Artisanal small-scale gold mining activities in Banyumas Regency, Indonesia and its mercury waste potency

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Artisanal small-scale gold mining activities in Banyumas Regency, Indonesia and its mercury waste potency

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Abstract. There are indications that Artisanal Small-Scale Gold Mining (ASGM) in Banyumas Regency is still using mercury for gold extraction. Mercury is a persistent and toxic compound for numerous organisms and human health. This research aims to describe the gold processing using mercury in Banyumas Regency based on an investigation in the location of the mining site and gold processing site. Further, monitoring the mercury level in several places was also conducted, such as water drain at gold mining area in Ajibarang District, Tajum River water, mercury waste reservoir and well water in the gold processing area, and water from processor lavatory. Our investigation showed that the extraction process takes place in a gold processor located in a populated area. Gold mercury amalgam is separated from the remaining mercury during this process, and the mercury waste is collected in a mercury waste reservoir. Usage of mercury must be a concern for gold processors and the local government because the Indonesian government is targeting that by 2025, ASGM will no longer use mercury-based on the National Action Plan for Reduction and Abolishment of Mercury Use. Furthermore, mercury levels from mercury waste reservoirs exceeded the quality standard according to Government Regulation No. 82 of 2001, and the Regulation of the Minister of Health No. 32 of 2017, reached 673 ppb. It was because the sampling location was directly linked to the main activity of gold processing. However, attention and effort are required to treat mercury waste in reservoirs not to pollute groundwater in the future. Furthermore, several strategic programs are necessary to implement good traditional gold mining under government monitoring.

Keywords: ASGM; Banyumas; mercury waste; National Action Plan for Reduction and Abolishment of Mercury Use

1. Introduction

Artisanal and small-scale gold mining (ASGM) is a broad term that refers to any type of informal gold mining. This sector is responsible for 15 to 20% of global gold production, which provides the livelihood for approximately 10 to 15 million people in 70 countries. Balifokus estimated there are 800 ASGM sites in Indonesia with approximately 250.000 miners involved directly in mining operations with the gold production of about 40 to 60 tons of gold annually [1].

Banyumas regency, Central Java Province, Indonesia, has many ASGM sites that are still operating today [2]. According to geological research, primary gold is hosted in low-sulfide epithermal ore bodies with base metal sub-types of sulfide and carbonate associations (calcite and ankerite). Since abundant gold resources are found in and around the mining villages, local people are drawn to gold mining and use it as their primary occupation. However, the minimum capital and limitation of education regarding mining techniques, rudimentary techniques, poor technology, and labor-intensive, insufficient training have created new environmental and health issues, particularly mercury exposure [1].

One of the technologies for the extraction of mercury is using mercury. Mercury-based artisanal and small-scale gold mining is the main source of anthropogenic mercury emissions. It contributes to about 37% of global mercury pollution [3]. In addition, the amalgamation process, tailings processing, and gold recovery generate a significant amount of mercury into the environment [4]. Mercury is a persistent and toxic compound that may be mobilized from polluted environments into numerous organisms. Mercury exposure has been proven to have an adverse impact on human health.

The Indonesian government ratified the Minamata Convention by issuing Law Number 11 of 2017 regarding mercury prohibition. The purpose of ratifying the Minamata Convention is to provide a legal basis for issuing laws and policies to preserve the environment, maintain human health, and protect future generations from the harmful effects of mercury. Later the Government of Indonesia released Presidential Regulation Number 21 of 2019 concerning the National Action Plan for Reduction and Abolishment of Mercury Use in an attempt to minimize mercury emissions in the environment. It targets that by 2025 ASGM will no longer use mercury.

This research aims to describe the gold processing using mercury in Banyumas Regency based on investigation in the location of mining site and gold processing site. Further, monitoring the mercury level in several locations was also conducted, such as water drain at gold mining area in Ajibarang District, Tajum River water, mercury waste reservoir and well water in the gold processing area, and water from processors lavatory.

2. Materials and Methods

2.1. Research method

This study consists of two parts, quantitative and qualitative approaches, to answer the objectives of this study. First, depth interviews with miners and gold processors were conducted to get information on the gold processing in ASGM. Further, the water samples were collected from several locations to obtain mercury concentration. This survey was conducted in December 2020.

2.2. Site description

To know the gold processing using mercury, we investigated the process of Underground Pit Mining in Ajibarang District and the extracting and refining of gold in Kedungbanteng District, Banyumas, Central Java. In addition, we conducted personal communication with the miner and gold processor. The sampling site is shown in Figure 1.

2.3. Water sample collection

Water sampling was conducted to characterize the presence of mercury level in water drain at gold mining area in Ajibarang District, Tajum River water, mercury waste reservoir, well water, and water from processor's lavatory in the gold processing area. Tajum River was chosen based on depth interview with a miner that mining waste from the mining site was discharged into the river system. Samples were collected in quartz bottles and preserved using 0.05 N of nitric acid, screw-capped, and stored at 5 °C.

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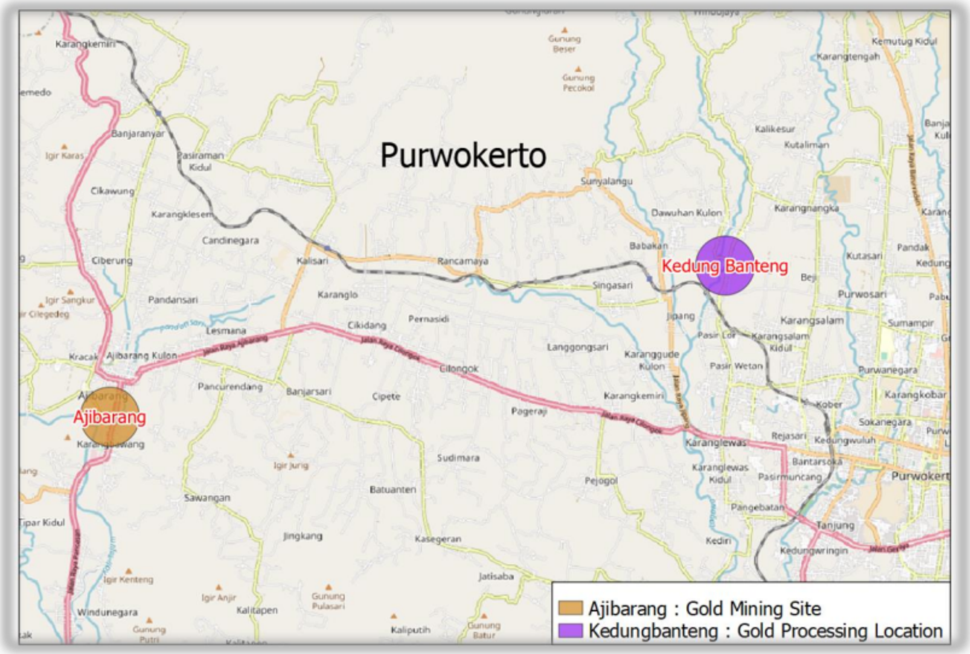

Figure 1. Locations of mining site and gold processing site

2.4. Mercury analysis

The analytical method for total mercury analysis was adapted from Standard Methods APHA 3112 B and EPA/SW-864 Methods 7471A for water samples. Prior to analysis, samples were filtered using a Millipore membrane filter of 0.45 µm. Precise volume of 100 mL of sample was pipetted to 250 mL Erlenmeyer flasks, then 5 mL of concentrated sulfuric acid and 2.5 mL of concentrated nitric acid were added. 15 mL of potassium permanganate solution was added to the mixture, let stand for 15 minutes, then heated in a water bath at 95 °C for 2 hours. After cooling to room temperature, a hydroxylamine-hydrochloride solution was added dropwise to reduce the excess of permanganate. Sample solutions are then reduced with 25 % (w/v) stannous chloride in an acidic solution to generate the mercury vapor and finally be measured using the atomic absorption instrument (AAS Agilent duo system). All the calibration solutions were treated similarly to the samples.

3. Results and Discussion

3.1. Gold processing activity in Banyumas Regency

Since 2000, gold mining in Banyumas has been growing, with the peak occurring between 2008 and 2010 [5]. Mostly, the investors and miners come from outside the region. Due to limited education, miners in the Ajibarang district in Banyumas Regency work without regard for occupational safety and health protocols. For example, in determining the location of the mine site, miners frequently rely only on their reasoning logic. Mining wells are dug approximately 26 meters vertically and more than 50 meters horizontally in the mining stage. Around the wall of mining well only construct by timber base, they believe this attempt is being made to prevent land collapse. As well know, the deeper site, the more acidic gas produced, which can be deadly to inhale. Therefore, most mining wells are equipped with an oxygen channel. A similar thing was reported by Musluhuddin *et al*. [6][7]; a blower is placed into the mining well to supply the oxygen availability. The blower is switched on for 1-2 hours through the compressor before the miner enters the mining well.

Mining products are manually mashed by hand. The mining materials are subsequently gathered, and gold is extracted using mercury. The gold extraction principally uses the whole ore amalgamation technique in the study area. The gold extraction is not in the same district as the ASGM location. The rocks are grinding in the trammels to get fine-grained. Fine-grained still grinding followed by inserting mercury into the trammels during the amalgamation process. The mercury-gold mixture is filtered using a cloth to separate mercury from the gold. The amalgam ball is then burned to remove any remaining mercury. According to UNIDO and UNEP [8], whole ore amalgam is regarded as a poor technique because it is inefficient to capture gold. It rarely captures more than 30% of the gold and releases large quantities of mercury. In the high ratio of mercury used to capture the gold up to 4:1, very high ratio up to 20:1 and extreme high reach 50:1. Because mercury is too dispersed to capture. Hence most mercury used is lost to the environment in the form of floured mercury. Figure 2 shows gold processing in Banyumas based on information from the gold processors.

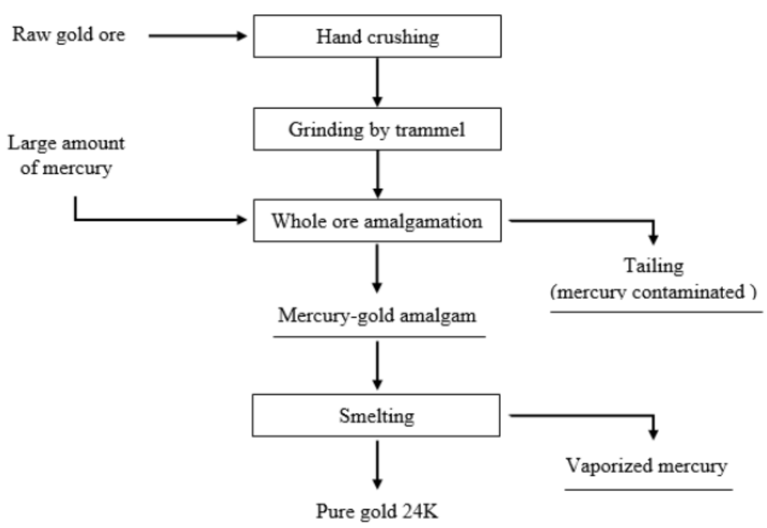

Figure 2. Scheme of gold processing (Modified from Yoshimura [9])

3.2. Mercury concentration in water samples

Based on the monitoring results, there is mercury contamination in the processor's lavatory, well water, river water, water drain, and waste reservoir (Table 1). The highest Hg concentration was obtained from wastewater in the waste reservoir up to 673.429 ppb. It exceeded the Government Regulation No. 82 of 2001 and the Regulation of the Minister of Health No. 32 of 2017. Based on these regulations, Mercury quality standards in Class II river water and groundwater are 2 ppb and 1 ppb, respectively. Worse yet, Hg content has adsorbed into the soil contaminating well water. However, Hg concentration in well water was 0.497 ppb, which means the mercury did not pollute the well water. Gold processor covers the waste reservoir with a plastic layer so that mercury does not pollute the soil. The mercury concentration in the water drain and processor's lavatory was up to 0.417 ppb and 0.314 ppb, respectively. The lowest Hg concentration was 0.289 ppb from river water. Mercury was found in low concentrations in the water drain and Tajum River because ASGM carries out no gold extraction process. Therefore, natural sources may cause the presence of mercury in low concentrations.

Table 1. Monitoring of Hg concentration

Area	THg Concentration (ppb)	Mercury Quality Standard
Processor's lavatory	0.314	1 ppb[1]
Well water	0.497	1 ppb[1]
Tajum River	0.289	2 ppb[2]
Water drain	0.417	2 ppb[2]
Waste reservoir	673.429	1 ppb[1]

[1] Regulation of the Minister of Health No. 32 of 2017, environmental health quality standards for water media for sanitary hygiene needs.
[2] Government Regulation No. 82 of 2001, quality standard in Class II river water.

Previous studies have also reported several cases of mercury contamination as the impact of ASGM activities in Banyumas from 2012-2019 (Table 2). In 2012, there was 37.3 ppm mercury suspended in mining wastewater. The waste is known to be the first disposal after the amalgamation process. The concentration of Hg decreases as the water flow moves before forming tailings sediment. It is known that mining waste from ASGM in the form of sediment has a lower mercury content of 0.197 ppm (data not shown) [10]. In addition, other cases were reported that Hg from tailings also pollutes other parts of the environment, such as groundwater (0.0001 – 0.0002 ppm), river water (0.0001 – 0.0002 ppm), river sediment (0.012 – 0.178 ppm), and soil (2.415 – 26.821 ppm) [1]. Muryani *et al.* [11] also found Hg pollution in groundwater, ranging from 0.00013 to 0.00184 ppm.

Budianta *et al.* [12] performed sustainability studies that revealed substantial amounts of mercury in amalgam balls were disposed of during the squeezing process. When significant amounts of mercury are utilized, it influences mercury removal from the environment. According to [13], fine particles are settled in sediment during the streamflow slows. As a result, Hg from gold mining regions bonds to suspended particles and travels downstream until it reaches better settling conditions. The fact that THg concentrations in river sediment were more significant than those detected in river water and soil [14] might support the hypothesis of Hg deposition.

Chronic toxicity was defined as the small and repeated doses of mercury in long-term exposure. Human hair is often used as a biomarker for methylmercury intoxication. It is because hair assessment reflects the Hg concentration in human blood simultaneously. Based on the study by [10], people living in Cihonje village had positive responses to mercury intoxication. Hg concentration in hair of people living in non-gold mining area = 3.97 ng/mg, whereas gold mining area = 5.40 ng/mg. ASGM activities significantly affected mercury in human bodies, especially the local Cihonje who live near the ASGM area. This is because they consume water from the Tajum River for daily needs, including irrigation, bathing, and washing. Some of the symptoms of acute mercury toxicity caused are insomnia, stomach aches, and diarrhea. Meanwhile, people who live far from the ASGM area usually feel pain in the motor organs, headaches, and difficulty breathing.

Physical damage due to ASGM activities was also reported to have occurred at several points in Banyumas Regency. Mining dug and the disposal of tailings in the surface land may reduce the vegetation growth in the soil. The longer the proposition of gold mining goes, the more land is covered with tailings which causes infertility in the soil while challenging to cultivate. Furthermore, the digging of mining wells is not paying attention to the site of the mining well opening and the threats to infrastructure and land. Several wells can be found on the same plot of land. As a result, many mining wells are located in the middle of settlements or along highways, causing harm to land and infrastructure [6]. Several other possibilities related to geological threats due to ASGM activities, such as the occurrence of intensive erosion resulting from mining sand from alluvial deposits around rivers and landslides on slopes near the opening mine and mine wells.

Mercury waste in reservoirs should be handled to prevent environmental pollution. Several alternative technologies of mercury waste treatment options are available (Table 3).

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Table 2. Monitoring of Hg Concentration in Banyumas Regency

Sampling Year	Sampling Area	Gold Ore (ppm)	Tailing (ppm)	Groundwater (ppm)	River Water (ppm)	River Sediment (ppm)	Soil (ppm)	Author
2012	Gumelar District, Banyumas Regency		37.3		27×10^{-5}			[10]
2016	Banyumas Regency		0.148 to 0.186	0.0001 to 0.0002	0.0001 to 0.0002	0.012 to 0.178	2.415 to 26.821	[1]
2017	Gumelar District, Banyumas Regency				2.46×10^{-6} to 27×10^{-6}			[3]
2019	Ajibarang District, Banyumas Regency			0.00013 to 0.00184				[11]
2019	Gumelar District, Banyumas Regency	0.008	10.138		1.003	9.747		[12]
2019	Gumelar District, Banyumas Regency	0.008	10.138				(0-20 cm) = 8.7 (40-60 cm) = 5.8	[14]

Table 3. Mercury waste treatment technologies

Type of Processing	References
Integrated artificial wetlands with Phragmites australis plants and microbes in compost	[15]
Initial treatment includes neutralization, clarifier, tertiary mercury removal, and sludge treatment.	[16,17]
Solidification and stabilization	[18]
Flue gas cleaning residues	[17]
Land washing	[19]
Thermal processing	[19]
Biological processing	[19]

3.3. Recommendation

ASGM should follow the guidelines set out by the government. Based on Presidential Regulation Number 21 of 2019 concerning the National Action Plan for Reduction and Abolishment of Mercury Use, by 2025, ASGM will no longer use mercury. Governments and organizations introduce several goodwill initiatives well, including educational intervention, mercury-free technology, processing centers, culture community dynamics and collaborations, and government support [20]. The educational intervention focuses on theory classes, demonstrations, and implementation of clean technology training programs (gravity concentration, flotation, and cyanide). This activity is designed to raise awareness of the hazards of mercury among miners [21]. In addition, the Ministry of Environment and Forestry (KLHK) started a program to provide economic transformation management facilities for gold miners in Banyumas who still use mercury in 2018-2019. As a result, it is anticipated that the gold miners would be able to find work in industries other than mining, such as tourism or waste recycling.

Several strategic programs can be carried out to develop gold miners and processors in Banyumas, including (a) Implementing socialization and education on mining management that poses minimal risk to the environment and workers' health; (b) Implementing socialization regarding the procedures for the gold mining process in accordance with occupational health and safety rules; (c) Supervision and control to ensure that existing artisanal gold miners and processors are not exploited. (d) Introducing a better alternative profession than being mercury miners and processors; (e) Improving institutions in traditional gold mining management.

4. Conclusions

The ASGM location and the gold extraction are not in the same district in Banyumas Regency. The gold extraction is principally using mercury in the whole ore amalgamation technique. Based on the monitoring results, several locations in ASGM and the gold extraction in Banyumas Regency, including of water drain, Tajum River water, mercury waste reservoir, and well water indicated mercury contamination. Mercury concentration in waste reservoir exceeded quality standard based on Government Regulation No. 82 of 2001 and the Regulation of the Minister of Health No. 32 of 2017. The mercury level on the waste reservoir reached 673 ppb. Mercury can be treated by using several technologies, such as remediation, stabilization and solidification, and soil washing. Several strategic programs are required to implement good traditional gold mining. However, the government should introduce and monitor miners and gold processors to implement these strategic programs.

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Declarations

Author contribution
Ajeng Arum Sari contributed as the main contributor of this paper. All authors read and approved the final paper.

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