Determination of Mercury (Hg) Risk Level (RQ) with Exposure through Fish and Drinking Water Consumption in Bulawa Sub-district, Bone Bolango District, Gorontalo Province, Indonesia

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ABSTRACT

Mercury (Hg) is a liquid metal element, silver at room temperature (25^{0}C and has a melting and boiling points at of -38.87^{0}and 35.0^{0}C, respectively. In traditional gold mining activities, Mercury (Hg) is used for gold purification (amalgamation). This study aims to determine the level of risk (RQ) in the community of Bulawa District who consume fish and drinking water sourced from the waters around traditional mining activities. This type of research is observational with an environmental health risk analysis design. Sampling was calculated using purposive sampling with the inclusion criteria by the researchers and resulted in 100 citizens. The results of the calculation of the level of Risk (RQ) of Mercury (Hg) consumption of fish and drinking water in the community of Bulawa District was 0.08 and 0.003, respectively, thus, RQ <1, meaning that it does not have an effect on health. However, this value can be used as a reference level of risk level (RQ) of Mercury (Hg) in people who consume fish and drinking water from the waters of traditional mining areas in Indonesia. Control measures can be taken to maintain the level of Risk (RQ) of Mercury (Hg) <1 through limiting the frequency of consumption and the rate of intake of fish and drinking water from surrounding waters. Warning signs of mercury contamination around mining waters can be also provided.

Keywords: *Mercury (Hg), Mine, Risk Level (RQ), Society*

Introduction

Merkury (Hg) is a liquid metal element in silver at room temperature (25^{0}C), has a melting point of -38.87^0 C and a boiling point of 35.0^{0}C. Mercury in aquatic environment comes from illegal traditional gold mining activities. Mercury in the mining sector is used for amalgamation process (gold refining). Pollution occurs because Mercury used to purify gold is disposed of freely in the waters. Over time, bioaccumulation of Mercury in water and fish causes increased mercury concentration. If humans consume water and fish, humans will also be exposed to mercury (Lestarisa, 2010)[(1)].

Mercury causes neurological symptoms, teratogenic effects, and increases the ratio of red blood cells to blood plasma. Methyl mercury has a high affinity for the sulfhidryl group which has a large effect on the dysfunction of the colinasetyl transferase enzyme. The result is acetylcholine deficiency which contributes to signs and symptoms of motor dysfunction (Broussard, 2002)[(2)].

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According to the Food and Drug Administration/ FDA (1996), the limit of mercury(Hg) in fish is 1 ppm (ATSDR, 1999)[3]. The Food and Drug Administration/ FDA (1997) also states that the limit of mercury in fish is ≤ 1 mg/kg (Permenkes, 2016)[4].

According to the Federal State Toxicology and Regulation Alliance Committee (1995), the standard concentration of Mercury in permissible drinking water is 2 **µg**/kg and based on the World Health Organization/ WHO (1984), the limit of mercury concentration is 0,0001 mg/L (ATSDR, 1999)[3].

The results of the Singga study (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[6]. In addition, the concentration of Mercury in drinking water is below the Threshold Value issued by the (Permenkes, 2010) by 0.001 mg/L[7].

Based on the previous research on the analysis of mercury exposure health risks in the community of Bulawa Subdistrict, Bone Bolango Regency, Gorontalo Province, the level of risk of exposure to Mercury through consumption of fish and drinking water in the community has not been performed. This makes the community of Bulawa District being exposed to mercury from fish and drinking water consumed. Based on the explanation above, the researchers measured the level of risk (RQ) exposure to Mercury (Hg) through consumption of fish and drinking water in the community of Bulawa District.

Materials and Method

This study aims to determine the level of risk (RQ) exposure to Mercury (Hg) through consumption of fish and drinking water in the community of Bulango District, Gorontalo Province with non reactive research using the dose response approach and *NOAEL*. The number of samples was 100 citizens. Sampling was performed by purposive sampling method;i.ecitizens of Bulawa Subdistrict, Bone Bolango District who consumed fish caught from Bulawa waters and had lived in the area for at least 1 year and used river water and ground water as drinking water.

The study began with a literature study on the calculation formula of the Reference Reference(RfD), non-carcinogenic intakes and the level of non-carcinogenic risk. Secondary data was then obtained; which includes respondent characteristics such as body weight, mercury exposure concentration(Hg), intake of fish and drinking water intake rates, duration of exposure, frequency of exposure and average duration of exposure which causes non-carcinogenic effects.

The variables in this study included the highest dose of toxin without causing effects on experimental animals (NOAEL) from Mercury(Hg), weight of experimental animals (W animals), body surface of experimental animals (BSA of experimental animals), workers' body weight(W), workers' height(h), workers' body surface area (BSA), reference dose of Mercury(Hg) for workers(RfD), as and the rate of consumption of fish and drinking water. Data analysis in this study was carried out using quantitative analysis manually to determine the level of risk(RQ) of Mercury(Hg).

The level of risk(RQ) of Mercury (Hg) uses the following formula (Tualeka, 2019)[8]:

$$RQ = \frac{Intake}{RFD}$$

Where:

RQ: Risk Level

Intake: The amount of risk agent intake received by individuals(mg/kg/day)

RfD: Daily exposure estimation(mg/kg)

Findings

A. Characteristics and Surface Area of Experimental Animal Bodies: Experimental animals are used as a support in testing a compound toxicity. This is because the response of humans to toxic is qualitatively similar as the response of animals. Therefore, this fact is used as a basis for extrapolating from animal to human data.

Table 1: Distribution of Characteristics of White Mice

Experimental animal (white mice)	W (kg)	BSA (m^2)
1	0.140	0.024
2	0.140	0.024
3	0.141	0.024
4	0.141	0.024
5	0.139	0.024

Conted…

6	0.141	0.024
Average	0.140	0.024

Based on the data of white mice body weight (W), the body surface area was obtained by using the following formula:

$BSA = 0.09\ W^{0.67}$

Where:

BSA:Body Surface area (m^2)

W: Weight (kg)

B. Characteristics, Surface Area, and Fish and Drinking Water Consumption Rate: The characteristics of the respondents used in this study included weight and consumption rate of fish and drinking water from 100 people in Bone Bolango District. The weight of the respondents was categorized into 40 kg, 45 kg, 50 kg, 55 kg, 60 kg, 65 kg and 70 kg. For the average height of respondents, the researchers used the average Indonesian height of 159 cm. Data on body weight and average height were used to calculate the surface area of the respondent's body. The surface area of the respondent's body uses the following formula (Tualeka, 2013)[8].

1. Body surface area

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

Where:

BSA: Body Surface (m^2)

W: Weight (kg)

h: Height(cm)

The calculation of the respondents' body surface with body weight of 40 Kg, 45 Kg, 50 Kg, 55 Kg, 60 Kg, 65 Kg and 70 kg are as follows:

Table 2: Distribution of Respondents' Weight 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
4	55	159	1.21
5	60	159	1.32

Conted…

6	65	159	1.43
7	70	159	1.54
Average	55	159	1.21

The result of the analysis of the calculation of the surface area of the respondents in table 2 show that the average body surface area of the respondents is 1.21 m^2.

2. Fish and Drinking Water Consumption Rate

Rate of fish consumption:

R = 0.2 kg/day

The rate of drinking water consumption:

R = 2 Liter/day

Table 3: Distribution of Characteristics of Respondents and Rate of Fish and Drinking Water consumption

Respondent	Wb (kg)	h (cm)	BSA (m2)	R of fish (kg/ day)	R of water (l/ day)
1	40	159	0.88	0.2	2
2	45	159	0.99	0.2	2
3	50	159	1.10	0.2	2
4	55	159	1.21	0.2	2
5	60	159	1.32	0.2	2
6	65	159	1.43	0.2	2
7	70	159	1.54	0.2	2
Average	55	159	1.21	0.2	2

The result of the calculation of the rate of consumption of fish and drinking water in table 3 shows that the average rate is 0.2 kg/day and 2 L/day, respectively.

C. Merkury Concentration (Hg): The results of measurements of mercury concentration in Bulawa Subdistrict, Bone Bolango District, Gorontalo were 0.0298 mg/kg (0.0036 ppm). Based on the measurement results, the average concentration of Mercury (Hg) in the respondent's drinking water in Bulawa District was 0.000478 mg/L (0.0000582 ppm). This concentration is still below the Threshold Value issued by the Minister of Health Regulation (2010)[7] of 0.001 mg/L.

The highest distribution of Mercury (Hg) concentrations in respondent's drinking water was

found in the Kaindudu Barat region of 0.00065 mg/L (0.000079 ppm) and the lowest was in drinking water in the village of Mamungaa by 0.000285 mg/L (0.00034 ppm).

D. Animal Kmand Human Km: Determination of the reference dosage of toxin for residents of Bulawa Subdistrict of Gorontalo Province was carried out by counting Animal Km and Human Km.

Animal Km

$$\text{Animal Km} = \frac{\text{W animal}}{\text{BSA animal}}$$

where:

Animal Km: Km factor on animal

W: Weight of white mice

BSA: Body Surface Area of white mice

Table 4: Results of Calculation of Animal Km in Experimental Animals (White Mice)

Experimental animal (White mice)	Animal Km
1	5.81
2	5.81
3	5.82
4	5.82
5	5.80
6	5.82
Average	5.81

The calculation results of Animal Km in table 4 show that the average Animal Km in white animals is 5.81.

1. Human Km

$$\text{Human Km} = \frac{\text{W human}}{\text{BSA human}}$$

Where;

Animal Km:Km factor on human

W:Respondents' weight

BSA: Respondents' Body Surface Area

Table 5: Calculation Result of Human Km

Respondent	Human Km
1	45.28
2	45.28
3	45.28
4	45.28
5	45.28

Conted…

6	45.28
7	45.28
Average	45.28

The results of the Human Km Calculation in table 5 show the average human Km for respondents in Bulawa District, Gorontalo Province by 45.28. The table of calculation results is as follows:

E. No Observed Adverse Effect Level (NOAEL) of Merkury (Hg): Determination of safe limits of chemical concentration begins with the determination of the highest dose without causing effects on experimental animals or No Observed Adverse Effect Level (NOAEL). According to the World Health Organization/WHO (2005)[9] the value of NOAEL Mercury (Hg) is 0.23 mg/kg.Day.

F. Reference Dose (RfD) of Merkury (Hg) Saridewi and Tualeka (2017)[9] stated that the reference dose (RfD) of toxin exposure is obtained using the formula from Shaw et.al (2007) as follows:

$$\text{RfD} = \text{NOAEL}\,\frac{\text{Animal Km}}{\text{Human Km}}$$

where:

RfD: Reference Dose (mg/kg)

Animal Km: Km factor on animal

Human Km: Km factor on animal

Based on the above formula, the RfD calculation results obtained from the NOAEL value of Mercury, the average Animal Km, and the Average Human Km are:

$$\text{RfD} = 0.23\,\frac{5.81}{45.28}$$
$$= 0.295 \text{ mg/kg}$$

C. Merkury Intake(Hg): According to Tualeka (2013)[8], the following formula can be used to calculate intake through fish and drinking water:

$$\text{Intake} = \frac{\text{C} \times \text{R} \times f\,\text{E} \times \text{Dt}}{\text{WB} \times t\,avg}$$

Intake of Mercury through fish in respondents with a body weight of 40 Kg, 45 Kg, 50 Kg, 55 Kg, 60 Kg, 65 Kg and 70 kg is as follows:

The average intake of Mercury (Hg) in Fish based on table 6 is 000009 mg/kg/day. Calculation result

of the average intake of Mercury (Hg) in drinking water based on table 7 is 0.00008 mg/kg/day.

H. Risk Level (RQ) of Merkury (Hg): According to Tualeka (2019)[8], the calculation of Mercury (Hg) level of risk (RQ) can use the following formula:

$$RQ = \frac{intake}{RfD}$$

Risk Level (RQ) of Mercury (Hg) through fish in respondents with a body weight of 40 Kg, 45 Kg, 50 Kg, 55 Kg, 60 Kg, 65 Kg and 70 kg is as follows:

Table 6: Calculation Results of Mercury (Hg) in Fish and Drinking Water from Respondents

Resp.	Wb	Intake (Ikan)	Intake (Air minum)	RfD	RQ (Ikan)	RQ (Air minum)
1	40	0.0001	0.000001	363	0.005	0.11
2	45	0.0001	0.00001	363	0.004	0.10
3	50	0.0001	0.00001	363	0.004	0.09
4	55	0.0001	0.00001	363	0.003	0.08
5	60	0.00009	0.00001	363	0.003	0.07
6	65	0.00009	0.00001	363	0.003	0.07
7	70	0.00008	0.00001	363	0.002	0.06
Average		0.00009	0.00008	363	0.003	0.08

The calculation of the Risk Level (RQ) of Mercury (Hg) average in Fish and Drinking Water based on table 8 is 0.003 and 0.08, respectively.

Discussion

Based on the results of this study, the value of the Risk Level (RQ) in the community consuming fish in Bulawa Subdistrict, Bone Bolango Regency, Gorontalo Province, Indonesia the waters surrounding traditional mining was 0.08 for fish and 0.003 for drinking water. The two results of this calculation indicate that the RQ value <1. The value of RQ <1 means that mercury has not affected the health of the community (Tualeka, 2013) [8]. The results of this study are smaller than the results of the study by Zolfaghari (2018)[12] showing the Risk Level (RQ) value of fish consumption was 0.2. The results of RQ calculation on the average drinking water consumption in this study are also smaller than that of Hartati's research[11] by RQ> 1 of 1.1.

The value of risk level in the present study is (RQ) <1 which can be used as a guide for consumption of fish and drinking water. With the average fish consumption rate (R) of 0.2 kg/day and drinking water of 2 L day, the community has not been at risk of being affected by health problems due to Mercury. This is because the calculation of RQ uses RfD derived from Indonesian body weight data. In conclusion, this figure can be used as a reference for the Indonesian people in consuming fish and drinking water sourced from the waters around traditional gold mining areas in Indonesia.

Conclusion

The Mercury RfD (Hg) is 0.023 mg/kg. The intakes of fish and drinking water are 0,0009 mg/kg and 0,0008 mg/L, respectively. The results of the calculation of risk level (RQ) on fish consumption and drinking water are 0.08 and 0.003, respectively. Value of risk level (RQ) <1 which means it has not caused an effect on health.

Recommendation

Control can be performed by local policy holders by guiding the rate of safe consumption of fish and drinking water in the Bulawa Subdistrict area, mapping water territories contaminated by Mercury (Hg) as well as installing warning signs and symbols that waters are contaminated, and providing information about consumption of fish species allowed in the general public and vulnerable groups such as pregnant women and children[3]. In addition, it is also necessary to limit the frequency of consumption of fish and drinking water from the waters around the mining site.

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

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