PHARMACOLOGY, MEDICAL REPORTS, ORTHOPEDIC, AND ILLNESS DETAILS (COMORBID)
Volume 2 Issue 1 (2023)

IDENTIFICATION OF MERCURY CONTENT AMONG CHILDREN WITH STUNTING AGED 25 - 59 MONTHS IN THE SMALL-SCALE GOLD MINING AREA OF KRUENG SABEE SUB-DISTRICT, ACEH JAYA REGENCY

Lensoni[1*], Ambia Nurdin[2], Santri Yulis[3]
[1-3]Public Health Study Program, Universitas Abulyatama
E-mail: [1)] soni@abulyatama.ac.id

Abstract

This study investigates the hazardous impact of mercury, classified as a Category B3 heavy metal waste, on human life and the environment. It focuses on the significant contribution of artisanal mining to mercury pollution and its adverse effects on the landscape. In particular, the research examines the health risks posed by mercury exposure to children living in Peri-Urban Artisanal and Small-Scale Gold Mining (PESK) areas, including compromised immune responses and the potential for stunting. Urine samples were collected from participants using purposive sampling in accordance with Minister of Health Regulation No. 43/2013 and analyzed using Atomic Absorption Spectroscopy (AAS). All ten samples exhibited the presence of mercury, with one falling below the 7 µg/L threshold established by Human Biomonitoring (HBM) guidelines. Notably, the study found that 99% of stunted toddlers exceeded the mercury threshold, while only 0.1% remained below it. This research contributes to a deeper understanding of the health and environmental implications associated with mercury contamination.

Keywords: *Artisanal Mining, Mercury Pollution, Stunting*

1. INTRODUCTION

Mercury is one of the heavy metals categorized as Hazardous and Toxic Substances (B3) waste due to its potential harm to living organisms and environmental pollution. Wastewater containing mercury must be treated beforehand to achieve a quality similar to non-toxic environmental water. Mercury-containing waste exhibits the strongest toxic properties compared to other heavy metals like Cadmium (Cd), Silver (Ag), Nickel (Ni), Lead (Pb), Arsenic (As), Chromium (Cr), Tin (Sn), and Zinc (Zn). Additionally, it possesses a strong toxic potency; mercury and its compounds easily react with sulfur-containing enzymes, forming mercury sulfide (HgS) compounds that can disrupt enzyme structures and functions (Lensoni, 2021).

Mercury is a highly dangerous heavy metal as it can accumulate within the body. It enters the body through the food chain, water, and when surpassing tolerance limits, it can lead to poisoning. Acute mercury poisoning symptoms include throat inflammation (pharyngitis), dysphagia, abdominal pain, nausea, vomiting, diarrhea with blood, and shock. Chronic mercury poisoning frequently affects two bodily systems: the digestive system and the nervous system (Lensoni et al., 2020). The sources of mercury pollution are broadly divided into two main categories: natural sources and those stemming from mining. The introduction of metals into aquatic environments can result from mining activities, household wastewater, urban runoff, industrial waste and emissions, and agricultural runoff. Artisanal mining activities are recognized as the largest contributor to mercury pollution in the environment. Moreover, such mining activities indirectly contribute to the degradation of landscapes and vegetation. The management of gold ore in artisanal mining involves two main processes: physical and chemical. The chemical process involves the use of mercury, which can be released into the environment (Bobby et al., 2002).

Mercury is classified as a heavy metal categorized under Hazardous and Toxic Substances (B3) due to its toxic and persistent nature, posing threats to the environment and humans (MENLH, 2013). Based on Law No. 32 of 2009 concerning Environmental Protection and Management, Article 69 clearly states that individuals are prohibited from disposing of B3 waste into the environment, including bodies of water. If B3 waste is dumped into rivers, it undoubtedly contaminates the river water and poses dangers to the health of people using it for drinking and daily needs (Soprima et al., 2016). Exposure to mercury can have adverse effects on the health of children residing in ASGM areas. Reduced immune responses or weakened immune systems in children living in ASGM areas, coupled with high mercury exposure risks and exacerbated by concurrent malnutrition, significantly increase the risk of stunting. Apart from malnutrition and infectious diseases, communities in ASGM areas are also prone to diarrhea (Puspita et al., 2020).

Generally, the Indonesian Government has issued several regulations pertaining to safeguarding the community against chemical pollution in the environment. These include Law No. 32 of 2009 on Environmental Protection and Management, Government Regulation No. 82 of 2001 on Air Quality Management and Pollution Control, Government Regulation No. 74 of 2001 on Hazardous and Toxic Substance Management, Government Regulation No. 66 of 2014 on Environmental Health, Government Regulation No. 101 of 2014 on Hazardous and Toxic Waste Management, along with relevant Minister of Health regulations. The permissible mercury content limit identifiable in the human body is 1 μg/g according to the World Health Organization. The threshold limit value for continuous elemental mercury vapor exposure over 8 hours per day or 40 hours per week, as per the American Conference of Governmental Industrial Hygienists (ACGIH), is 0.05 mg/m^3. The safe threshold value for mercury in food and beverages, referring to Chief of the Food and Drug Monitoring Agency Decree No. HK.00.06.1.52.4011 of 2009, ranges from 0.01 to 1.0 ppm. Meanwhile, the maximum concentration in drinking water is regulated at 0.001 mg/l under the Ministry of Health Regulation No. 492/Menkes/Per/IV/2010 concerning Drinking Water Quality Requirements (Zaharani & Salami, 2015). In 2013, the Minamata Convention was established, aiming to protect human health and the environment from anthropogenic mercury and its compounds emissions, with the Indonesian Government signing alongside 91 other countries. During the 67th World Health Assembly in 2014, the World Health Assembly recommended the WHO Secretariat's assistance to countries in implementing the health aspects of the Minamata Convention (Rany, 2017).

The risk of mercury exposure in the community can come from contamination of water bodies, soil, air and even the food chain such as rice, fish and other foods. Nervous system and behavioral disorders occur after various forms of mercury are inhaled, ingested or absorbed through the skin with symptoms such as tremors, insomnia, memory loss, neuromuscular effects, dizziness and cognitive and motor dysfunction (Sarah & Tomi, 2016). In general, 75% of mercury exposure is in the form of elemental and inorganic mercury, mostly associated with inhalation of vapors from dental amalgam used in dental fillings. 25% of exposure is organic mercury (mainly methyl mercury in fish or fish-derived products). The safe dose of mercury is between 2.0 micrograms per kg body weight per day for inorganic (and elemental) mercury and 1.0 for organic mercury. Regardless of the chemical form of mercury exposed, the kidneys and central nervous system are the 2 target organs of mercury toxicity. Mercury pollution will accumulate in various environmental media such as water, air, soil and accumulate in the food chain as a result of mercury exposure (Nasution, 2019).

Exceeding limits of heavy metal pollution in soil and water can gradually impact plants and ecosystems over time through accumulation (Astiti & Sugianti, 2014). During rainfall, waste disposal sites from mining can overflow into various areas like rivers and fields, leading to environmental damage (Soprima et al., 2016). Mercury carried by river water can undergo absorption and transportation. Absorption is a substance's ability to adhere to surfaces, while transportation involves movement into environmental compartments, distributing quickly to nearby compartments (Soprima et al., 2016). This can lead to pollution on soil surfaces, transported by mercury pollution from river water. The mercury content in this process will settle at the sediment's bottom. Contaminated soil becomes toxic and can pollute plants growing nearby. If consumed, these plants can lead to mercury accumulation in human bodies (Soprima et al., 2016).

Air containing mercury can also adhere to human skin, accumulating and showing negative effects on health within 5-10 years (Maisarah, 2019). The use of mercury (Hg) in gold mining is a significant cause of river water contamination. In water, mercury can undergo biotransformation into organic methyl mercury or phenyl mercury compounds due to bacterial decomposition. These organic compounds are absorbed by microorganisms that enter the food chain, resulting in accumulation and biomagnification within organisms (Puspita, 2020). The movement of mercury into compartments like wellbottoms or water streams in the environment quickly distributes mercury to nearby compartments (Santi et al., 2019). Fish and aquatic creatures living in rivers also experience contamination. This mercury contamination is an example of mercury pollution in the food chain (Handri, 2020).

Stunting is a term for disrupted linear growth in the first 1000 days of life, resulting in failure to reach adult height. Stunting can be measured using height-for-age (HAZ) z-scores less than -2 standard deviations (SD) based on WHO growth standards (Laksono and Kusrini, 2019). Global predictions indicate that one in five children will experience stunting by 2020 (De Onis et al., 2012). Results from Riskesdas in 2007, 2013, and 2018 show that stunting rates in Indonesian toddlers are above 30%, with 3 out of 10 children born in Indonesia being stunted (Laksono et al., 2019).

Stunting is a manifestation of chronic malnutrition (Reinhardt & Fanzo, 2014). Childhood stunting can lead to negative health effects such as cognitive development decline, and in adulthood, it can increase the risk of life-threatening complications during childbirth, reduced performance, and increased non-communicable disease risk factors like obesity, high blood pressure, and cardiovascular diseases (Vilcins et al., 2018). Accumulated heavy metals in the body are a cause of degenerative diseases, particularly cancer. Some toxic heavy metals in the human body include arsenic (As), cadmium (Cd), copper (Cu), lead (Pb), and mercury (Hg) (Puspita et al., 2020). Heavy metal pollution can occur through air, water, and soil contamination, greatly affecting environmental health and posing risks to human health. The impact of heavy metal pollution on the human body can lead to respiratory infections and poisoning. High-level exposure to heavy metals can harm the immune system, brain, lungs, heart, kidneys, mental disorders, body coordination disorders, and even vision impairment (Khaira, 2019).

Limited biomarker exposure examination laboratories are also a challenge in providing healthcare for health disorders due to mercury exposure (Zahri, 2019). Stewart et al.'s study (2013) in Uganda explains that children with diarrhea have decreased appetite, leading to reduced nutrient intake. The high occurrence of diarrhea, coupled with repeated disruptions in nutrient absorption and loss in children, disrupts the growth process. Stunted toddlers with a high prevalence of diarrhea will have a lower immune response. The decrease in immune response or immune system in children living in PESK areas, with a high risk of mercury exposure compounded by simultaneous malnutrition, greatly increases the risk of stunting (Puspita et al., 2020).

In this study, we will explore whether there is a risk of stunting in young children due to mercury exposure. Stunting, a serious issue in child growth and development, can have long-term impacts on their health and quality of life. Mercury, as an environmental element, has garnered attention due to its potential impact on child development. In efforts to better understand the link between mercury exposure and the risk of stunting in toddlers, this study will gather relevant information and analyze existing data. With a better understanding of mercury's potential impact on child growth, appropriate preventive measures and interventions can be designed to protect the younger generation from potential risks.

2. LITERATURE REVIEW

2.1. Mercury

Mercury is a rare element in the Earth's crust, mainly concentrated in certain volcanic areas and mineral deposits of heavy metals. Mercury is used in various applications, including dental amalgams, as a fungicide, and in industrial processes such as gold mining. Mercury is also used in the production of chlorine gas and caustic soda, thermometers, dental fillings, and batteries (Widowati et al., 2008).

Mercury, also known as quicksilver, originates from the Latin word "Hydrargyrum," which means "water of silver." It is a chemical element on the periodic table with the symbol Hg, atomic number 80, and atomic weight 200.59. This transition metal of Group IIB appears silver-white and is liquid at room temperature, with a low vaporization point. Mercury (Hg) will solidify under a pressure of 7,640 Atm (Sudarmo, 2004).

2.2. Sources of Mercury Exposure

As a heavy metal that can harm living organisms and pollute the environment, there are several sources of mercury exposure, including:

a. Manufacturing Industries
   Kalimantan, one of the most polluted areas globally due to gold mining activities that use mercury in the gold extraction process. The mercury vaporizes during the smelting process, emitting toxic chemicals that contaminate the air, water, and surrounding life forms near mining sites (Mareta & Fitriyah, 2017).
b. Cosmetic Use
   Mercury can act as a skin whitening agent and preservative, extending the shelf life of products. Mercury is a hazardous heavy metal that can be toxic even in

small concentrations. Its use in skin-whitening creams can lead to skin color changes, black spots, allergies, skin irritation, and high-dose usage effects (Kissi, 2013). The initial use of mercury in cosmetics included inorganic mercury creams and ointments as antiseptics. Its usage requires monitoring and should not be arbitrary. Mercury compounds present in cosmetics include mercury aminiation, mercury iodide, mercurous chloride, mercurous oxide, and mercury chloride (Fanni, 2012).

c. Small-Scale Gold Mining (PESK)
Mercury is used to extract gold from ore as a stable amalgam. The amalgam is then heated to vaporize mercury and isolate gold (Esdaile & Chalker, 2018). Amalgamation in gold mining separates gold from gravel. Gold is bound to ore using mercury (Hg) in a device called an amalgamator. The mercury waste is then disposed of in containers or wells.

d. Mercury from Natural Sources
Heavy metals naturally enter water through various means. Hg enters bodies of water, primarily through volcanic activities, groundwater seepage from mercury deposits, and others. Pb enters water through the crystallization of airborne Pb aided by rainwater. Additionally, corrosion of mineral rocks from wave and wind impacts can cause lead to enter water. Cu enters water through erosion or weathering of mineral rocks and the dissolution of Cu compounds in the atmosphere, carried down by rain. Cd naturally enters water in small amounts (Palar, 1994).

e. Mercury from Power Generation
Coal-fired power plants are a commonly used type of thermal power plant due to their high efficiency in generating economical electrical energy. These plants convert chemical energy in fuel to electrical energy. Mercury (Hg) is a persistent heavy metal that bioaccumulates in the environment with unique physical and chemical properties. Hg is emitted into the atmosphere by various anthropogenic and natural sources (Bjørklund et al., 2017). Anthropogenic Hg sources include coal combustion for power generation, mining, oil refining, solid waste incineration, metal smelting processes, and cement production (UNEP, 2013). Long-term health effects due to high Hg exposure levels include anxiety, excessive shame, anorexia, sleep problems, loss of appetite, irritability, fatigue, forgetfulness, tremors, vision disturbances, and hearing impairments (ATSDR, 2018).

f. Mercury from Coal Mining
Coal is formed from consolidated plants between rock layers and transformed by pressure and heat over millions of years to form coal seams (WCI, 2005). When coal is burned, it produces waste in the form of ash, composed of 80% fly ash and 20% bottom ash. Fly ash is carried by exhaust gases through a dust control device with an electrostatic precipitator (ESP), which captures 99.5% of the fly ash, while the remaining 0.5% is emitted through stacks. Meanwhile, Lead (Pb) and mercury (Hg) pollutants are part of the heavy metal air pollutants contained in the ash. In coal mines, the concentration of Hg in fly ash is greater than in coal due to the high absorption capacity of fly ash for Hg. Fly ash's strong absorption capability for Hg comes from the high chlorine content in coal and the high content of unburned carbon in fly ash (Zhang et al., 2008). This result is found in the study

"Contribution of Metropolitan to Lead and Mercury Air Pollutants from Coal-Fired Power Plants" (Yulinawati et al., 2019).

2.3. Effects of Mercury

In terms of infant growth from mothers exposed to MeHg, studies have shown a significant correlation between babies born to mothers who consumed contaminated rice due to fungicide use. These babies experienced brain damage, including mental retardation, deafness, visual field constriction, microcephaly, cerebral palsy, ataxia, blindness, and swallowing disorders. As a result of exposure to elemental Hg and MeHg vapor, these compounds can breach the blood-brain barrier and cause irreversible brain damage, leading to permanent paralysis. Hg ingested through digestion may slow down the central nervous system, and initial symptoms after several months of exposure might be nonspecific, such as fatigue, blurred vision, or hearing loss (deafness) (Candra & Nugroho, 2019).

If there is an accumulation of organic Hg salts or phenylmercury in the kidneys through the central nervous system, it can lead to increased tubular epithelium permeability, thereby impairing kidney function (kidney dysfunction). Exposure to mercury vapor or mercury salts through the respiratory tract can also result in kidney failure due to proteinuria or nephrotic syndrome and acute tubular necrosis (Candra & Nugroho, 2019). The duration, intensity, route of exposure, and form of Hg have significant effects on the affected system. Acute mercury inhalation poisoning affects the respiratory system, while mercury salts ingested affect the central nervous system. The impact on the cardiovascular system is secondary.

3. RESEARCH METHODS

The research employed an experimental test method. In this method, urine samples from children aged 25 to 59 months with stunting were used to analyze the mercury content present in their urine. Samples were collected from a specific population to identify the mercury content in children aged 25 to 59 months with stunting in small-scale gold mining areas. A total of 10 individuals were included in the study using the total sampling method. Inclusion and Exclusion Criteria:

a. Inclusion
   - Families permitting urine collection from their toddlers.
   - Good communication with the families.
   - Absence of mental disabilities.
   - Not suffering from contagious illnesses.

b. Exclusion
   - Some families not allowing urine collection from their children.
   - Some stunted children having contagious diseases.
   - Some families being uncooperative during the survey.

Numerous studies have attempted to determine mercury levels in blood, urine, tissues, pharmaceutical samples, human and animal hair. Several methods utilize Atomic Absorption Spectrometry (AAS) and Inductively Coupled Plasma Mass Spectrometry (ICP-MS). In this study, optimal conditions for mercury determination using graphite furnace atomic absorption spectrometry (temperature and drying time, ashing temperature and time, atomization temperature and time) in pharmaceutical products (thimerosal and products containing thimerosal) were investigated. A method was proposed for mercury determination in pharmaceutical samples using palladium chloride as a chemical modifier (Yang et al., 2002).

Furthermore, graphite furnace atomic absorption spectrometry (GFAAS) was also applied using different chemical modifiers for the determination of low mercury levels with higher sensitivity and lower detection limits, especially when mercury vapor had been concentrated in the graphite furnace with palladium and palladium-rhodium as absorbent and matrix modifiers. However, the instrumentation and chemical reagents for GFAAS technique are often expensive (Alexiu et al., 2004). Nevertheless, this serves as an alternative method to the official technique for the indirect determination of thimerosal using vapor atomic absorption spectrometry, which requires reagent consumption and lengthy analysis time (Yang et al., 2002).

4. RESULTS AND DISCUSSION

4.1. Result

Table 1. Distribution of Respondents According to Gender

No	Gender	Frequency	(%)
1	Man	5	50%
2	Women	5	50%
Total		**10**	**100%**

Based on table 1, it can be seen that male respondents are 50% and women are balanced at 50% of the 10 respondents.

Table 2. Distribution of Respondents According to Age (per month)

No	Age (Month)	Frequency	(%)
1	25	1	9%
2	26	1	9%
3	29	1	9%
4	37	2	19%
5	41	1	9%
6	42	1	9%
7	43	1	9%
8	53	1	9%

9	54	1	9%
Total		**11**	**100%**

Based on table 2 above, it is known that the age of respondents 37 months is more with a frequency of 2 C-people and a percentage of 19%. Respondents aged 25 months, 26 months, 29 months, 41 months, 42 months, 43 months, 53 months and 54 months were 1 person with a percentage of 9%.

Table 3. Urine Test Results for Children Aged 25-59 Months

Test Sample Code	Unit	Quality Standard	Analysis Result	Desc.
1	ug/l	-	71,48	
2	ug/l	-	78,92	
3	ug/l	-	19,52	
4	ug/l	-	79,57	lih. (1)
5	ug/l	-	67,95	lih. (1)
6	ug/l	-	16,34	
7	ug/l	-	31,83	
8	ug/l	-	1,552	
9	ug/l	-	78,59	lih. (1)
10	ug/l	-	87,69	

4.2. Discussion

The results of this study indicate that all collected urine samples contain mercury. Nine urine samples have mercury levels above the threshold set by Human Biomonitoring (HBM), which is 7 µg/L (Lensoni et al., 2023), while one urine sample has mercury content below the established threshold. This indicates that 99% of stunted toddlers have mercury in their urine, while 0.1% have mercury levels below the set threshold. This research is in line with the study by Sofia et al. (2017), which reported that the highest mercury concentration in hair was recorded in Paya Seumantok village (48.1 µg/g), followed by Panton Makmur village (42.1 µg/g), Panggong village (35.2 µg/g), and Curek village (11.3 µg/g). The highest mercury concentration in Paya Seumantok village is due to the presence of numerous artisanal gold processing industries in that area. Lensoni (2023) reported that the concentration of mercury in the urine of Paya Seumantok villagers Sixteen out of 91 urine samples showed no mercury, while the remaining 75 samples were found to contain mercury. The average urinary mercury level among local residents near the location was 8.392 µg/L (SD: 6.721 g/L), and the minimum and maximum urinary mercury levels in this study were 0.19 µg/L and 28.31 µg/L, respectively. Mercury accumulation in these organisms is significantly higher in clams than in fish, with average concentrations of 2.882 ± 148 and 0.321 ± 18.7 mg/kg dry weight, respectively. The highest mercury content is indicated in the Meureubo River.

The bioaccumulation of mercury content in fish was found to be minimum in the head (197.8 ± 10.2 µg/kg dry weight), while the maximum bioaccumulation in fish was found in the eyes (382 ± 1.3 µg/kg dry weight). Mercury concentrations vary greatly in the following order: Eyes - Muscle - Fins - Bones - Head (Suhendrayatna, 2012).

5. CONCLUSION

The findings of this research have revealed that, out of the nine urine samples collected from children aged 25 to 59 months suffering from stunting, nine of them contained mercury levels exceeding the threshold set by Human Biomonitoring (HBM) at 7 µg/L. However, one urine sample had mercury content below the established threshold. This indicates that approximately 99% of stunted children have mercury content in their urine above the designated limit, while 0.1% have mercury content below the established threshold. Consequently, raising awareness and educating the public about the dangers of mercury on children's health is crucial, along with implementing stricter monitoring of products containing mercury, including cosmetics and everyday consumer goods.

Preventive measures to reduce mercury exposure in stunted children are necessary, involving the avoidance of environmental contamination and minimizing the use of mercury-containing products. Furthermore, regular health monitoring of children exposed to mercury is essential for identifying potential health impacts. Further research is also needed to comprehend the long-term effects of mercury exposure on stunted children and to develop more effective interventions to safeguard the health of the younger generation.

REFERENCES

Astiti, L. G. S., & Sugianti, T. (2014). Dampak penambangan emas tradisional pada lingkungan dan pakan ternak di Pulau Lombok. *Sains Peternakan: Jurnal Penelitian Ilmu Peternakan*, *12*(2), 101–106.

Bjørklund, G., Dadar, M., Mutter, J., & Aaseth, J. (2017). The toxicology of mercury: Current research and emerging trends. *Environmental Research*, *159*, 545–554.

Bobby J. Polii, & Desmi N. Sonya. (2002). Pendugaan Kandungan Merkuri Dan Sianida Di Daerah Aliran Sungai (Das) Buyat Minahasa. *Ekoton*, *2*(1), 31–37.

Candra, Y. A., & Nugroho, Y. A. (2019). Fitoremediasi Merkuri dari Tanah Tercemar Limbah Bekas Tambang Emas Rakyat dengan Rumput Teki (Cyperus kyllingia). *Agrika*, *13*(1), 33–47.

Laksono, A. D., Kusrini, I., & Laksono, A. D. (2019). Gambaran Prevalensi Balita Stunting dan Faktor yang Berkaitan di Indonesia: Analisis Lanjut Profil Kesehatan Indonesia Tahun 2017. *ResearchGate, March*, 0–12.

Lensoni, Nurdin, A., & Zaini, Z. I. (2020). *Jurnal Aceh Medika*. *4*(2), 102–112.

Lensoni. (2021). Proses Adsorbsi Merkuri Pada Limbah Cair Pertambangan Emas Dengan Menggunakan Ampas Kopi. *Saufa Yarah*, *9623*(2), 105–111.

Mareta, A., & Fitriyah, F. K. (2017). *Pengaruh kinerja lingkungan dan kepemilikan asing terhadap nilai perusahaan (Studi pada perusahaan manufaktur yang mengikuti PROPER dan terdaftar di Bursa Efek Indonesia periode 2013-2015).*

Nasution, Z. (2019). Pengaturan Penangkapan Dan Perdagangan Hiu Berbasis Masyarakat Di Sentra Pendaratan Ikan. *PROSIDING PUSAT RISET PERIKANAN*, *1*(1), 162–167.

Puspita, D., Patmasari, D., Sella, S., & Purbayanti, D. (2020). Review: Risiko Stunting pada Anak yang Tinggal di Area Pertambangan Emas Skala Kecil. *Borneo Journal of Medical Laboratory Technology*, *3*(1), 161–167. https://doi.org/10.33084/bjmlt.v3i1.1906

Reinhardt, K., & Fanzo, J. (2014). Addressing chronic malnutrition through multi-sectoral, sustainable approaches: a review of the causes and consequences. *Frontiers in Nutrition*, *1*, 13.

Soprima, M., Kusnoputranto, H., & Inswiasri, I. (2016). Kajian Risiko Kesehatan Masyarakat Akibat Pajanan Merkuri Pada Pertambangan Emas Rakyat Di Kabupaten Lebak, Banten. *Jurnal Ekologi Kesehatan*, *14*(4), 296–308. https://doi.org/10.22435/jek.v14i4.4708.296-308

Sudarmo, U. (2004). Kimia untuk SMA kelas XI. *Jakarta: Erlangga*.

Suhendrayatna. (2012). *Mercury in sediment and freshwater organisms from Kr . Sikulat River around the artisanal gold mining plants in Sawang , Aceh Province , Indonesia*. *2*(2), 22–24.

Vilcins, D., Sly, P. D., & Jagals, P. (2018). Environmental risk factors associated with child stunting: a systematic review of the literature. *Annals of Global Health*, *84*(4), 551.

Widowati, W., Sastiono, A., & Jusuf, R. (2008). Efek toksik logam pencegahan dan penanggulangan pencemaran. *Penerbit Andi. Yogyakarta*, 2–206.

Yulinawati, H., Zulaiha, S., Pristianty, R., & Siami, L. (2019). Kontribusi Metropolitan terhadap Polutan Udara Berbahaya Timbal dan Merkuri dari Pembangkit Listrik Tenaga Uap (Batu Bara). *Seminar Nasional Pembangunan Wilayah Dan Kota Berkelanjutan*, *1*(1).

Zaharani, F., & Salami, I. R. S. (2015). Kandungan merkuri pada urin dan rambut sebagai indikasi paparan merkuri terhadap pekerja tambang emas tanpa izin (PETI) di desa pasar terusan kecamatan muara bulian kabupaten batanghari-Jambi. *Jurnal Teknik Lingkungan*, *21*(2), 169–179.