MOE of less than 1 means that the risk is at a high level (high risk), while a MOE that is in the range of $1 < MOE < 10$ indicates a low-risk level and a $MOE > 10$ indicates that risk is manageable or can be said to be zero risk.

The detection of lead in the rice samples tested in this study indicates that the food consumed by the people around the Tangerang industrial area has been exposed to the heavy metal Pb. Based on the Regulation of the Food and Drug Supervisory Agency Number 5 of 2018, the maximum limit for Pb levels in cereals and cereal products, including rice, of 0.25 mg/kg [10]. Meanwhile, the Pb level for natural mineral water and its source is a maximum of 0.01 mg/kg. From the data obtained, it is known that the two types of rice samples consumed by some children in the Tangerang industrial area turned out to contain lead concentrations that were far above the quality standard for maximum levels of Pb, namely 3.18 mg/kg and 0.83 mg/kg. While water is used for cooking and by some people for drinking, it is still within normal limits for lead levels in water.

As the findings in this study showed that the tested tap water had a lead level of <0.0033 mg/L, the Tangerang City Environment Agency said that according to the results of routine control of water quality in the Tangerang area, both the city and district are still within safe and suitable limits for consumption. Tangerang Environmental Services has also periodically carried out exhaust gas and roadside air emission tests where the results still meet the standards that have been set. However, the finding of two types of rice that are still identified as containing lead with levels that are not low is still a problem that must be explored in depth. whether the rice comes from agricultural land located in the Tangerang industrial area or is distributed from agricultural products from other areas.

## Conclusion

The data assessment carried out on the food samples studied used the left-censored data rule to obtain three exposure scenarios. The first exposure is in the lower bound data or on the Pb level within the lower limit, middle bound (middle limit), and upper bound (upper limit). From the three treatments, the authors' data analysis showed that at the lower bound where all exposure numbers are considered zero because Pb levels <LOQ, the MOE cannot be calculated, and the risk is considered non-existent. While in the middle bound, it was found that Pb exposure of half the LOQ was able to have an impact on exposure to a high-risk level. Likewise, the analysis of exposure to the upper bound data assumes that the amount of Pb in food is equal to the LOQ, which is 0.165 mg/kg. Thus, exposure to the lowest limit of Pb quantification in the tool used for AAS testing can provide a high risk of being able to provide the potential for decreased intelligence or low cognitive power in children in the future.

However, if the calculated average Pb exposure produced by the food samples consumed daily by the studied children is 6.98 mcg/kg BW/day and is still in the range of global lead exposure rates reported by WHO (0.03-9 mcg/kg BW/day). This means that the average Pb exposure that can occur in children in the middle-bound data is also experienced by other countries in the world. So, this does not necessarily have to be something to be too afraid of, but also not to be ignored, considering the threat of declining intelligence with a high potential risk is something that can hinder the realization of the Indonesia Emas visions in carrying out human resource development with all forms of mastery of scientific development and technology.

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