Mercury (Hg) contamination on water, sediment and macrozoobenthos in Waelata River, Wamsait Village, Waelata Sub-district, Buru District, Maluku Province

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Abstract, Gold was found in Buru Island, Maluku Province, Indonesia in November, 2011. Since then, the artisanal small-scale gold mining (ASGM) activity was started in Botak Mount up to now. Mercury was used to extract gold through amalgamation process and produce high volume of wastewater contaminated by Hg to Waelata River, straight to Kayeli Bay. This caused serious problem for the environment. Sampling was done in three locations in Waelata River, Wamsait Village, Waelata Sub-District, Buru District, with the three times of repetition to determine the mercury (Hg) concentration level in the water, sediment and macrozoobenthos. The research result showed that the highest Hg concentration mean in the water, sediment and macrozoobenthos was in ST.02 with the respective values namely 0.0012±0.0001 ppm, 0.0833±0.0062 ppm and 0.0088±0.0003 ppm. On the other hand, the lowest Hg concentration mean was found in ST.01 with the respective values namely < 0.0005±0.0000 ppm, 0.0228±0.0019 ppm and 0.0050±0.0034 ppm. The wastewater was produced by the gold mining activities that did not flow to ST.01, so that Hg in the wastewater did not have any correlation with the Hg in sediment and macrozoobenthos (p<0.05), however it flowed from ST.02 to ST.03 so that the Hg in the water has correlation with Hg in sediment and macrozoobenthos (p>0.05).

1. Introduction
The mercury (Hg) contamination still becomes big problem for the environment and health in developing countries. The artisanal small-scale gold mining (ASGM) activity frequently uses Hg [1]. ASGM occupies in the most of developing countries in the world. At least, there are one hundred million people in 55 countries, both directly and indirectly, who depends on the ASGM [2]. The spreading of ASGM in various Indonesia areas causes negative effect on the environment and it is commonly implicated by pollution problem which really disturbs the ecosystem and human’s health [3,4], so that Indonesia has encountered mercury danger as the effect of the of mercury pollution has increased in various areas. The number of miner is estimated about 2 million people in 800 areas of ASGM who can produce 100 ton of gold annually.

On November 2011, gold was found in Botak Mount, Buru Island Maluku Province. Since then, the ASGM was conducted in Botak Mount [5] up to now and the mining area was about 250
In 2012, the people’s mining in Wamsait Village, Waelata Sub-District, Buru District, becomes rampant and uncontrolled. Mercury is utilised to extract gold (Au) from golden seeds using amalgamation process in steel milling (drum) [6], and it needs around 20 g Hg for 1 g Au produced [7]. A report in 2006 by United Nations Environment Program (UNEP) showed that the Hg’s demand in the small scale gold mining is higher than in the other operations [8].

Mining operational which has illegal and not controlled characteristics inhibits the estimation which can be relied from the amount of Au extracted or number of worker of ASGM in Buru Island, commonly becomes problematic in the operation, ASGM [3]. However, hundreds of drum operated in Botak Mount and around them during the research, produced high volume of wastewater contaminated by Hg and sediment into the water of Kayeli Bay [5]. Every drum was assumed to use 1 kg of Hg for each rotation in the extraction of Au from the seed. The management time for each drum is 4 hours, thus the management process in 24 hours, the intensity of the management can reach 5-7 times of process. In Botak Mount, there were 500 drums operated, thus there were 500 kg of mercury used in each rotation. If each 1 kg of mercury produces waste of 10 g, then it was estimated that the mercury waste disposed to the environment is 5 kg for one rotation. This is very worrying because it can pollute the water around Botak Mount, and cause contamination problem which is really disturbing for the ecosystem and human’s life [4].

Mercury belongs to heavy metal which is categorized as Hazardous and Toxic Material waste because it has toxic and persistent properties so that it harms the living environment and human [9]. Mercury is cheap and easily accessed metal. This metal is admitted to be priority hazardous substances by the Agency of Toxic Substances and List of Diseases because of the high toxicity, mobility and the long living period [10], and was identified by the World Health Organization as global contaminant which has high risk for the human’s health [11]. A research in 2006 estimated that there were 100-150 ton of Hg deposited in the environment annually from the activity of small scale gold mining in Indonesia [3].

Research about the pollution of Hg in water, biota, and blood have been conducted by Center for Environmental Health Engineering of Ambo in 2012 by testing 8 water samples which showed that the Hg concentration was estimated around 0.0049 – 0.0529 mg.L⁻¹, with the highest concentration was in Waepa River, as much as 0.0529 mg.L⁻¹ [12]. The result of research conducted in the watershed of Waepa River concluded that the mercury concentration has been distributed with the sediment concentration in the upstream reached 0.102 mg.L⁻¹ and in the downstream reached 0.031 mg.L⁻¹ [13]. Other researchers found that the mercury concentration in the sediment of Wamsait River and Kayeli Bay were respectively 0.35 and 7.66 mg/Kg [5]. In accordance with this research, the mercury concentration in Anadara Granosa shell in Kayeli Bay, Buru District, in average was 0.35 mg/kg which has exceed the reference concentration determined by EPA, which is as much as 0.042 mg/kg [8].

The mining activities in Botak Mount was the trigger of pollution, therefore it caused big problems for the human being because of its toxicity and can be accumulated in food chain. The environmental problem which should be faced is tailing disposed in the environment without any specific treatment [14]. The metal content in the water and water organism commonly always increases from time to time because of the metal characteristics which is bioaccumulative so that organism is really good to be used as metal pollution indicator in water environment [15]. After that, metal will experience biotransformation in order to become more metabolite, while some others go to the organ target, such as nerve and kidney [16]. This research aims to analyze the Hg concentration in the water, sediment, and macrozoobenthos, as well as its relationship with the community health.

2. Material and method

2.1. Location

The research location in Waelata River (Figure 1), in Wamsait Village, Waelata Sub-District, Buru District, Maluku Province, Indonesia. This river flows to Kayeli Bay. This river has a function as
the place for bathing, washing, and defecating for Wamsait villagers. The Artisanal small-scale gold mining industry waste in Botak Mount flows to Waelata River and then enter the Kayeli Bay [5].

![Figure 1. Sampling Location Map.](image)

The three stations of sampling were chosen based on the closeness level with the human activities. Station 1 (ST.01) is in the upstream and used as control station because there is no mining activity and gold management. Station 02 (ST.02) is marked by the human activities such as washing, bathing, defecating and is near the gold management unit. Station 03 (ST.03) is quite far from the residence (Table 1).

| Location Name | Sample Code | Samples Type            | Samples Location          |
|---------------|-------------|--------------------------|----------------------------|
| Waelata River | ST 01       | Water, benthos, sediment | E 127° 01' 26,06" S -3° 24' 21,74" |
| Waelata River | ST 02       | Water, benthos, sediment | E 127° 02' 18,29" S -3° 23' 57,33" |
| Waelata River | ST 03       | Water, benthos, sediment | E 127° 03' 04,96" S -3° 23' 23,18" |

2.2. Analysis of mercury (Hg)
2.2.1. Samples collection process
Samples analyzed in this research are water, sediment, and macrozoobenthos taken from Waelata for three times repetition. The sampling was done in April – Mei 2019. The water sampling was conducted at the depth of 35 cm below the water surface using bottle with the capacity of 250 mL and screw cap. The bottle was sterilized using 10% nitrate acid and rinsed using aquadest before being used [17]. The water sample was acidified with 5 mL of nitrate acid to avoid metal degradation cause by microorganism [11].

Sediment sample was taken and put into polyethylene plastic bag and added by 10% of nitrate acid. Sediment sample was taken using pipe with diameter of 2 cm which was pressed into the sediment to obtain the sediment layer of 10 - 15 cm [18]. All samples were stored in a deep freezer at -10°C [19].

The macrozoobenthos samples was taken along with the sediment. The samples were kept in polyethylene plastic bag and preserved using alcohol of 70%.
2.2.2. Samples treatment
All water samples were melted at room temperature of 27°C before being frozen in freezer [11], then put in Mercury Vapour Unit Atomic Absorption Spectrophotometer (MVU AAS) to test the metal content. The value was presented in the form of ppm.

The sediment samples were taken from freezer and dried in the air for 3 days. After that, it was dried using oven at the temperature of 105 ± 20°C until the weight became constant, sifted and weighted for 2 g, mixed with water as much as 50 mL to be analyzed in term of its metal weight [11].

Macrozoobenthos samples which have been preserved were then tested in terms in its Hg content through IK-MK-01.57 test method using Mercury Vapour Unit Atomic Absorption Spectrophotometer (MVU AAS) tools after being wet distilled.

2.3. Data analysis
The data analysis used is descriptive analysis method by explaining the result of Hg concentration in the water, sediment, and macrozoobenthos, by using SPSS program. Regression analysis (Pearson correlation) was used to see whether there is a relationship between Hg in the water, sediment, and macrozoobenthos [20]. For all of these tests, the significance level determined was Sig (α) 0.05. Mercury in the water compared to the Water Quality Criteria based on the class II of Government Regulation of the Republic of Indonesia No 82 of 2001.

3. Result and discussion
3.1. Content of mercury (Hg) in water, sediment, and macrozoobenthos.
The Hg concentration in the water, sediment ad macrozoobenthos, is determined based on the sampling of the three stations (ST.01, ST.02, and ST.03). The concentration of (Hg) in the water, sediment and macrozoobenthos can be seen in the table 2.

| Table 2. The concentration of mercury (Hg) in the water, sediment and macrozoobenthos |
|---------------------------------|----------------|----------------|----------------|
| Concentration                   | ST.01          | ST.02          | ST.03          |
| Hg in the water (ppm)           | < 0.0005       | 0.0011         | 0.0008         |
| Mean                            | < 0.0005       | 0.0013         | 0.0006         |
| Thresholda)                    | 0.002 ppm      |                |                |
| Hg in the sediment (ppm)        | 0.0214         | 0.0895         | 0.0616         |
| Mean                            | 0.0228±0.0019  | 0.0833±0.0062  | 0.0605±0.0028  |
| Thresholdb)                    | 0.1 ppm        |                |                |
| Hg in macrozoobenthos (ppm)     | 0.0022         | 0.0088         | 0.0045         |
| Mean                            | 0.0050±0.0034  | 0.0088±0.0003  | 0.0051±0.0007  |
| Thresholdc)                    | 0.05 ppm       |                |                |

Source: Primary Data, 2019

a) Water Quality Criteria based on the Class II of the Government Regulation of the Republic of Indonesia No 82 of 2001 [21]

b) Threshold of Sediment based on ANZECC 2000 [5]

c) Threshold of Macrozoobenthos based on WHO [11]

The mean of highest Hg concentration in the water was in ST.02 which is 0.0012 ppm and the lowest concentration was in ST.01 as the controls station (<0.0005±0.0000 ppm). All of these values do not exceed the threshold determined by the Water Quality Criteria of Class II based on
the Government Regulation of the Republic of Indonesia No. 82 of 2001 which is 0.002 ppm. The lowest concentration was in ST.01 which was lower than the threshold of LOD (Limit of Detection) or concentration limit detected by Mercury Vapour Unit Atomic Absorption Spectrophotometer (MVU AAS) used in the water mercury test.

The highest mean of Hg concentration in the sediment (0.0833±0.0062 ppm) was recorded in ST.02, while the lowest mean concentration (0.0228±0.0019 ppm) was found in ST.01. The highest mean of Hg concentration in macrozoobenthos (0.0088±0.0003 ppm) was found in ST.02, while the lowest mean concentration (0.0050±0.0034 ppm) was recorded in ST.01. The concentration mean of Hg in the water, sediment and macrozoobenthos, in ST.02 was higher than ST.01 and ST.03. This is due to ST.02 is near the small scale gold mining waste disposal site.

3.2. The correlation of mercury (Hg) in the water, sediment and macrozoobenthos

In ST.01, the correlation between Hg concentration in the sediment and macrozoobenthos is significant ($r = -0.007; N = 9; \alpha = 0.05$) because of the value of $p = 0.498 (p>0.05)$. In addition, the correlation between the Hg concentration in the water and sediment ($r = 0.000; N = 9; \alpha = 0.05$) and the correlation between the concentration of Hg in the water and macrozoobenthos ($r = 0.000; N = 9; \alpha = 0.05$) is not significant because of the $p$ value $=0.000 (p<0.05)$.

In ST.02, the correlation between the Hg concentration in the water and sediment ($r = 0.009; N = 9; \alpha = 0.05$), the correlation between the Hg concentration in the water and macrozoobenthos ($r = 0.918; N = 9; \alpha = 0.05$) and the correlation between the Hg concentration in the sediment and macrozoobenthos ($r = 0.406; N = 9; \alpha = 0.05$) is significant because the $p$ value is $p > 0.05$.

**Table 3. The coefficient of correlation of Hg concentration in water, sediment and macrozoobenthos.**

| Station and parameter | The correlation coefficient ($r$) | The significance of 1–tailed |
|----------------------|----------------------------------|-----------------------------|
|                      | mercury(Hg)                      |                             |
| ST.01                | Water vs sediment                | 0.000                       | 0.000                       |
|                      | Water vs macrozoobenthos         | 0.000                       | 0.000                       |
|                      | Sediment vs macrozoobenthos      | -0.007                      | 0.498                       |
| ST.02                | Water vs sediment                | 0.009                       | 0.497                       |
|                      | Water vs macrozoobenthos         | 0.918                       | 0.130                       |
|                      | Sediment vs macrozoobenthos      | 0.406                       | 0.367                       |
| ST.03                | Water vs sediment                | -0.649                      | 0.275                       |
|                      | Water vs macrozoobenthos         | -0.936                      | 0.115                       |
|                      | Sediment vs macrozoobenthos      | 0.339                       | 0.390                       |

The significance value of $\alpha = 0.05$

In ST.03, the correlation between Hg concentration in the water and sediment ($r = -0.649; N = 9; \alpha = 0.05$), correlation between Hg concentration and macrozoobenthos ($r = -0.936; N = 9; \alpha = 0.05$) and correlation between Hg concentration in the sediment and macrozoobenthos ($r = 0.339; N = 9; \alpha = 0.05$) is significant with $p$ value $p>0.05$.

At the ST.01, there is no correlation found between the Hg concentrations in the water and sediment as well as water and macrozoobenthos. This is due to that ST.01 is a control station which is not polluted by the gold mining activities. Meanwhile, the correlation between the Hg concentration in the sediment and macrozoobenthos is significant because the Hg content is naturally in the habitat of macrozoobenthos.

At ST.02 and ST.03, there is correlation found between the Hg concentration in the water, sediment and macrozoobenthos. These two stations are close to each other with the activity of gold management and the wastewater flows through ST.02 and ST.03.
4. Conclusion
The highest mean of mercury concentration in the water, sediment, and macrozoobenthos was at ST.02 with the values are 0.0012±0.0001 ppm, 0.0833±0.0062 ppm and 00088±0.003 ppm, respectively. On the other hand, the lowest mean of Hg concentration was at ST.01 with the values are < 0.0005±0.0000 ppm, 0.0228±0.0019 ppm and 0.0050±0.0034 ppm, respectively. The wastewater of gold mining activity does not flow to ST.01 so that Hg in the water does not have any correlation with the Hg in sediment and macrozoobenthos (p>0.05), however it flows to ST.02 and ST.03 so that the Hg in the water, has correlation with Hg in the sediment and macrozoobenthos (p<0.05).

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