Safe Concentration of Mercury (Hg) Exposure in Fish Consumed by the Residents of Bulawa Subdistrict, Bone Bolango District, Gorontalo Province, Indonesia

Deviyanti Wahyu Izati[1], Abdul Rohim Tualeka[1], Siprianus Singga[2], Pudhi 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]Health Polytechnic of Ministry Health, Kupang, Indonesia; [3]Departemen of Development of Islamic Society, State Islamic University Sunan Ampel, Surabaya, Indonesia; [4]Departement of Occupational Health and Safety, Faculty of Public Health, Hassanudin University, Makassar, Indonesia; [5]Faculty of Nurse, University of Brawijaya, Malang, Indonesia

ABSTRACT

Mercury is one of the persistent chemicals and is bioaccumulative in the ecosystem. It negatively affects human health and environment. Indonesia has been identified in the use of mercury in industrial sector, especially small industries. High level of mercury needs to be reduced and eliminated. The present study aims to determine the safe concentration of mercury that has negative impact on health of the community of Bulawa Sub-district, Bone Bolango District, Gorontalo. The approach taken in this study was cross sectional with observational research. In the present study, the population was all residents of Bulawa Subdistrict, Bone Bolango District, Gorontalo who were exposed to mercury from fish. The sample in this study was 100 residents who consumed fish caught in Bulawa waters. Sampling was carried out by purposive sampling. Data analysis performed in manual quantitative data analysis to determine the safe (C safe) concentration of mercury for workers. Experimental data includes white rats (W animals), body surface area of white mice (BSA animals), body weight (W) , workers' height (h), workers' respiratory rate (BR), workers' body surface area (BSA), working time (t), mercury concentration (C), NOAEL, animal km, human km, and safe limits for toxin doses (RfD).

The results showed that the measurement of mercury concentration in Bulawa District, Bone Bolango District, Gorontalo was 0.128 mg/m^3 (0.0156 ppm). This value can be used as a reference limit for safe concentration of mercury in the residents who consume fish originating from the waters of traditional mining areas in Indonesia. Control efforts can be created by reducing mercury concentrations in fish, or reducing the rate of fish consumption and limiting the duration of exposure.

Keywords: *Mercury (Hg), safe concentration, residents*

Introduction

Mercury is one of the persistent chemicals and is bioaccumulative in the ecosystem. It has negative impact on human health and the environment. Indonesia has been identified in the use of mercury in industrial sector, especially small industries. The high level of mercury use needs to be reduced and eliminated to avoid health impact (Permenkes, 2016) [(1)].

Mercury is a naturally occurring metal found throughout the environment. Mercury enters the

Correspondence Author:
Abdul Rohim Tualeka
Department of Occupational Health and Safety,
Public Health Faculty, Airlangga University,
60115 Surabaya, East Java, Indonesia
Phone: +62-31-5920948
Email: abdul-r-t@fkm.unair.ac.id

environment as the result of the normal breakdown of minerals in rocks and soil from exposure to wind and water, and from volcanic activity. Mercury releases from natural sources have remained relatively constant in recent history, resulting in a steady rise in environmental mercury. Human activities since the start of the industrial age (e.g., mining, burning of fossil fuels) have resulted in additional release of mercury to the environment[12].

That is true, most of the mercury found in nature is produced by industry; reaching +- 10,000 tons annually. The use of mercury is very high with +- 3,000 types of uses in the processing industry of chemicals, process of making drugs used by humans as well as the basic ingredients of making insecticides for agriculture (Christian et.al., 1970) [2].

All components of mercury - both in the form of methyl and alkyl forms - which enter the human body continuously can cause permanent damage to the brain, liver and kidneys (Roger et al., 1984)[3].

There is a safe limit for mercury entering the body so as not to cause health problems. The limit of mercury in fish is ≤ 1 mg/kg (Permenkes, 2016)[1]. According to the Indonesian National Standard (2009) mercury concentration in fish is 0.3 mg/kg[4].

According to the research results conducted by Singga (2013), Mercury concentration in fish samples in Bulawak Subdistrict, Bone Bolango District, Gorontalo Province was 0.0298 mg/kg[5]. This shows that Mercury concentration in fish in the area was still below the Threshold Value issued by the Indonesian National Standard (2009) by 0.3 mg/kg[4].

In the previous study on the analysis of the health risk of mercury exposure in the community, Bulawa Subdistrict- a subdistrict located in Bone Bolango District, Grorontalo was one of the sub-districts prone to potential danger of mercury pollution due to Illegal Gold Mining (PETI) activities. The mining is located in the upper side of the rivers that pass through the village, causing the villages to potentially be contaminated with mercury from the illegal mining activities. Mercury that is carried by the river water flow changes to methyl mercury and pollutes the sea and fish in the coastal district of Bulawa. This is what causes the community of Bulawa District to be exposed to mercury. Previous research has not calculated the safe concentration of mercury for fish in these waters, is it safe to eat or not. Therefore, a research related to safe concentration of mercury exposure in the community of Bulawa Subdistrict, Bone Bolangan District, Gorontalo is needed.

Material and Method

The present study aims to determine the safe concentration of mercury in fish caught in Bulawa Subdistrict, Bone Bolango District, Gorontalo. The approach taken was cross sectional with observational research. The population in this study was all communities of Bulawa Subdistrict, Bone Bolango District, Gorontalo who were exposed to mercury from fish. The sample in this study was 100 residents consuming fish caught in Bulawa waters. Sampling was carried out by purposive sampling.

The design of the study includes laboratory examination data taken from mercury concentrations in the blood and hair and mercury concentrations in fish. In addition to laboratory data, several other data were also taken such as respondents' weight, primary data from interview questionnaires to the public in the form of respondent characteristics, exposure frequency, duration of exposure, and consumption rate.

The variables in this study include the characteristics of experimental animals in the form of mice, community characteristics which include body weight, body surface area, and worker breathing rate. In addition, mercury concentration was also included in the study variables obtained from previous research literature studies.

Determination of safe (C safe) concentration of Mercury (Hg) is calculated using the following formula (Tualeka, 2019)[6].

$$\text{C safe of fish} = \frac{(\text{R}fd)(\text{W}b)}{(\alpha)(\text{R})}$$

Where:

Csafe: safe concentration (mg/kg)

Rfd: Reference dose (mg/kg)

α: % substance absorbed in the lungs

R: consumption rate (kg/hari)

Findings

A. Characteristics of Experimental Animal and Surface Area of Experimental Animal (White Mice): Toxicity test of chemical compounds in humans can generally be tested in animals for human response to toxicity is qualitatively similar to that of animals. In carrying out the toxicity test, white mice were selected.

Table 1: Distribution of Characteristics of Experimental

Experimental Animal	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

Animals (White Mice): Based on white rat body weight data, the body surface area of white mice was calculated using the following formula:

BSA Animal = 0,09 $W^{0.67}$

where:

BSA: Body Surface Area (m^2)

W: Weight (kg)

A. Workers' Characteristics, Body Surface Area and Respiratory Rate: Characteristics taken from the community of Bulawa District, Bone Bolango District, Gorontalo include weight and duration of exposure. The duration of exposure in a day in this study was 24 hours. The weight of the respondents studied was categorized into 40 kg, 45 kg, 50 kg, 55 kg, 60 kg, 65 kg and 70 kg. The height used is height from the average Indonesian adult at 159 cm.

Based on these data the body surface area of the community and respiratory rate are calculated using the following formula:

1. Body Surface Area

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

Where:

BSA: Body Surface Area (m^2)

W: Weight (kg)

H: Height (cm)

Table 2: Respondents' Weight Distribution and Body Surface Area (BSA)

Respondent	Wb (kg)	h (cm)	BSA (m^2)
1	40	159	0.88
2	45	159	0.99
3	50	159	1.10

Conted…

4	55	159	1.21
5	60	159	1.32
6	65	159	1,43
7	70	159	1,54
Average	55	159	1,21

From the calculation, the average body surface area of the respondent is 1.21m^2.

2. Fish consumption rate:

R = 0,2 kg/day

Table 3: Distribution of Respondents' Characteristics, Rate of Fish Consumption

Repon-dent	Wb (kg)	h (cm)	BSA (m^2)	R fish (kg/day)
1	40	159	0.88	0,2
2	45	159	0.99	0,2
3	50	159	1.10	0,2
4	55	159	1.21	0,2
5	60	159	1.32	0,2
6	65	159	1,43	0,2
7	70	159	1,54	0,2
Average	55	159	1,21	0,2

The average rate of consumption of fish and drinking water in table 3 is 0.2 kg/day.

B. Mercury Consumption: The results of measurements of mercury concentration in Bulawa Subdistrict, Bone Bolango District, Gorontalo were 0.0298 mg/kg (0.0036 ppm). [5].

Mercury concentration in fish consumed by the residents in Bulawa Subdistrict is below the national standard for mercury concentrations in fish by 0.3 mg/kg[7].

C. NOAEL (No Observed Adverse Effect Level): To find out a value that can cause adverse health effects for humans, a toxicity test is carried out. Toxicity test is one of the activities in the field of toxicology research which aims to evaluate a substance against living things. To find out the safe dosage that does not cause an effect, a toxicity test was carried out with No Observed Adverse Effect Level (NOAEL).

According to World Health Organization (WHO) NOAEL value of the mercury is 0.23 mg/kg [8].

D. Reference Dose: Tualeka (2013) states that the Dose Reference (RfD) of toxin exposure can be calculated using the following formula[9]:

$$RfD = \frac{NOAEL}{100}$$

Based on the above formula, the RfD value is obtained in the following way

$$RfD = \frac{0,23}{100}$$
$$= 0.0023 \text{ mg/kg}$$

Where:

RfD : Reference Dose (mg/kg)

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

Based on the formula, the calculation results show that the safe limit of mercury doses is 0.0023 mg/kg.

E. Limits of Safe Mercury Concentration: According to Tualeka (2013) [9], determination of the safe limits of mercury concentration is as follows

$$C\ safe = \frac{(RfD)(Wb)}{(\delta)(R)}$$

$$C\ safe = \frac{(0,0023)(55)}{(80\%)(0,2)}$$
$$= 0,79 \text{ mg/kg}$$

Where:

Csafe : safe concentration (mg/kg)

RfD : Reference dose (mg/kg)

α : % substances absorbed by the lungs

R : consumption rate (kg/day)

The molecular weight of mercury is 200.59[2], while the percentage of mercury absorbed by the lungs is 80%. [10].

Based on the results of calculations above the safe concentration of mercury exposure in fish in Bulawa Subdistrict, Bone Bolango District, Gorontalo is 0.79 mg/kg.

The results of maercury safe limit concentration in Bulawa Subdistrict, Bone Bolango District, Gorontalo can be used to predict safe toxin concentrations and as a comparison with the NAB determined by the National Standardization Agency, ACGIH, NIOSH and OSHA (William, 1985 in Tualeka, 2013)[9].

Discussion

Determination of safe concentration of mercury in Bulawa District, Bone Bolango District, Gorontalo Indonesia is based on No Observed Adverse Effect Level (NOAEL). No Observed Adverse Effect Level (NOAEL) used in this study is from ATSDR and WHO with NOAEL value of fish mercury 0.23 mg/kg.

RfD Value Based on the calculation result is 0.0023 mg/kg. The results of this research are lower than that of the Environmental Protection Agency (EPA) in Broussard, L.A. et.al.[7] which shows RfD in mercury 0.3 mg/kg. Thus, the result of this research shows that the safe RfD in the study area is safer for the community.

Based on the results of this study, the value of safe concentration of mercury in Bulawa Subdistrict, Bone Bolango District, Gorontalo is 0.79 mg/kg. The value result of this research is also lower than the FDA (1996) Food and Drug Administration provision on mercury limit in fish by ≤ 1 mg/kg (Broussard, L.A. Et. Al.)[7]. Thus, the results of this research can be used as a reference for the safe concentration of mercury in people who consume fish originating from the waters of traditional mining areas in Indonesia.

Conclusion

The results of mercury NOAEL measurements in Bulawa District, Bone Bolango District, Gorontalo Province, Indonesia was 0.0051 mg/kg. Reference Dose (RfD) of Mercury after calculation is 00075 mg/kg. Safe concentration of mercury in Bulawa District, Bone Bolango Regency, Gorontalo Province, Indonesia is 0.0042 mg/m^3 (0.0014 ppm).

The use of mercury can cause health effect, such as inciden of mercury poisioning. So, control recommendations for mercury problems in Bulawa Subdistrict, Bone Bolango District, Gorontalo Province, Indonesia are to reduce mercury concentration in fish or reduce fish consumption rates and limit the duration of exposure. The residents must be able to sort out any fish with low mercury concentrations so as not to cause health problems later on. Also the government should

give the information about mercury and its impacts for health and environment, and the government should to take measurement of mercuy levels in the environtmental regulary[13].

Conflict of Interest: All authors have no conflicts of interest to declare.

Source of Funding: This is an article "Safe Concentration of Mercury (Hg) Exposure in Fish Consumed by the Residents of Bulawa Subdistrict, Bone Bolango District, Gorontalo Province, Indonesia" of Occupational Health and Safety Department that was supported by Faculty of Public Health, Airlangga University.

Ethical Clearance: The study was approved by the institutional Ethical Board of Health Polytechnic of Ministry Health, Kupang Indonesia.

REFERENCE

1. Peraturan Menteri Kesehatan Indonesia. Rencana Aksi Nasional Pengendalian Dampak Kesehatan Akibat Pajanan Merkuri Tahun 2016-2020. Jakarta; 2016.
2. Christian G.D et al. Atomic Absorbtion Spectroscopy Application in Agricultur, Biology and Medicine. New York; 1970.
3. Roger et.al. Water Analysis : Inorganic Species. 2nd Ed. Academic Press; 1984.
4. BSN. Standar Nasional Indonesia : Batas Maksimum Cemaran Logam Berat Dalam Pangan. Jakarta: BSN; 2009
5. Singga, Siprianus. Analisis Risiko Kesehatan Pajanan Merkuri Pada Masyarakat Kecamatan Bulawa Kabupaten Bone Bolango Provinsi Gorontalo. Kupang: Joulnal MKMI; 2013.21–8.
6. Tualeka AR, Wibrata DA, Ahsan A, Rahmawati P, Russeng SS, Wahyu A. Determination of Highest Dose of Ammonia without Effect at Work Environment through the Expression of Interleukin-2 Cell in Rattus Novergicus. Surabaya: OAMJMS; 2019.7(6):897–902.
7. Broussard LA, Hammett-stabler CA, Winecker RE. The Toxicology of Mercury. Los Angsles: Laboratory Medicine; 2002. vol. 33, no. 8, p.614-625
8. WHO. Elemental Mercury and Inorganic Mercury Compounds : Human Health Aspects. Geneva: International Programe on Chemical Safety (IPCS) World Health Organization;2003.
9. Tualeka, AR. Toksikologi Industri. Surabaya: Graha Ilmu Mulia; 2013.
10. Alfian Zul. Merkuri : Antara Manfaat Dan Efek Penggunaannya Bagi Bagi Kesehatan Manusia dan Lingkungan [Disertasi]. Medan: USU Repository; 2006.
11. ACGIH. Threshold Limit Values (TLVs) and Biological Exposure Indices (BEIs). Cincinnati; 2012.
12. ATSDR. Toxicological Profile for Mercury. ATSDR's Toxicological Profiles. Georgia: U.S. Department Of Health and Human Services Public Health Service; 1999.
13. Junita, Nita R. Risiko Keracunan Merkuri (Hg) pada Pekerja Penambangan Emas Tanpa Izin (PETI) di Desa Cisarua Kecamatan Nanggung Kabupaten Bogor Tahun 2013. Skripsi. Universitas Islam Negeri Syarif Hidayatullah Jakarta; 2013