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Determining Mercury Safe Concentration in Shells in the Unlicensed Gold Mining Area of Kayeli Village, Buru Regency, Maluku Province, Indonesia

Nesya Eka Ramadhani[1], Abdul Rohim Tualeka[1], Bacrudin Lain[2], Pudji Rahmawati[3], Syamsiar S Russeng[4], Atjo Wahyu[4], Ahsan[5]

[1]Department of Occupational Health and Safety, Faculty of Public Health, Airlangga University, 60115 Surabaya, East Java, Indonesia; [2]Department of Environmental Health, Health, Health Polytechnic Ministry of Health Maluku, 97233 Negeri Lama, Ambon, Indonesia; [3]Department of Development of Islamic Society, State Islamic University Sunan Ampel, Surabaya, East Java, Indonesia; [4]Department of Occupational Health and Safety, Faculty of Public Health, Hasanuddin University, Makassar, East Java, Indonesia; [5]Faculty of Nurse, University of Brawijaya, Malang, Indonesia

ABSTRACT

Mercury is one of the metals in the environment which naturally occurs and is classified as a hazardous material. Mercury is a silver white heavy metal and has persistent properties. It is liquid, volatile, bioaccumulation and harmful to health and the environment. This study aimed to determine the safe concentration of mercury exposure in the community in the area of unlicensed gold mining areas (PETI) in Kayeli Village, Buru Regency, Maluku Province, Indonesia. This study was an observational study with an environmental health risk analysis approach. The sample of this study was 67 people and the object of this study was *Polymesoda erosa* shells. The variables were the No Observed Adverse Effect Level (NOAEL), Reference Dose (RfD), mercury concentrations in the shells, body weight, shell consumption rate and safe concentrations of mercury in the shells. The result showed mercury concentration in *Polymesoda erosa* in 9 different sample locations was 0.756 mg/kg and the safe concentration of mercury exposure was 0.71 mg/kg. It was less than the Indonesian National Standard of the maximum limit of heavy metal contamination in food. It can be concluded that the safe concentration of mercury in the shells of illegal gold mining areas in Maluku province of Indonesia is safe and can be used as a reference for the community.

Keywords: *mercury, gold mining, safe concentration, community*

Introduction

Mercury is one of the metals in the environment which is naturally formed and is classified as a hazardous material. Mercury is a silver white heavy metal and has persistent properties. It is liquid, volatile, bioaccumulation and harmful to health and the environment.[1] Mercury is formed naturally and consists of three forms, namely elemental, inorganic and organic.[2] Some people are exposed to mercury in daily basis through activities like inhalation, consumption of contaminated food and beverages and skin contact.[3]

Most of the mercury in the environment comes from human activities, one of which is gold mining.[3] Gold mining in Indonesia is mostly unlicensed gold mining (PETI). This kind of gold mining process is a traditional one as it uses mercury in the amalgamation process.

The gold beans obtained from this mining will be milled with a jumble tool and added with mercury to make it into sand powder. After that, the powder will be mixed with mercury for one more time. The mercury waste from this process will contaminate the soil. This process

Corresponding Author:
Abdul Rohim Tualeka
Department of Occupational Health and Safety,
Public Health Faculty, Airlangga University,
Surabaya, East Java, Indonesia
Phone: +62 81 333 519 732
Email: abdul-r-t@fkm.unair.ac.id

also produces waste in the form of tailings which will be discharged into the river and pollute the environment.[4]

According to the Agency for Toxic Substances and Disease Registry, mercury can bring negative effect to human health. It can damage brain and kidney function. Inhaling mercury vapor in the form of methyl mercury causes mercury to go to the brain and affect the nervous system, while consuming mercury-contaminated foods will cause accumulation of mercury in the kidneys which later can harm the kidneys.[5]

Broussard (2002) stated that the digestive tract is the main route of methyl mercury into the body. However, methyl mercury can also be absorbed through the lungs and skin. More than 90% of methyl mercury absorbed by the body enters erythrocytes and binds to hemoglobin, while the rest of 10% is found in the brain and slowly undergoes demethylation which causes neuronal necrosis and becomes toxic to the cerebral cortex.[6]

Mercury not only affects adult health, but also children's health. Mercury exposure, which can be in the form of contaminated food such as fish and shellfish, can affect children development process. Children who are exposed to mercury can experience decreasing brain ability, mental retardation and inability to move. Mercury is also dangerous for pregnant women. Women who are exposed to mercury during pregnancy have a risk of blindness, seizures and inability to speak.[5]

The safe concentration of mercury exposure through inhalation is 0.1 mg/m^3.[7] In Indonesia, it has been set that the safe concentration of mercury exposure is 0.001 mg/L for drinking water and 1 mg/kg for shellfish.[9] There are in approximate 85.57% of workers in the area of Unlicensed Gold Mining (PETI) who consume mercury-contaminated shellfish in a daily basis.[8] Yet, the mercury concentration in the shellfish is still unknown.

A previous study analyzed the health risk of mercury exposure in the community of unlicensed gold mining areas (PETI) in Maluku Province of Indonesia. However, it only calculated consumption intake and estimated risk quotient (RQ) and didn't calculate the Reference Dose (RfD) and safe concentration of mercury exposure in shellfish. Therefore, this study is aimed to calculate the Reference Dose (RfD) and safe concentration of mercury exposure in the shells using No Observed Adverse Effect Level (NOAEL).

Material and Method

This study was an observational study using an environmental health risk analysis approach. The context of this research was the community of illegal gold mining areas. They were people living in Kayeli Village, Teluk Kayeli Subdistrict, Buru District, Maluku Province, Indonesia.

The sample was 67 out of 588 people living in the area. The object of this research is *Polymesoda erosa* shells which were taken from three different locations of tailing discharge around the beach. Three shells were taken as the sample for every location, with total of 9 sample shells.

The variables of this study were No Observed Adverse Effect Level (NOAEL), Reference Dose (RfD), mercury concentration in shells, body weight, shellfish consumption rate and safe concentration of mercury in the shellfish.

The measurement result analysis was conducted at the Makassar Health Laboratory Center. To determine the safe concentration of mercury exposure, quantitative data analysis was carried out manually.

The research was started by determining the NOEAL in the experimental animal and followed by calculating the Reference Dose (RfD) and safe concentration of mercury in the shellfish. The calculation using the following formula (Tualeka,2019).[9]

$$c \text{ safe} = \frac{(\mathrm{R}f\,\mathrm{D})(\mathrm{W}b)}{(\alpha)(\mathrm{R})}$$

Annotation:

c safe : safe concentration (mg/kg)

RfD : reference dose (mg/kg)

α : % substance absorbed by lung

R : consumption rate (kg/day)

Findings

A. **Characteristics and Body Surface Area of Experimental Body:** The toxicity test was carried out using experimental animals, namely white rats. This was due to the similarity of biochemical systems of experimental animals to the mechanism of the human biology system, so that white rats have qualitatively a similar response to humans.

Table 1 shows the characteristics of experimental animals, its body weight and body surface area.

Table 1: Distribution of Experimental Animal Characteristic (White Rats)

Experimental Animal (White Rats)	W (kg)	BSA (m^2)
1	0.1405	0.024165
2	0.1405	0.024165
3	0.1410	0.024223
4	0.1410	0.024223
5	0.1395	0.024050
6	0.1415	0.024165

To calculate the body surface area of the experimental animal, the following formula is used:

$$\mathbf{BSA = 0.09\ W^{0.67}}$$

Annotation:

BSA : Body Surface Area (m2)

W : Weight (kg)

B. Characteristic of Workers and Shellfish Consumption Rate: The characteristics of 67 samples of workers in communities in the gold mining area without permission from Kayeli Village, Buru Regency, Maluku Province, Indonesia are shown in table 2. It was found that the average body weight was 71 kg, the average height used was Indonesian average of 159 cm, the consumption rate of shellfish was 0.284 kg/day and the average working time is 7 hours/day.

Body surface area and consumption rate was calculated using the body weight and height.

1. **Workers Body Surface Area:** Body surface area was calculated using the formula of Tualeka and Saridewi as shown below:

$$BSA = \sqrt{W.h/3600}$$

$$= \sqrt{71.159/3600}$$

$$= 1.77\ m^2$$

Annotation:

BSA : Body Surface Area (m^2)

W : Weight (kg)

h : Height (cm)

2. Laju Konsumsi: According to Tualeka (2013), the consumption rate is 0.284 kg/day.[10]

Table 2: Distribution of Characteristics of Workers, Body Consumption Rate and Body Surface Area in Kayeli Village, Buru Regency, Maluku Province

Sample	W (kg)	h (cm)	R (kg/day)	BSA (m^2)
67	71	159	0.284	1.77

C. Mercury Concentration

Tabel 3: Mercury concentration in *Polymesoda erosa* shells in Kayeli Village, Buru Regency, Maluku Province

Location	Concentration (mg/kg)
1.1	0.3438
1.2	0.5481
1.3	0.6133
2.1	0.3563
2.2	0.4929
2.3	0.5955
3.1	0.3930
3.2	0.7244
3.3	2.7406
Rata-rata	0.756

The measurement results of the safe concentration of mercury exposure in shells in the unlicensed gold mining area in Kayeli Village, Buru Regency, Maluku Province, Indonesia was to 0.756 mg/kg, below the limit of the Indonesia National Standard of 1 mg/kg.

D. NOAEL (No Observed Adverse Effect Level): The purpose of researches in the field of industrial toxicology is to be able to evaluate the safety of a substance. No Observed Adverse Effect Level (NOAEL) is the highest dose without causing effects on experimental animals, which later is used to determine the safe limits of a chemical. World Health Organization (2005) stated that NOAEL from mercury is 0.23 mg/kg.[11]

E. Reference Dose: Tualeka (2013) stated that the Reference Dose is calculated using the following formula.[10]

$$RfD = \frac{NOAEL}{100} = \frac{0.23}{100} = 0.0023 \text{ mg/kg}$$

Annotation:

RfD : Reference Dose (mg/kg)

NOAEL : No Observed Adverse Effect Level (mg/kg)

Using the formula above, the reference dose of mercury in the shellfish is 0.0023 mg/kg.

F. Safe Concentration of Mercury: The calculation of mercury concentration in the illegal gold mining area in Kayeli Village, Buru Regency, Maluku Province, Indonesia used the formula (Tualeka, 2013) as follows.[10]

$$C\ safe = \frac{(RfD)(Wb)}{(\alpha)(R)} = \frac{(0.0023)(71)}{(81\%)(0.284)} = 0.71 \text{ mg/kg}$$

Annotation:

C safe : safe concentration (mg/kg)

RfD : reference dose (mg/kg)

α : % substance absorbed by the lung (percentage of mercury is 80%)[13]

R : consumption rate (kg/day)

Based on the above calculations, it can be seen that the safe concentration of mercury exposure to shellfish in the illegal gold mining area of Kayeli Village, Buru Regency, Maluku Province, Indonesia is 0.71 mg/kg.

Discussion

The measurement of mercury on concentration of *Polymesoda erosa* shells in Kayeli Village, Buru Regency, Maluku Province were carried out from three different locations of tailing discharge around the beach. Three shells were taken as the sample for each location, so the total was 9 sample shells.

The result of NOAEL calculation is 0.23 mg/kg. This result is in line with the limit value set by the World Health Organization and the Agency for Toxic Substances and Disease Registry which stated the NOAEL of mercury to be 0.23 mg/kg. Then, it can be said that the value of No Observed Adverse Effect Level (NOAEL) is safe for the community.

Reference Dose (RfD) in the illegal gold mining area of Kayeli Village, Buru Regency, Maluku Province, Indonesia was 0.0023 mg/kg/day. It is below the RfD of the Environmental Protection Agency in Broussard (2002) of 0.3 mg/kg/day.[6] It can be said that the reference dose (RfD) of mercury in the illegal gold mining area in Kayeli Village, Buru Regency, Maluku Province, Indonesia is safe for the community.

The measurement result of safe concentration of mercury exposure in shellfish in the illegal gold mining area of Kayeli Village, Buru Regency, Maluku Province, Indonesia was 0.71 mg/kg. It is below the standard of regulations set by other bodies. According to the Food and Drug Administration in Broussard (2002) the safe concentration of mercury is 1 mg/kg.[6] Regulation of the Head of the Republic of Indonesia Drug and Food Control Agency Number HK.00.06.1.52.4011.[3] concerning Determination of the Maximum Limit of Microbial and Chemical Contaminants in Foods also mentioned that the safe limit of mercury in shellfish is 1 mg/kg.[12] In addition, the Indonesian National Standard regarding the maximum limit of heavy metal contamination in food also mentioned that the safe concentration of mercury exposure to shellfish is 1 mg/kg.[13] Therefore, it can be said that the safe concentration of mercury in shells in the unlicensed gold mining area in Kayeli Village, Buru Regency, Maluku Province, Indonesia is safe and can be used as a reference for the community.

Conclusion

The concentration of mercury in shellfish measured at 9 points in the illegal gold mining area in Kayeli Village, Buru Regency, Maluku Province, Indonesia was 0.756 mg/kg. The calculation results of safe concentration of mercury exposure to shellfish using No Observed Adverse Effect Level (NOAEL) and Dose Reference (RfD) was 0.71 mg/kg. So, it can be concluded that the safe concentration of shellfish in the illegal gold mining area in Kayeli Village, Buru Regency, Maluku Province, Indonesia is safe for the community because it is less than 1 mg/kg.

To control mercury exposure to shellfish consumed by the community in the area of gold mining without permission in Kayeli Village, Buru Regency, Maluku Province, Indonesia, some efforts can be taken. We recommend mapping the mercury-contaminated areas, providing information for public about the concentration and types of shellfish that are safe for consumption and periodic health checks from local health services.

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Ethical Clearance: The study was approved by the instutitional Ethical Board of Diponegoro University.

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