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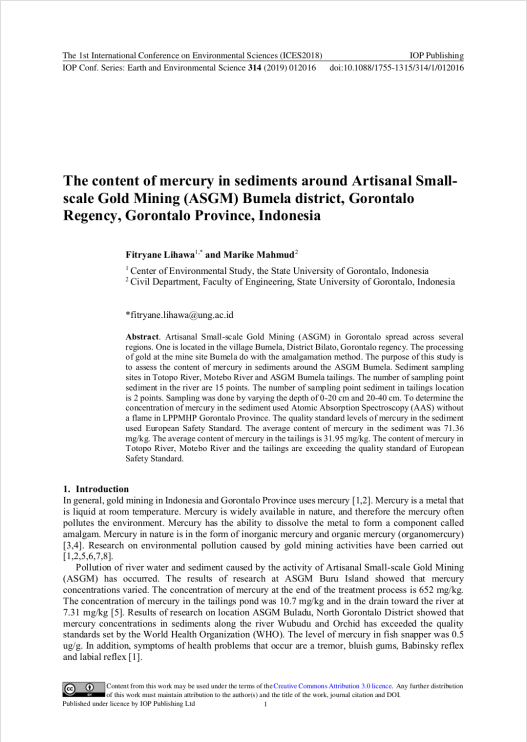

The content of mercury in sediments around Artisanal Small-scale Gold Mining (ASGM) Bumela district, Gorontalo Regency, Gorontalo Province, Indonesia

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Abstract. Artisanal Small-scale Gold Mining (ASGM) in Gorontalo spread across several regions. One is located in the village Bumela, District Bilato, Gorontalo regency. The processing of gold at the mine site Bumela do with the amalgamation method. The purpose of this study is to assess the content of mercury in sediments around the ASGM Bumela. Sediment sampling sites in Totopo River, Motebo River and ASGM Bumela tailings. The number of sampling point sediment in the river are 15 points. The number of sampling point sediment in tailings location is 2 points. Sampling was done by varying the depth of 0-20 cm and 20-40 cm. To determine the concentration of mercury in the sediment used Atomic Absorption Spectroscopy (AAS) without a flame in LPPMHP Gorontalo Province. The quality standard levels of mercury in the sediment used European Safety Standard. The average content of mercury in the sediment was 71.36 mg/kg. The average content of mercury in the tailings is 31.95 mg/kg. The content of mercury in Totopo River, Motebo River and the tailings are exceeding the quality standard of European Safety Standard.

1. Introduction

In general, gold mining in Indonesia and Gorontalo Province uses mercury [1,2]. Mercury is a metal that is liquid at room temperature. Mercury is widely available in nature, and therefore the mercury often pollutes the environment. Mercury has the ability to dissolve the metal to form a component called amalgam. Mercury in nature is in the form of inorganic mercury and organic mercury (organomercury) [3,4]. Research on environmental pollution caused by gold mining activities have been carried out [1,2,5,6,7,8].

Pollution of river water and sediment caused by the activity of Artisanal Small-scale Gold Mining (ASGM) has occurred. The results of research at ASGM Buru Island showed that mercury concentrations varied. The concentration of mercury at the end of the treatment process is 652 mg/kg. The concentration of mercury in the tailings pond was 10.7 mg/kg and in the drain toward the river at 7.31 mg/kg [5]. Results of research on location ASGM Buladu, North Gorontalo District showed that mercury concentrations in sediments along the river Wubudu and Orchid has exceeded the quality standards set by the World Health Organization (WHO). The level of mercury in fish snapper was 0.5 ug/g. In addition, symptoms of health problems that occur are a tremor, bluish gums, Babinsky reflex and labial reflex [1].

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Pollution of river water and sediment caused by the activity of Artisanal Small-scale Gold Mining (ASGM) has occurred. The results of research at ASGM Buru Island showed that mercury concentrations varied. The concentration of mercury at the end of the treatment process is 652 mg/kg. The concentration of mercury in the tailings pond was 10.7 mg/kg and in the drain toward the river at 7.31 mg/kg [5]. Results of research on location ASGM Buladu, North Gorontalo District showed that mercury concentrations in sediments along the river Wubudu and Orchid has exceeded the quality standards set by the World Health Organization (WHO). The level of mercury in fish snapper was 0.5 ug/g. In addition, symptoms of health problems that occur are a tremor, bluish gums, Babinsky reflex and labial reflex [1].

Mercury goes into the sediment will accumulate and be absorbed by plants and fish. This will cause the plants and animals of water will be polluted by mercury [6,7]. Therefore it is necessary to investigate mercury pollution in the sediment at the site of ASGM Bumela, Gorontalo Regency.

2. Research methods

2.1. Research Locations

The study was conducted in Artisanal Small-scale Gold Mining (ASGM) Bumela Village, District Bilato, Gorontalo regency. Distance ASGM Bumela to County Government Center Gorontalo is 54 km. Access to the location can be reached by car or motorcycle with a travel time ± 1 hour. Distance from the village center to the mine site Bumela ± 8 km and can be reached by foot or by motorcycle.

Sediment samples were taken from the river Totopo (station S1 - S13) and the River Motebo (station S14 and S15). Sediment samples from the tailings totaled 2 samples (stations ST1 and ST2) (Figure 1). Sampling sediment using a hand drill. At each point, sediment samples were taken at a depth of 0-20 cm and a depth of 20-40 cm. The equipment used should be sufficient to guarantee the security of the sample. The distance of each sampling point of processing site is shown in Table 1.

Table 1. The distance of the sampling point from the the gold processing site

Sampling Point	Name Rivers	Distance (km)
S1	Totopo	7.5
S2	Totopo	5.47
S3	Totopo	2.14
S4	Totopo	4.16
S5	Totopo	3.50
S6	Totopo	5.16
S7	Totopo	1.85
S8	Totopo	1.45
S9	Totopo	1.26
S10	Totopo	1.14
S11	Totopo	908
S12	Totopo	746
S13	Totopo	467
S14	Left Motebo	28
S15	Right Motebo	39

Source: Results of the interpretation of the map, 2018

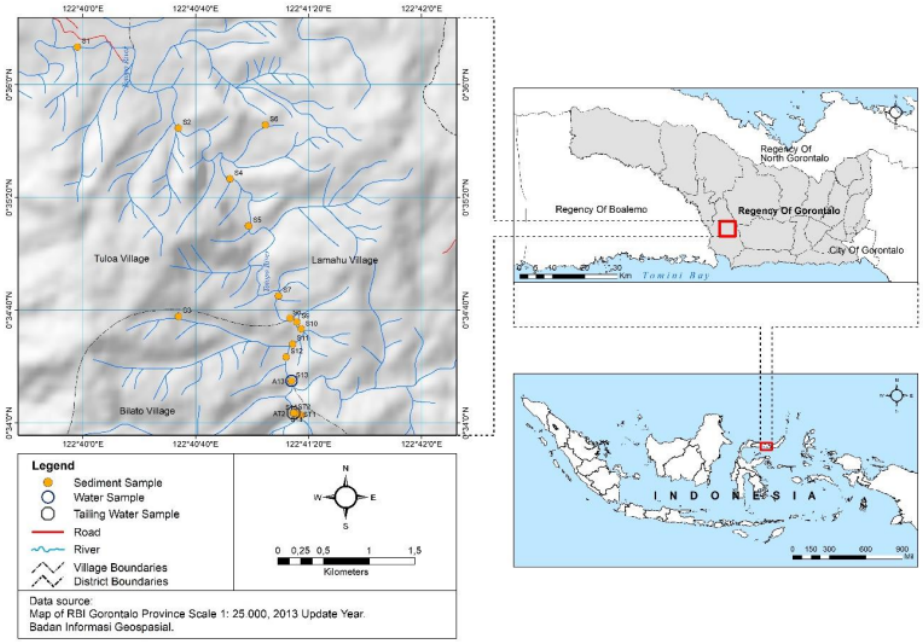

Figure 1. Map of research sites

2.2 Analysis procedures

To determine the concentration of mercury in the water used Atomic Absorption Spectroscopy (AAS) without flame in the Laboratory of PPMHP, Gorontalo Province. Without flame atomization performed by passing electrical energy in a carbon rod (CRA - Carbon Rod Atomizer) or carbon tubes (GTA - Graphite Tube Atomizer) having two electrodes. Samples were inserted into the CRA or GTA. Electric current is applied so that the rod or tube becomes hot (temperature rose to high) and elements analyzed will be atomized. The temperature can be set up to 3000 ºC. Heating the sample solution through three stages: 1) drying to evaporate the solvent; 2) ashing, the furnace temperature was raised gradually until decomposition and evaporation of the organic compounds present in a sample in order to obtain salt or metal oxide; 3) atomization. The standard material used is a Certified Raw Material (CRM). The concentration of mercury in the sediment compared with the European Safety Standard. Safety limit value content of mercury in the sediment is 2 mg/kg.

3. Results and discussion

3.1 The general overview of the study site

Artisanal Small-scale gold mining (ASGM) Bumela is one mine site located in the district of Gorontalo. ASGM Bumela known as the "Pertambangan Tangga 2000". ASGM Bumela has been operating since several decades ago. Miners in this location from the local area (district of Gorontalo and vicinity) and from outside the area Gorontalo. The number of miners varies depending on the result of the mine. There are no data on the number of miners. If mining results increases, the number of miners will increase. Conversely, if the mining declined, the number of miners will be reduced. At the time of the survey, the number of miners is ± 150 person. Total operating drum when it is 12 units. In each unit consists of 10 pieces of the drum.

The processing method in the ASGM Bumela is the amalgamation method. Amalgamation is the gold extraction process by mixing gold ore with mercury (Hg). This method uses a round drum so that the material will be crushed and mercury mines will bind gold compounds (Figure 2).

(a) (b)

Figure 2. a) Drum for gold processing; b) Waste gold mining

The interview with one of the miners explained that one drum will grind 5 kg of rock. In one drum will be mixed mercury (Hg) as much as 3 ounces. Processing results will then be squeezed with a cloth. This process aims to separate the mercury from amalgam. Mercury obtained can be reused for the next process. In each processing, the mercury will be reduced 0.1 ounces. End process is burning to vaporize the mercury, so that left only a gold alloy. The average gold produced in the ASGM Bumela is 2.5 grams per drum [9].

3.2 Mercury in the sediment

Sediment sampling carried out at the same location as the location of water sampling. Sediment sampling by variations in depth that is at a depth of 1-20 cm and 20-40 cm. The result of the content of mercury in the sediment analysis are shown in Table 2.

Table 2. The content of mercury in river sediments Totopo, Gorontalo Regency

Sampling Point	The content of Mercury (mg/kg)			Remarks
	Mercury	The average per-point sampling	*European Safety Standard*	
S1.1	30.99	33.545	2	Exceeds
S1.2	36.10			Exceeds
S2.1	67.71	60.59	2	Exceeds
S2.2	53.47			Exceeds
S3.1	31.32	71.005	2	Exceeds
S3.2	110.69			Exceeds
S4.1	68.27	70.74	2	Exceeds
S4.2	73.21			Exceeds
S5.1	104.82	107.295	2	Exceeds
S5.2	109.77			Exceeds
S6.1	117.73	117.195	2	Exceeds
S6.2	116.66			Exceeds

S7.1	104.56	103.905	2	Exceeds
S7.2	103.25			Exceeds
S8.1	107.12	107.425	2	Exceeds
S8.2	107.73			Exceeds
S9.1	34.56	34.535	2	Exceeds
S9.2	34.51			Exceeds
S10.1	58.72	58.615	2	Exceeds
S10.2	58.51			Exceeds
S11.1	42.40	82.9	2	Exceeds
S11.2	40.50			Exceeds
S12.1	79.45	76.295	2	Exceeds
S12.2	73.14			Exceeds
S13.1	77.51	78.005	2	Exceeds
S13.2	78.50			Exceeds
S14.1	53.77	53.585	2	Exceeds
S14.2	53.40			Exceeds
S15.1	16.5	16.6	2	Exceeds
S15.2	16.7			Exceeds
mean	71.36			
SD	31.39			
Max	117.3			
Min	16.5			

Source: results of laboratory analysis, 2018

The results of the study show that mercury content varies with depth. At the sampling point S1 S3, S4, S5, S13, mercury content at a depth 20 – 40 cm was higher than the mercury content at a depth of 10 – 20 cm. The other sampling point (S2, S6, S7, S8, S10, S11, S12), mercury content at a depth of 20 – 40 cm is lower than the mercury content at a depth 10 – 20 cm. At the sampling point S9, S14, S15, mercury content is relatively the same in both depths. This shows that in some locations there has been an accumulation of mercury in sediments.

Comparison charts levels of mercury in the river sediment quality standards European Safety Standard is shown in Figure 3.

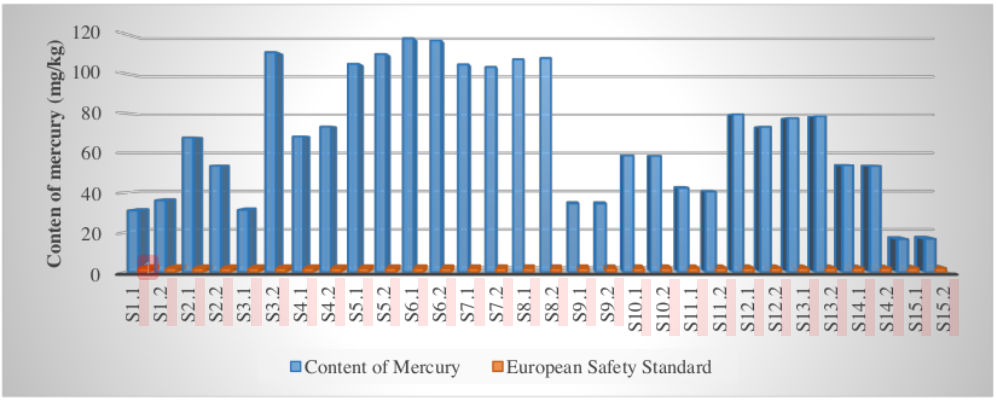

Figure 3. Comparison charts on the mercury content of river sediments with European Safety Standard

Table 3. The content of mercury in the sediment of tailings at the site Bumela ASGM, Gorontalo Regency

Sampling Point	The content of Mercury (mg/kg)			Remarks
	Mercury	The average per-point sampling	*European Safety Standard*	
ST1.1	32.40	26.915	2	Exceeds
ST1.2	21.43			Exceeds
ST2.1	22.77	36.985	2	Exceeds
ST2.2	51.20			Exceeds
mean	31.95			
SD	11.89			
Max	51.20			
Min	21.43			

Source: results of laboratory analysis, 2018

Comparison charts level of mercury content in tailings sediment with European Safety Standard shown in Figure 4.

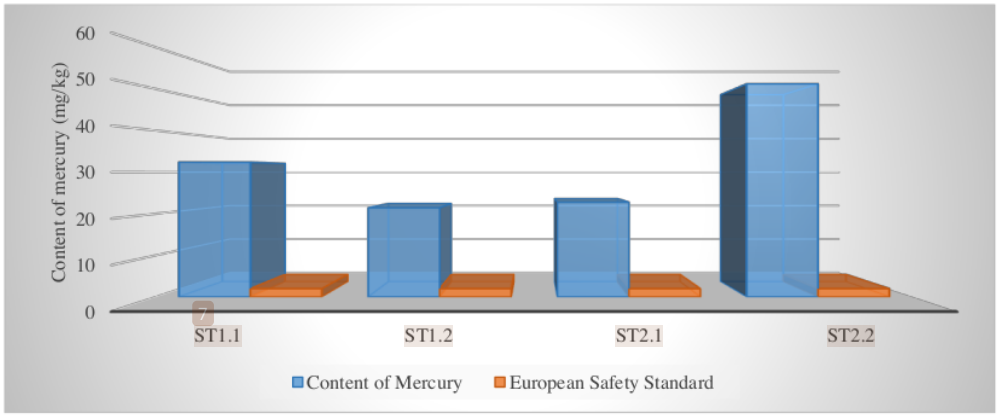

Figure 4. Comparison charts levels of mercury in the sediment of tailings with quality standards European Safety Standard

The results of content analysis of mercury in river sediments Totopo showed that sediment load has exceeded the European Safety Standard. The average content of mercury in river sediments 71.36 mg/kg is higher than the European Safety Standard. Similarly, the content of mercury in ASGM Bumela tailings. The average content of mercury in the tailings is 31.95 mg/kg higher than the European Safety Standard (2 mg/kg). This is due to the process of gold panning in the river Totopo.

3.3 The concentration of mercury in sediments based on the distance from the mine site

The distance of each sampling point of the gold processing site varies (Figure 5).

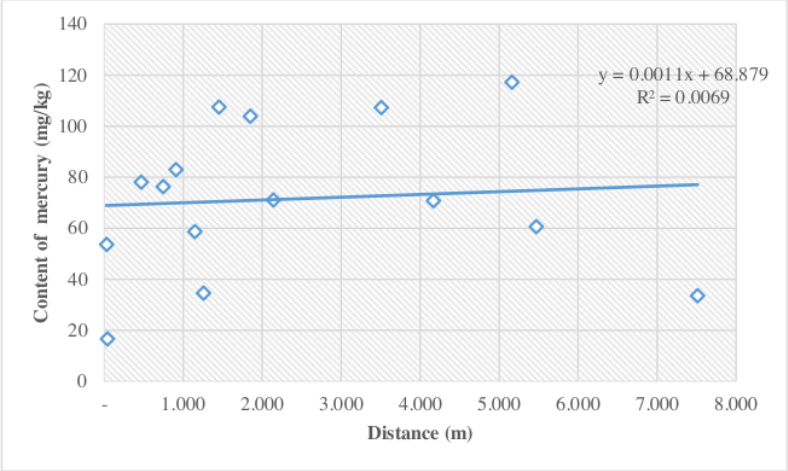

Figure 5. Charts the relationship between the content of mercury in the sediments at a distance from the location of the gold processing

The results showed that the content of mercury in sediment was not affected by distance from the location processing. The only determinant coefficient of 0.0069. Figure 5 shows the highest mercury content is at a distance of 5.159 km of the location processing. This is due to the location to be around buildup tailing will be recycled by the public. On the other hand, the content of mercury in the river Motebo lower than the levels of mercury in the river Totopo (Table 2). The Motebo river is the first river to be the location for the disposal of gold processing waste.

3.4 Discussion

Processing of gold mines in Gorontalo Province in general use mercury. Mercury miners illegally obtain a price of IDR 750,000 - IDR 1,500,000 per kilogram. Results of interviews with miners found that to produce 5 kg of gold from rocks used 85 grams of mercury. After the process, the mercury will be reduced by 2.8 grams. To produce 1 gram of gold, used 20 grams of mercury. After the amalgamation process, 19 grams of mercury released into the tailings and 1 gram evaporate into the air [10]. Mercury in the tailings will be washed away by the water and into a river. Finally, will settle to the bottom of the river. This causes the mercury in the sediment to be high. Several studies on the content of mercury in the sediments indicate that the content of mercury in the sediment has exceeded the quality standard [1,2,5].

The research results obtained ASGM Buru Island in the mercury content of the sediment in the channel leading to the river is 7.31 mg/kg [5]. The content of mercury in the sediments at the ASGM Buladu is 13-17 mg/kg [1]. Mercury in water will be consumed by fish, so it will happen accumulation and biomagnification in fish. Fish are eaten by humans and finally, Mercury bioaccumulation will occur in the human body.

If the terms of the processing locations within the mine with a mercury content of mercury showed that the distribution pattern is not dependent on the distance of the source of the pollutants. Mercury distribution pattern is influenced by several variables, including variable geochemical and hydrological systems. Deposition of mercury in the river affected by the water flow characteristics and the physical condition of the riverbed [11].

The solution to overcoming the problem of the use of mercury in gold mining must be done comprehensively. Some of the strategies that can be done are to educate miners. Educational materials in the form of environmental health, the alternative method in mining processing. Some techniques reduced mercury releases including retorts, mill leaching, vat-leaching, and others replaced mercury

from the process such as magnets, direct smelting, sluices, and borax [3,12,13]. Clean Tech Mine has been applied in Artisanal and Small-scale Gold Mining (ASGM) by the natives of Mozambique. Application of Clean Tech Mine is an innovative and inexpensive practice in mining activities [14]. Phytoremediation is one method that can be done to overcome the problem of mercury pollution in the environment [15,16].

4. Conclusion

Activity Artisanal Small-scale Gold Mining (ASGM) in the village of Bumela, District Totopo, Gorontalo Regency has resulted in environmental pollution. One indicator is the mercury content in the river sediment. The average content of mercury in the sediment was 71.36 mg/kg. The average content of mercury in the tailings is 31.95 mg/kg. The content of mercury in river sediments and tailings Totopo is above the quality standard of European Safety Standard.

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