NO. ISSN 2987-4564

ANALYSIS OF MERCURY (HG) CONTENT IN URINE AND ITS IMPACT ON HEALTH DISORDERS OF ILLEGAL GOLD MINING WORKERS IN MALOMBA VILLAGE, DONDO SUB-DISTRICT, TOLITOLI DISTRICT

Sakinah[1]*, Tri Santoso[2], Sitti Aminah[3], Sri Hastuti Virgianti P[4]
[1234]Tadulako University, Indonesia
*sakinawahid02@gmail.com

ABSTRACT

Mercury is a heavy metal element that very easily enters the bodies of living creatures and joins the food chain. The living creatures most likely to be directly exposed to mercury are traditional miners who use the amalgam method to extract gold ore. The danger of poisoning posed by mercury for humans can be diagnosed through analysis of mercury levels in urine. Furthermore, this research aims to determine mercury levels in the urine of gold mine workers and to obtain information regarding the mercury content in the urine and the health problems of gold mine workers. The method used in this research was the calibration curve method with Cold Vapor Atomic Absorption Spectophotometry (CV-AAS) analysis and descriptive methods from the results of questionnaire interviews. The results show that the mercury levels in mine workers have exceeded the threshold value set by WHO of 4 ppb while the highest mercury level obtained is 44.1 ppb, the lowest mercury level is 8.38 ppb and the control sample is 6.32 ppb, and there are 2 respondents that have symptoms of mercury exposure, namely respondent OP showing symptoms of mercury exposure in the form of frequent tingling, itching, easy fatigue, headache and eye irritation, and respondent YP showing symptoms of mercury exposure in the form of tremors, frequent tingling, itching, weakness of taste buds, difficulty swallowing, diarrhea, and headache. Based on the research results, it is found that the bodies of mining workers in Malomba Village show symptoms of exposure to mercury.

Keywords: *Mercury (Hg), Urine, Gold mine workers, Tolitoli*

1. INTRODUCTION

Hg (Mercury) is one of the heavy metal elements in the form of a liquid phase at room temperature (25˚C), volatile, and found in nature even though the levels are very low. Naturally, mercury has the property of easily binding and settling in waters, which causes the metal to easily enter the bodies of living things and join the food chain (Suteja, et al. 2019). Metal mercury is usually widely used in gold mining activities.

Amalgamation is one of the processes in gold mining that uses mercury. Mercury is used as an auxiliary material in the gold processing process which is in accordance with its nature, namely binding, in this processing process mercury binds gold so that it is easily separated from other particles. If this mercury is not managed properly, it will have an impact on polluting not only the environment but for the gold miners themselves. One of the negative impacts for a mine worker is the high level of mercury in the body. Mercury (Hg) can enter the human body through mercury-contaminated food, through the respiratory organs or lungs and finally by absorption through the skin, all of these processes will enter the blood to the kidneys, then excreted into urine (Novarianti, 2013).

High mercury levels in the bodies of small-scale gold mine workers are one of the impacts of the absence of adequate personal protective equipment (PPE) facilities at work, as well as poor hygienic practices. Therefore, miners, especially artisanal miners, need to be trained to know the dangers of eating and drinking in the work area, the need to use personal protective equipment, and improve work methods to minimise exposure in the workplace (Dartey et al. 2013).

NO. ISSN 2987-4564

Mercury exposure in the body can be determined by measuring pollutant levels in body tissues, such as hair, blood, urine, nails and breast milk. Measurement of these body tissues is known as Biological Markers or biomarkers that will help in the assessment of exposure to a pollutant. One of the biomarkers that can be used to assess mercury exposure to the body is through the measurement of urine samples. According to Baeum, et al (2011), urine is a good biomarker for acute exposure to inorganic mercury. Mercury levels in urine can be detected after approximately 2-3 weeks of exposure. Examination of mercury levels in urine can be done by the Atomic Absorption Spectrophotometer (SSA) method (Fong, et al. 2007).

Traditional gold mining is found in various places in Indonesia, one of which is in Malomba Village, Dondo Sub-District, Tolitoli District. However, this gold mining is included in unlicensed gold mining (PETI). The gold content in the area attracts local residents to conduct gold mining because the location of the mining activity is only 500 metres from residential areas in Malomba Village (Rosita, 2022). The gold processing produces waste that has the potential to cause a decrease in environmental quality ranging from pollution of surface water, groundwater, to the risk of health problems for miners and people living around the mining site. Waste from gold processing is disposed of in the river. The river is used daily by the Malomba Village community as clean water, watering crops and a source of drinking water for livestock of the community living around the river (Rosita, 2022). This could result in gold mining workers in Malomba Village, Dondo Sub-district, Toiltoli District being contaminated with mercury in their bodies, hence the need for this research to measure mercury levels in the urine of illegal gold mining workers and its impact on health problems.

2. METHODS

This research is a type of laboratory experimental research to determine the levels of mercury metal in the urine of gold mine workers and using questionnaires to describe the impact of mercury (Hg) content in urine with health problems of gold mine workers. The samples used in this research came from mining in Malomba Village, Dondo Sub-District, Tolitoli District. Gold mining in Malomba Village is illegal. Therefore, the number of workers cannot be known precisely. Based on this, the sample was taken using accidental sampling technique, where sampling was carried out on respondents who happened to be at the research location (Ariawan, 1998), A total of 9 samples were taken from mine workers who worked at 3 points of the mining location, each point of the mining location was taken 3 samples, and 1 control sample came from people who lived around the mining location but were not mine workers and had never been to the mining location point.

Tools and Materials

The tools used in this research were a 60 mL sample bottle, 10 mL measuring cup, 50 mL volumetric flask, 10 mL measuring pipette, 100 mL erlenmeyer, funnel, a drop pipette, a set of atomic absorption spectrophotometer (AAS).

The materials used in this research are mine workers' urine, concentrated HNO_3, distilled water, 1000 ppm mercury standard solution and filter paper.

Urine Sampling

The sample bottle that will be used as a place to store urine is sterilised first using 2 mL of HNO_3 solution, then shaken until the HNO_3 solution hits the entire surface of the sample bottle (Rosita, 2022). Next, enter the urine into the sample bottle, after all the urine is collected, 4 drops of 4 M HNO_3 solution are dripped, and each respondent who provided a urine sample filled out questionnaire data to determine the impact of mercury (Hg) on the health problems of gold mine workers. (Asiah, dkk. 2015).

Sample Preparation

Each sample was taken as much as 20 mL and added 8 mL of concentrated HNO_3 solution. The sample was then allowed to stand for 48 hours, then filtered using filter paper (Asiah, et al. 2015).

Preparation of Standard Solution

The 1000 ppb mercury standard solution was made into a series of standard solutions of 10 ppb, 50 ppb, 100 ppb, 150 ppb, 200 ppb, and 250 ppb. Then measure the absorbance with a wavelength of 253.7 nm and make a calibration curve for mercury (Hg) levels.

Analysis of Mercury Level

Measurement of mercury metal concentration in urine samples was carried out using an atomic absorption spectrophotometer (SSA) at a wavelength of 253.7 nm.

Data Analysis

Concentrations of mercury metal were obtained by analysing sample uptake data using calibration curves and information on the impact of mercury (Hg) in urine on health problems was obtained from distributing questionnaires to respondents.

3. RESULTS & DISCUSSION

Preparation of Standard Solution and Calibration Curve

Mercury (Hg) standard solutions used are concentrations of 10 ppb; 50 ppb; 100 ppb; 150 ppb; 200 ppb; 250 ppb can be seen in Table 1.

Table 1. Calibration curve of mercury

Name	Concentration (ppb)	Absorbance
Standard 1	10	0,0182
Standard 2	50	0,0591
Standard 3	100	0,1053
Standard 4	150	0,1486
Standard 5	200	0,1964
Standard 6	250	0,2414

By using the calibration curve between concentration and absorbance, the regression equation is $y = 0.0009x + 0.0112$, with $r^2 = 0.999$. The calibration curve between concentration and absorbance can be seen in Figure 1.

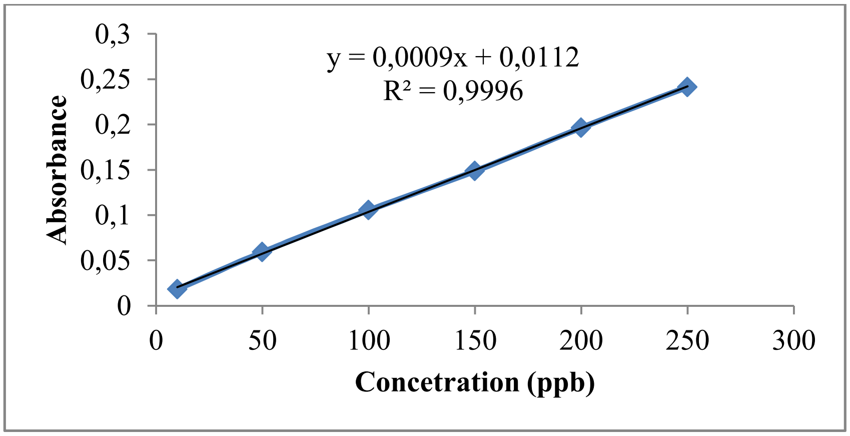

Figure 1. Mercury calibration curve

Mercury Levels in the Urine of Mine Workers

The results of the measurement of mercury (Hg) metal uptake from the urine samples of mine workers can be seen in Table 2.

Table 2. Mercury levels in the urine of mine workers

No.	Location	Sample Code	Absorbance	Mercury Level (ppb)	Average (ppb)
1.	Location 1	AR	0,0437	35,22	48,72
		HW	0,0519	44,10	
		SAK	0,0729	66,84	
2.	Location 2	RK	0,0329	23,53	29,88
		OP	0,0344	25,16	
		RM	0,049	40,96	
3.	Location 3	SJ	0,0189	8,38	19,53
		YP	0,0303	20,72	
		KL	0,0384	29,49	
4.	-	AM	0,017	6,32	-

Based on the data in Table 2, it can be seen that the results of mercury levels in mine workers have exceeded the threshold value (NAB) of mercury in urine set by WHO which is 4 ppb (WHO, 1993), this is because the miners were found to still use traditional methods and without personal protective equipment when processing gold using mercury. The method of processing materials using mercury is still carried out freely by miners, such as in the amalgam process miners do not use any tools for the process, they mix gold-containing rocks with mercury using only their hands, then when the amalgam is heated anyone who is around the burning location can be exposed to mercury vapour from the combustion (Zaharani, et al. 2015). In the control sample, the mercury level in the body has exceeded the threshold value (NAB), this is because the control sample is a community living around the mining site and based on the results of the control sample interview said that the control sample's house had been a place for burning amalgam which caused anyone around the burning site to be exposed to mercury vapor from the combustion (Zaharani et al. 2015). The control sample (non-mine workers) had the lowest mercury levels among the other samples (mine workers), indicating that non-mine workers are less likely to be exposed to mercury than mine workers. The results of this research are in line with Gundo, et al (2020), that the results of the analysis of mercury levels in miner urine samples have an average mercury level of 0.0250 mg/L, which indicates that it has exceeded the threshold value (NAB) of 0.004 mg/L.

Comparison of mercury levels between location 1, location 2 and location 3 can be seen in Figure 2. Location 1 has very high mercury levels, location 2 has moderate mercury levels and location 3 has low mercury levels.

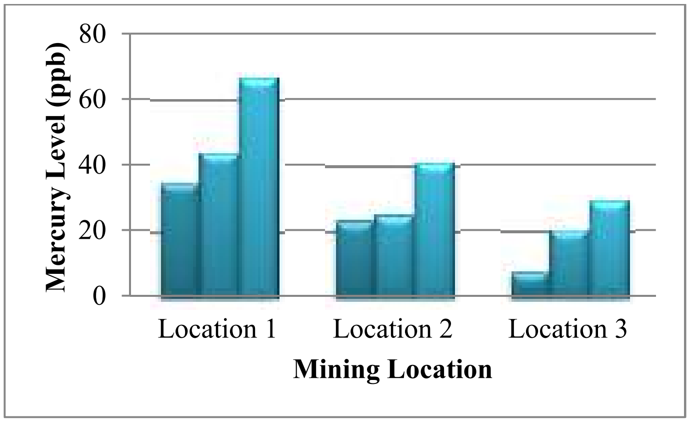

Figure 2. Mercury levels by location

Mine workers in location 1 have very high average mercury levels because the location uses quite a lot of mercury metal to form gold metal grains. Location 2 has a moderate average mercury level because when panning location 2 uses not enough mercury metal because during the formation of gold grains sometimes miners get gold grains that have merged with mercury metal. Meanwhile, mine workers in location 3 have low average mercury levels because the location does not use metal mercury when panning due to the seepage of metal mercury from location 2 so that the gold obtained has formed grains that have been mixed with metal mercury.

Mercury that is discharged into the river as a residue of the amalgamation process in PETI activities will undergo a methylisation process with the help of bacteria. The change process requires two chemical reaction steps, namely the oxidation process from Hg^0 to Hg^{2+}, then a chemical reaction that changes the form of Hg^{2+} to CH_3Hg^+. The chemical reactions that occur in the methylation process are controlled by sulfate-reducing bacteria and other microbes (Alpers & Hunerlach, 2000). Normal metabolism in almost all living organisms will certainly involve methylation reactions so that methyl mercury ions in water bodies will be eaten by aquatic biota and then enter the food chain system (Palar, 2008).

Mercury entering the body other than through the food chain system can also occur due to daily human activities such as consuming river water polluted by mercury, bathing and brushing teeth using mercury-contaminated river water, working in PETI areas and consuming vegetables produced from around rivers polluted by mercury. Prolonged exposure to mercury causes health problems in humans, especially those exposed to mercury-contaminated environmental conditions. Mercury poisoning that usually occurs in communities living around mining sites is usually chronic (EPA, 1984). Communities living around rivers that are tailings of gold processing usually experience mercury poisoning of the methyl mercury type and enter the body through the digestive tract. Organic forms such as methyl mercury are about 90% absorbed by the intestinal wall, this form can also penetrate the blood barrier and placenta so that it can cause teratogenic effects and neurological disorders (Alfian, 2006).

Health Conditions of Mine Workers

The impact of mercury (Hg) in urine on health problems was obtained by distributing questionnaires to respondents. The questionnaire on the impact of mercury (Hg) content in urine on health problems consists of 10 questions using a Guttman scale with Yes and No answer options, Yes answers are given a score of 1 and No answers are given a score of 0. The results of the interview on the health conditions of mine workers can be seen in Table 3.

Table 3. Total results of questionnaire data

Respondent Code	Answer Choice Result	
	Yes	No
HW	0	10
SAK	4	6
AR	4	6
SJ	4	6
RK	1	9
OP	5	5
YP	7	3
RM	3	7
KL	1	9
AM (-)	0	10

The data from the questionnaire with a Guttman scale was then analysed whether mercury has an impact or no impact on the health of mine workers. Data results with a percentage < 50% indicate that mercury has no impact on the health of mine workers, while data results with a percentage ≥ 50% indicate that mercury has an impact on the health of mine workers. The percentage results using the Guttman scale can be seen in Table 4.

Table 4. Percentage Results Using the Guttman Scale

Respondent Code	Data Result Percentage (%)	Category
HW	0	No Impact
SAK	40	NoImpact
AR	40	No Impact
SJ	40	No Impact
RK	10	No Impact
OP	50	Impact
YP	70	Impact
RM	30	No Impact
KL	10	No Impact
AM (-)	0	No Impact

The health conditions of mine workers due to mercury exposure are divided into two categories, namely impact on mine workers' health problems and no impact on mine workers' health problems. Based on Table 4, there are 2 respondents who show symptoms of mercury exposure, namely OP and YP, and 8 other respondents do not show symptoms of mercury exposure. OP showed symptoms of mercury exposure in the form of frequent tingling, itching, fatigue, headache and eye irritation, while YP showed symptoms of mercury exposure in the form of tremors, frequent tingling, itching, weakness of taste buds, difficulty swallowing, diarrhoea and headache.

Factors that can determine whether or not mercury can have an impact on the body are as follows: (1) The type of mercury concerned. Mercury in nature is divided into three forms: metallic mercury, organic mercury, and inorganic mercury. According to Oda and Ingle (1981), organic mercury, especially methyl mercury, is more toxic than other mercury compounds. Mercury, both metal and methyl mercury (CH_3Hg^+), usually enters the human body through digestion, either from fish, shellfish, shrimp, or mercury-contaminated waters. However, when in metal form, most of it can usually be excreted. The rest will accumulate in the kidneys and nervous system which will one day be disturbing if the accumulation increases. Mercury in the form of metal is not so dangerous, because only 15% is absorbed by the human body, but once exposed to nature, under certain conditions it can react with methane from the decomposition of organic compounds to form toxic methyl mercury. In the form of methyl mercury, most of it will accumulate in the brain. Because the absorption is large, it can cause various disorders in a short time. To explain how mercury enters the human body, mercury that enters the water easily bonds with the chemical element chlorine in seawater. Bonding with chlorine ions to form inorganic mercury (HgCl) easily enters plankton and can move to other marine life, then undergoes changes by microorganisms into organic mercury (methyl mercury) in sediments on the seabed. The nature of methyl mercury that can accumulate in the body of living things is what brings disease (Kristianingrum, 2009). (2) The amount of mercury absorbed. How much mercury enters the body is also a determining factor. High exposure doses tend to have a greater negative impact than low doses. (3) Age or developmental stage of the exposed person (foetus is most vulnerable). Age may affect the presence of mercury in the body, Because the increasing age, the greater the risk of accumulation of mercury exposure, especially at the age of growth and old age, because at an advanced age the function of organs such as the kidneys, liver and brain has decreased, while in children the organs are still in the process of growth both in function and size so that they are vulnerable to substances that enter these organs (Reza, et al. 2016), this relates to OP and YP respondents who are at an advanced age, namely OP aged 44 years and YP aged 46 years. (4) Duration of exposure. The longer a person is exposed to mercury, the more mercury is absorbed into his body (Hananingtyas, 2013). Respondent YP has worked as a gold miner for 13 years, while OP for 3 years. (5) Route of exposure (inhalation, ingestion or skin contact). Mercury generally enters the body through air, water or food which is absorbed in varying amounts. Meanwhile, the human body cannot process forms of methyl mercury so mercury remains in the body for a relatively long time and can cause health problems (Prihantini & Hutagalung, 2018).

4. CONCLUSION

Based on the results of the research that has been carried out, it can be concluded as follows: (1) The mercury content in the urine of gold mine workers in Malomba Village, Dondo Sub-District, Tolitoli District has exceeded the threshold value (NAB) set by WHO which is 4 μg/L, the results of mercury levels obtained in mine workers at location 1 are RM by 40.96 ppb; AR by 35.22 ppb; HW by 44.1 ppb, the results of mercury levels in mine workers at location 2 are RK by 23.53 ppb; OP by 25.16 ppb; RM by 40.96 ppb, the results of mercury levels in mine workers at location 3 are SJ by 8.38 ppb; YP by 20.72 ppb; KL by 29.49 ppb; and control sample AM (-) by 6.32 ppb. (2) Of the 9 samples of mine workers analysed, 2 samples were in the category of showing symptoms of mercury exposure, namely OP and YP, and the other 7 samples were in the category of not showing symptoms of mercury exposure. Symptoms of mercury exposure felt by mine workers are tremors, frequent tingling, itching, weakness of taste buds, difficulty swallowing, diarrhoea, fatigue, headaches, asthma, and eye irritation.

5. ACKNOWLEDGMENTS

The author is grateful to the chemistry education study programme, teacher training and education faculty, tadulako university. As well as all parties who have helped and contributed to the author's life that cannot be listed one by one in this sheet.

REFERENCES

Alfian Z. 2006. *Mercury: Between the benefits and effects of its use on human health and the environment. Professor's Inaugural Speech*. USU.

Alpers, C, N, and Hunerlach, M, P. (2000). *Mercury contamination from historic gold mining in California. U.S. Geological Survey*. USGD Fact Sheeet FS-061-00, p. 5.

Asiah, N., Alfian, Z., Anwar, J., Siregar, Y., & Bangun, D. (2015). Effect of work duration on mercury (Hg) levels in the urine of gold mine workers (Case study in Panton Luas Village, Sawang District, South Aceh Regency). *Journal of Chemical Education*, 7(2), 8-9.

Baeum, Jenifer. Stephan Bose - O'Reilly. Raffaella Mateucci Gothe. Beate Lettmeir, Gabriele Roider, Gustav Drasch, and Uwe Siebert. (2011). Human biomonitoring data from mercury-exposed miners in six artisanal small-scale gold mining areas in Asia and Africa. *Journal Minerals 2011*, 1, pp 122 - 143.

Dartey, E., Sarpong, K., Darko, G., & Acheampong-Marfo, M. (2013). Urinary arsenic and mercury levels in artisanal miners in some communities in the Obuasi Municipality of Ghana. *Journal of Environmental Chemistry*, 5(5), 113-118.

EPA. 1984. *Mercury health effects update, Health Issue Assessment*. US Environmental Protection Agency, Washington D.C. (Report No. EPA-600/8-84-019F).

Fong, B. M. W., Siu, T. S., Lee, J. S. K., & Tam, S. (2007). Determination of mercury in whole blood and urine by inductively coupled plasma mass spectrometry. *Journal of analytical toxicology*, 31(5), 281-287.

Gundo, ISD, Polii, BJ, & Umboh, JM. (2020). Mercury content in artisanal gold miners. *Indonesian Journal of Public Health and Community Medicine*, 1(3), 13-18.

Hanangnityas, Izza, et al. (2013). Relationship between mercury (Hg) exposure and thyroid function disorders in traditional gold miners in Jendi village, Selogiri district, Wonogiri Regency. *Indonesian Journal of Environmental Health*, 12(1), 58-63.

International Agency for research on cancer World Health Organisation. (1993). *Monographs on the evaluation of carcinogenic risk to humans*. Vol. 58.

Kristianingrum, S. (2009). Review of simple, selective, preconcentration, and spectrophotometric determination of mercury analysis techniques. In *Proceedings of the National Seminar* (Vol. 16).

Novarianti, N. (2013). *Analysis of risk factors for mercury (Hg) exposure in gold miners in Kawatuna Village, Palu City, Central Sulawesi*. (Doctoral dissertation, Hassanuddin University).

Oda, C.E. and Ingle, J.D. (1981). Continuous flow cold vapour atomic absorption determination of mercury. *Anal Chem*. Vol.53, p 2030-2031.

Palar H. (2008). *Heavy metal pollution and toxicology*. Jakarta: Rineka Cipta.

Prihantini, N. N., & Hutagalung, P. (2018). Health problems due to mercury exposure in workers in the cosmetics industry. *Widya Scientific Journal*, 5(1), 56- 61.

Reza, et al. (2016). Analysis of differences in potential risks of mercury exposure in communities in Tahi Ite Village, Rarowatu District, Bombana Regency. *Scientific Journal of Public Health Students*, 1(4), 1-13.

Rosita, M. (2022). *Analysis of mercury metal (Hg) in Janja River water in the mining area of Malomba Village, Dondo Subdistrict, Tolitoli Regency*. Thesis, Tadulako University. Palu.

Suteja, Y., Purwiyanto, A. I. S., & Agustriani, F. (2019). Mercury (Hg) in surface waters of Banyuasin River Estuary, South Sumatra, Indonesia. *Journal of Marine and Aquatic Sciences*, 5(2), 177-184.

Zaharani, F., & Salami, I. R. S. (2015). Mercury content in urine and hair as an indication of mercury exposure to unlicensed gold mine (PETI) workers in Pasar Terusan Village, Muara Bulian sub-district, Batang Hari district, Jambi. *Journal of Environmental Engineering*, 21(2), 169-179.