Effects of Small-Scale Gold Mining (SGM) to Mercury and Nutrient Contents in Soil in Kokap Subdistrict, Kulonprogo, Yogyakarta

Rika Ernawati[1], Tedy Agung Cahyadi[2], Shahensah Anand Anggian Rambe[3]

[1,2,3] Universitas Pembangunan Nasional "Veteran" Yogyakarta, Indonesia

Abstract

Gold processing in *Dusun* Sangon, Kalirejo Village, Kokap Subdistrict, Kulonprogo Regency, Special Region of Yogyakarta Province uses amalgamation method. Mercury use in gold processing has a potential impact on environmental damage and health of organism. Therefore, management on mercury-contaminated soil is needed to reduce environmental impacts. However, before performing soil management, it is important to conduct research on initial condition of research location, including research on the soil's nutrient quality and mercury content. Testing was conducted in the laboratory. Mercury (Hg) content testing used mercury analyzer testing method. pH testing used ISRIC 6th 2002 method. Organic carbon testing used SNI 13-4720-1998 testing method. Total nitrogen testing used SNI 2803-2010 testing method. C/N Ratio testing used SNI 13-4720-1998; SNI 2803-2010 testing methods. Results show that mercury contents in residual samples of gold ore and soil samples were 4.81 mg/kg and 88.63 mg/kg respectively, which were included in TC-B and TC-A in the aforementioned order. Meanwhile, mercury content in gold ore Samples 1 and 2 were 0.28 ppm and 0.14181 ppm respectively. Soil nutrient content parameters of Organic C, Total N, and C/N ratio were found to be very low. These results might be influenced by processing activities in gold ore mining.

Keywords: Small-scale gold mining, Mercury, Nutrient, Soil

INTRODUCTION

In Indonesia, there are 713 locations of small-scale gold mining, spreading across Java, Sumatera, Kalimantan, and Sulawesi and employing approximately 60,000 people (Aspinall, 2001). Gold mining business in Kokap region has taken place for decades, starting from the discovery of quartz veins containing gold at Sangon and its surroundings by traditional gold miners from Tasikmalaya (Setiabudi, 2005).

Gold mining in *Dusun* Sangon, Kalirejo Village, Kokap Subdistrict, Kulonprogo Regency, Special Region of Yogyakarta Province uses amalgamation method with mercury. Mercury is toxic heavy metal considered as one of ten primary chemicals which become primary environmental concern (WHO, 2017). Mercury usage in gold mining has potential impact on environmental damage and health of organism. Mercury in environment comes from two main sources: geogenic and anthropogenic, and has toxicity nature (Marrugo*, et al.*, 2015).

Gold mining activities in many developing countries which uses amalgam technology causes significant mercury pollution in soil and bodies of water; this serious problem of mercury pollution also happens in developed countries (Li*, et al.*, 2015; Cordy*, et al.*, 2011; Drace*, et al.*, 2012; Krisnayanti*, et al.*, 2012). According to several studies, mercury-contaminated soil has caused significant threats to water supply, which in turn will affect agricultural output quality (Horvat*, et al.*, 2003; Qiu*, et al.*, 2005). Therefore, mercury-contaminated soil needs to be managed to reduce its environmental impact. However, before performing management on the contaminated soil, it is important to conduct research on its initial condition, including its nutrient quality and mercury content. The research results can then be used for consideration in choosing methods used for remediation of the contaminated soil.

RESEARCH AREA

This study was conducted at one of small-scale gold mines at *Dusun* Sangon, Kalirejo Village, Kokap Subdistrict, Kulonprogo Regency, Special Region of Yogyakarta Province. It is located approximately at 50 km west to the City of Yogyakarta, at UTM 49 M 396664 m E 9133375 m S (Figure 1). The research location has tropical climate, with drought and rainy season occurring alternately from May to October and from November to April respectively. The research area has an average rainfall of 1430 mm per year, with average rainy days of 12 per month. Highest rainfall occurs in January (689 mm; 18 rainy days). The research area has slope steepness between 25% and 40%. The regional geology of the research area is included in old andesite formation, shown in the center, north, west, and southwest of the area. The constituent lithology consists of andesite breccia with matrix of sandy tuff. Fragments consist of pyroxene andesite to andesite and horblende (Bemmelen, 1949).
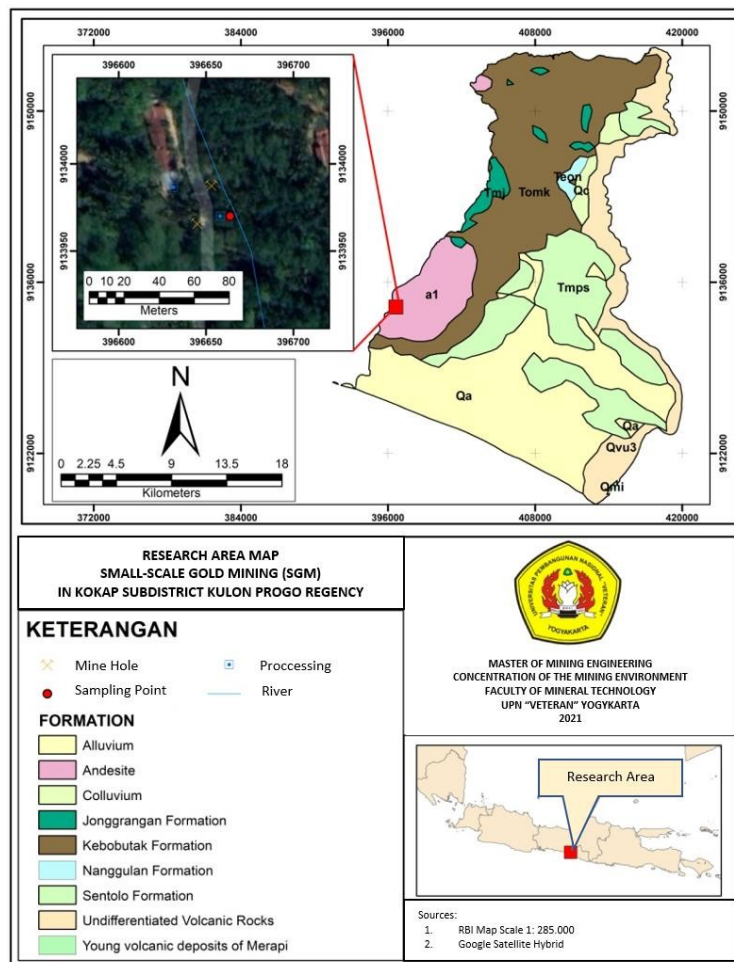

Figure 1. Research Area Map

RESEARCH METHODOLOGY

This research was conducted with purposive sampling method by taking soil samples in areas or points that allow proper representation of research location. This was done by taking two samples, consisting of sample of gold ore processing residue and soil sample from the gold processing area. Soil sampling referred to SNI 8520:2018 on the way of collection of solid hazardous and toxic (H&T) waste. Soil samples were taken from 15 cm below soil level by using stainless steel hand auger (Figure 2). Then, mercury (Hg) testing was conducted by using mercury analyzer method at Integrated Research and Testing Laboratory (LPPT) of Universitas Gadjah Mada, while testing on pH (with ISRIC 6th 2002 method), organic carbon (with SNI 13-4720-1998 method), total nitrogen (with SNI 2803-2010 method),

and C/N ratio (with SNI 13-4720-1998 and SNI 2803-2010 methods) were conducted at dilakukan di Center for Environmental Health Engineering and Disease Control (BBTKLPP) of Yogyakarta.

Figure 2. Soil Sample Collection

RESULTS AND DISCUSSION

Mercury content in gold mines in Sangon

Testing was conducted on two samples: sample of gold ore processing residue and soil sample by analyzing their mercury content in laboratory through mercury analyzer. The results were used to understand soil condition after gold processing with amalgamation method. Mercury content testing results were compared to the standard value of toxic characteristics through total concentration for defining the ways of management of soil contaminated with hazardous and toxic waste. The results are presented in Table 1. There are three standard values of toxic characteristics pursuant to Appendix XIII of Government Regulation No. 22 of 2021 on the Implementation of Conservation and Management of Environment as follows:

1. Should pollutant concentration found to be greater than Total Concentration "A" (TC-A), the polluted soil is managed in accordance with Category 1 of H&T Waste Management, which includes H&T waste with acute and direct impacts to humans and confirmable negative impacts to environment.
2. Should pollutant concentration found to be similar to or lesser than TC-A and greater than Total Concentration "B" (TC-B), the polluted soil is managed in accordance with Category 2 of H&T Waste Management, which includes H&T waste with delayed effects, indirect impacts to humans and environment, and sub-chronic or chronic toxicity.
3. Should pollutant concentration found to be similar to or lesser than TC-B and greater than Total Concentration "C" (TC-C), the polluted soil is managed in accordance with non-H&T Waste Management, which is non-H&T waste with no technical agreement, so that all technical standards are listed in environmental agreement.

Table 1. Mercury contents in sample ore residue and sample soil

Samples	Hg contents	Unit	Testing method	Standard value (mg/kg)		
				TC-A	TC-B	TC-C
Ore residue	4.81	mg/kg	Mercury analyzer	300	75	0.3
Soil	88.63					

Source: Lab testing results (2021)

Mercury contents in sample ore residue and sample soil were measured to be very high, amounted to 4.81 mg/kg (TC-B) and 88.63 mg/kg (TC-A) respectively, in accordance with definition of management of soil contaminated with H&T waste pursuant to Appendix XIII of Government Regulation No. 22 of 2021 on the Implementation of Conservation and Management of Environment.

Mercury content in gold ores in Sangon

Mercury content in gold ores in Sangon was obtained from literature study on research by Sumarjono, *et al.* (2019) on the mercury content in gold ores in Sangon. The results of this research were used to understand mercury content in gold ores before gold processing with amalgamation method as found in sub IV.1 was conducted. The researchers conducted testing on two samples of gold ores collected at the research area, which were called Gold Ore Sample 1 and Gold Ore Sample 2. The results of research by Sumarjono, *et al.* (2019) are shown in Table 2.

Table 2. Testing results of mercury content in gold ore

Parameter	Unit	Samples		Testing method
		Gold Ore 1	Gold Ore 2	
Hg	ppm	0.28	0.14181	Mercury analyzer

Source: Sumarjono, et al. (2019)

The results showed that mercury contents in gold ore Samples 1 and 2 were 0.28 ppm and 0.14181 ppm respectively. Sangon gold ores have mercury content closely related to their mineralization process during magma differentiation process.

pH, Organic Carbon, Total Nitrogen, and C/N Ratio values
Testing was conducted on two samples: sample of gold ore processing residue and soil sample by laboratory analysis. Testing results were used to understand pH level of both samples and the soil sample's nutrient content after gold processing with mercury was conducted. The values of respective parameters were classified based on the results of research by Soil Research Center of the Department of Agriculture (1983). Classification results were used as guidelines in conducting the appropriate soil quality improvement and soil remediation to reduce mercury pollution impacts to the environment. Testing results show that pH level of gold ore residue was 8.05 which was considered neutral to slightly alkaline while soil pH level was 7.42 which was considered neutral. Organic-C content in both samples were considered very low, amounted to 0.30% in gold ore residue sample and 0.36% in soil sample. Mustofa (2007) in his research stated that organic matter content in soil in form of organic-C should be maintained at not less than 2%, so that organic matter content in the soil does not decrease over time due to mineralization decomposition process. Meanwhile, total-N content in both samples were

considered very low, amounted to 0.06%. Results of pH level and soil nutrient content testing are presented in Table 3.

Table 3. Results of testing of pH level and organic-C, total-N, and C/N ratio parameters of soil nutrient content

Parameters	Unit	Samples		Testing method
		Ore residue	Soil	
pH	-	8.05	7.42	ISRIC 6th 2002
Organic carbon	mg/kg	3022.71	3632.31	SNI 13-4720-1998
Total nitrogen	mg/kg	618.682	627.038	SNI 2803-2010
C/N ratio	-	4.886	5.793	SNI 13-4720-1998; SNI 2803-2010

Source: Lab testing, 2021.

Decrease in pH level and organic matter content causes low activity of soil microbes. Soil microbes have important functions in providing nutrients for plant survivability. Soil nutrient content, with parameters of organic-C, total-N, and C/N ratio were found to be very low. This could be influenced by the processing activities on gold ore mining site which uses amalgamation method (Mulyani, *et al.* 2021; Naiola 1997; Zulfikah, *et al.* 2014), so that mercury waste, the processing's residue, was collected in the tailings pond which previously came into contact with the surrounding environment of the mining site, such as soil, water, and air. Mercury impacts on soil were shown in the soil quality decrease which influenced soil nutrient parameters.

One of the most important aspects in total soil nutrient balance is the ratio of organic carbon to nitrogen (C/N ratio). The C/N ratio of organic matter is the comparison between the number of carbon (C) content and the number of nitrogen (N) content present in an organic matter. Based on the results, it is suggested that soil remediation uses phytoremediation method by combining several additives such as biochar and compost to improve nutrient quality and reduce mercury content in soil (Hidayat, 2015; Hamzah, 2012; Lestari, 2020).

CONCLUSION
Based on the research results, it can be concluded that:
1. Mercury contents in gold ore residue and soil samples were 4.81 mg/kg (TC-B) and 88.63 mg/kg (TC-A) respectively.
2. Mercury content in gold ores were significantly small compared to the result of mercury content testing on soil after gold processing activities, amounted to 0.28 ppm and 0.14181 ppm in gold ore Samples 1 and 2 respectively.
3. Gold ore residue sample pH level was 8.05, considered neutral to slightly alkaline, while soil sample pH level was 7.42, considered neutral. Organic-C content in gold ore residue and soil samples were found to be characteristically very low, amounted to 0.30% and 0.36% respectively. Meanwhile, total-N content in gold ore residue and soil samples were found to be very low, amounted to 0.06%. The results show the reduction of soil quality due to gold mining activities.

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