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Carrying Capacity of Mercury Pollution to Rivers in the Gold Mining Area of Pancurendang Village, Banyumas

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Abstract

Wastewater from small-scale gold processing is causing mercury contamination in the river. It is important to know the estimation of the carrying capacity of river pollution due to mercury to support the improvement of the river ecosystem. The research objective was to calculate the load capacity of mercury pollution (Hg) in rivers around the gold mining and processing area of Pancurendang Village, Ajibarang District, Banyumas Regency, Central Java. The research begins with river discharge measurements. River discharge is measured by referring to SNI 8066: 2015. Water sampling was carried out at 12 river points with a purposive method that took into account the location (upstream, middle, downstream) and river characteristics, according to SNI 6989-78: 2008. Actual mercury levels in river water were tested at the UGM Integrated Research and Testing Laboratory (LPPT) with Mercury Analyzer. The results of the mercury and discharge levels are used to calculate the actual pollution load. The maximum pollution load is based on the quality standard of mercury in class 2 rivers, namely 0.005 ppm multiplied by river discharge. The load capacity of mercury pollution is obtained from the difference between the maximum pollution load and the actual pollution load. The results of river discharge measurements at the research location are quite varied, ranging from 0.0024-2.925 meters/second. The results of the calculation of the carrying capacity of mercury pollution loads in the river area around the gold mining and processing of Pancurendang Village show a range of 0.0000048-0.005904 kg/day with an average of 0.001325948 kg/day. The capacity of the river in Pancurendang Village has not exceeded its capacity.

Keywords: pollution load, environmental carrying capacity, gold mining, mercury pollution, rivers

I. INTRODUCTION

There were small-scale gold mining activities in Indonesia in 2001, with a total of 713 locations spread across Java, Sumatra, Kalimantan, and Sulawesi, with 60,000 individual and group miners (Aspinall, 2001). In 2010, this number increased to 900 locations, with 250,000 miners (Ismawati, 2010). Most of these mining activities are unlicensed and use mercury in gold processing. Traditional gold processing, including in Columbia, generally uses amalgamation techniques, namely by mixing

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gold-containing ore with mercury to form amalgam in water media (Betancur-Corredor, Loaiza-Usuga, Denich, & Borgemeister, 2018). The gold processing business using mercury should not dispose of its waste (tailings) into the river flow so that there is no mercury contamination in the surrounding environment, but in reality, many small-scale traditional gold miners dispose of wastewater from gold processing directly into the surrounding rivers. The environment contaminated by mercury can endanger the health and lives of other human beings due to the entry of mercury in the food chain (Pratiwi & Ariesyady, 2012).

The liquid waste from amalgamation, which is discharged into the environment, will partially seep into the ground and partially flow above the soil surface into ditches and end up in rivers and empties into the sea (Chen, Huang, Li, & Chen, 2019). Liquid waste that seeps into the ground can potentially contaminate groundwater (Putra, Sungkowo, & Muryani, 2019). Several previous studies have investigated mercury concentrations in gold processing wastewater (Sumual, 2009), rivers, and river sediments (Subanri, 2008). Some have researched the pollution load on rivers (Rahayu, Juwana, & Marganingrum, 2018) but not specific to mercury. The research objective was to calculate the load capacity of mercury pollution (Hg) in rivers around the gold mining and processing area of Pancurendang Village, Ajibarang District, Banyumas Regency, Central Java. The results of this study are expected to know how much mercury is allowed to enter the environment, especially rivers. The data input related to the load capacity of mercury pollution in this area is hoped to be used as a consideration in determining environmental pollution control efforts so that the water quality standards set by the government can still be met.

II. LITERATURE REVIEW

Small scale gold mining in Pancurendang Village as the research object uses mercury in the process of separating gold from rock. This mining has been carried out by residents since 2016 until now using the underground mining method in the form of vertical wells. Mining activities are carried out in the area on the banks of Sungai Datar and Sungai Tajur, which are adjacent to the rice fields of the surrounding community. Gold processing activities are carried out around residential areas (Muryani, Hudawan, & Rahmah, 2020). The following is an overview of gold processing activities in Pancurendang Village, Banyumas Regency.

Figure 1. Gold Processing in Pancurendang Village Using Pound, Gelundung, and Mercury Tools (Muryani, Hudawan, & Rahmah, 2020)

Mercury (Hg) is a pollutant produced from human activities or purely from nature that can bioaccumulate so that it affects the environment and human life. Mercury can change its chemical composition due to the environment and the process of moving from one place to another, which eventually gets deposited in basins along with other sedimentary materials (Kumari, Amit, Jamwal, Mishra, & Singh, 2020). Mercury is a global pollutant and is a very toxic metal, which means it can hurt human health and the environment. Mercury, from mining activities that are released directly into water bodies, is deposited in the soil or river sediments (Verma, Sankhla, & Kumar, 2018). Based on the Hazardous and Disease Agency, mercury occupies the third position in the three most dangerous substances (Kumari, Amit, Jamwal, Mishra, & Singh, 2020).

The carrying capacity of the aquatic environment is defined as the maximum pollutant that can be accepted by surface water without reducing the function of the water and can meet the quality of water for certain needs (Yan, Gao, Li, & Gao, 2019). Pollution Load is divided into two parts, namely the Maximum Pollution Load (BPM) and the Actual Pollution Load (BPA). The maximum pollution load is obtained by multiplying the river discharge with the concentration based on the applicable quality standard, while the measured pollution load is obtained by multiplying the river flowrate with the concentration of the measurement results. The results of the BPA are then compared with the results of the BPM as a quality standard for pollution load. If the results from the BPA are greater than the BPM, it can be ascertained that the river can no longer accommodate the pollutant load (Sampe, Juwana, & Marganingrum, 2018). Class 2 surface water quality standards are pH 6-9, and mercury (Hg) of 0.002 mg / L refers to Government Regulation Number 82 of 2001 concerning Water Quality Management and Water Pollution Control.

In Mahmud's (2012) research on a model of the temporal-spatial distribution of mercury concentrations due to traditional gold mining as a basis for monitoring and evaluating pollution in the Tulabolo River ecosystem, Gorontalo Province states that at low discharge (dry season), mercury concentrations are good in basic sediments, floating sediments, and very high water. Aswadi's (2012) research results related to the Mercury Pollution Control Model due to People's Gold Mining in the Poboya River, Palu City, states that heavy metals Cd, Pb, and Hg were detected at all stations. Water quality at upstream stations is generally worse than downstream. Subanri (2008), in his research on the study of mercury (Hg) pollution load on the water of the Menyuke River, Landak Regency, West Kalimantan, found that the average Hg content in water was 0.5334 ppb. The study said that there was no correlation between distance and Hg levels in the Menyuke River water.

III. RESEARCH METHODOLOGY

The main data for calculating the pollution load in river discharge and mercury levels in river water. The research begins with river discharge measurements. River discharge is measured by referring to SNI 8066: 2015. River discharge measurements were carried out at 12 points in July 2020 (dry season). Flow measurement includes the process of measuring current velocity using a current meter, depth, and width of the flow and calculating the wet cross-sectional area to calculate the river / open channel discharge. Discharge measurement is carried out to obtain an instantaneous discharge.

Water sampling was carried out at 12 river points with a purposive method that considers the location (upstream, middle, downstream) and river characteristics, according to SNI 6989-78: 2008. The water samples taken were carried out in a composite manner on the river water surface in a 1-liter plastic bottle container to obtain information about the content of the river water quality. The actual mercury levels in river water were tested at the UGM Integrated Research and Testing Laboratory (LPPT) using the Mercury Analyzer method. The results of the mercury level and discharge test were used to calculate the actual pollution load.

Data analysis was carried out by simple mathematical calculation methods and descriptive-quantitative analysis. The calculation of the pollution load is based on the measurement results of river discharge and mercury levels in river water as well as the quality standard data of mercury in the river. The maximum pollution load (BPM) is based on the quality standard of mercury in class II rivers, namely 0.005 ppm multiplied by river discharge. Actual Pollution Load (BPA) is the measured river pollution load value obtained from the multiplication of river discharge with mercury levels. The difference between BPM and BPA is a value that shows the load capacity of river pollution against mercury. The following is the calculation formula for BPM and BPA (Rahayu, Juwana, & Marganingrum, 2018).

$$BPM = Q \times CBM \qquad (1)$$

BPM is Maximum Pollution Load (kg / day); Q is river discharge (m3 / second); and CBM is maximum concentration found in quality standards (mg / liter) / ppm.

$$BPA = Q \times CM \qquad (2)$$

BPA is Measured Actual Pollution Load (kg / day), Q is river discharge (m3 / second), and CM is measurement concentration (mg / liter) / ppm

IV. FINDING AND DISCUSSION

The carrying capacity of mercury pollution load is obtained from the difference in pollution load maximum (BPM) and actual pollution load (BPA). To be able to calculate this, it requires river discharge data, actual Hg concentration, and Hg quality standards for class II river water. Table 1 shows the results obtained from the results of instantaneous discharge measurements in the field and the value of actual Hg concentration.

Table 1.Results of measurement of river discharge in Pancurendang Village

Number of Sampling Points	Coordinates of		River Width (m)	Depth Average (m)	Flow Velocity (m / s)	Discharge (m^3/ s)	Actual Hg (ppm)
	X	Y					
1	289378	9179901	4.2	0.231	0, 49067	0.42	<0.00007
2	289166	9179753	4.4	0.208	0.25	0.20067	<0.00007
3	289016	9179685	4.3	0.35	0.185	0.15667	0.00164
4	289692	9179199	1.4	0.49	0.003	0.003518	<0.00007
5	289540	9179258	1.9	0.107	0.03	0.003651	<0.00007
6	289322	9179324	4.7	0.153	0.3	0.018435	<0.00007
7	289064	9179483	0.49	0.113	0.04229	0.0024	0.00106
8	289026	9179613	1.2	0.113	0.04018	0.00377	<0.00007
9	288910	9179697	5.8	0.322	0.02358	0.0024	0.00008
10	288745	9179857	16	0.36	0.41667	1.797	<0.00007
11	288774	9179747	19	0.35	0.59267	2.952	0.00018
12	288596	9179601	18	0.363	0.65733	2.925	<0.00007

Source: results of measurements and calculations, July 2020 (dry season)

Measurement results in river discharge at the research location is varied, 0.0024 until 2.925 meters/second. The river character in Pancurendang Village is getting wider at the downstream side, the current is getting heavier, so the discharge is getting bigger. The discharge value in this study is influenced by the width of the river, the depth of the river, and the current velocity. The depth and width of the river produce the cross-sectional area of the river. River flow velocity determined by river length, shape (winding or straight), flow pattern, relief, bed material, rainfall or other recharge, and drainage pattern (Norhadi, Marzuki, & Wicaksono, 2015). The river conditions at several sampling points are shown in Figures 2, 3, and 4.

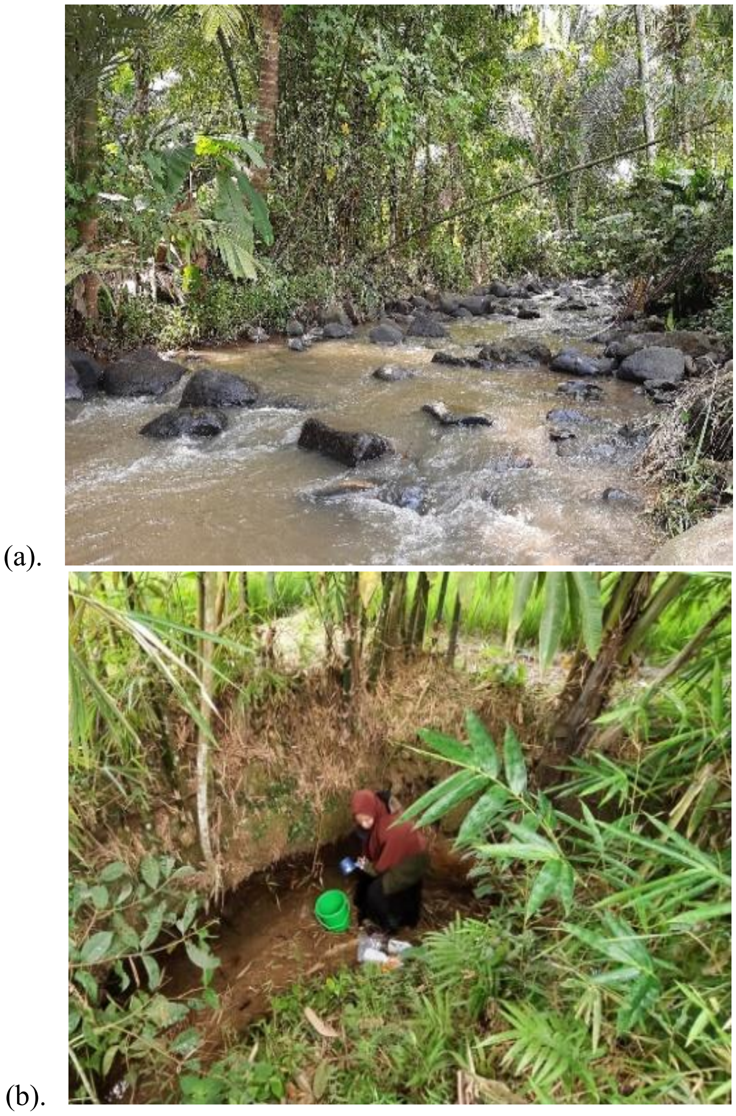
(a).
(b).

Figure 2. River conditions at point 1 (a) and point 4 (b)


Figure 3. River conditions at point 7

Figure 4. River conditions at point 12

Table 1 showed the value of Hg (mercury) levels was not detected at eight sampling points. Although mercury concentrations in surface water are not detected, it does not mean that the levels are 0. Mercury has likely been deposited on riverbeds due to its heavy metal. The nature of mercury as heavy metal in acidic conditions will more easily settle in the bottom or river sediments (Pranoto, Masykur, Fatimah, & Prabawani, 2018). It is known that the river pH value at 12 sampling points is in the range of 5-7.7. Points 3, 7, 9, and 11 where mercury was detected are located in a fairly dense mining spot area. To calculate the actual pollution load and the carrying capacity of the pollution load, the undetected sampling point is assumed to be 0.00005 ppm.

Table 2. Results of the calculations Hg pollution load capacity of the river in the Pancurendang Village

No.Sampling Point	Coordinates		Discharge (m^3/ s)	BPM (kg / day)	BPA (kg / day)	Capacity (kg / day)
	X	Y				
1	289378	9179901	0,42	0,00084	0,000021	0,000819
2	289166	9179753	0.20067	0.000401333	1.00333E-05	0.0003913
3	289016	9179685	0.15667	0.000313333	0.000256933	0.0000564
4	289692	9179199	0.003518	0.000007035	1.75875E-07	6.85913E-06
5	289540	9179258	0.003651	0.000007302	1.8255E-07	7.11945E-06
6	289322	9179324	0.018435	0.00003687	9.2175E-07	3.59483E-05
7	289064	9179483	0.0024	0,0000048	0.000002544	0.000002256
8	289026	9179613	0.00377	7.53333E-06	1.88333E-07	0.000007345

No.Sampling Point	Coordinates		Discharge (m^3/ s)	BPM (kg / day)	BPA (kg / day)	Capacity (kg / day)
	X	Y				
9	288910	9179697	0.0024	0.0000048	0.000000192	0.000004608
10	288745	9179857	1.797	0.003594	0.00008985	0.00350415
11	288774	9179747	2.952	0.005904	0.00053136	0.00537264
12	288596	9179601	2.925	0.00585	0.00014625	0.00570375
Note: Hg river Water Quality Standards = 0.002 ppm Actual Hg <0.00007 ppm convert to 0.00005 ppm					**Average**	**0.001325948**

Source: calculation, 2020

Table 2 shows the amount of mercury that can still be accommodated by rivers in the area around the gold mining and processing of Pancurendang Village in mg/day. The average value of the carrying capacity of the pollution load on mercury in the river in Pancurendang Village is 0.001325948 kg/day. In general, it can be said that the carrying capacity of mercury pollution in Pancurendang Village is still up to its capacity, even in dry season conditions. Mahmud (2012) stated that in the dry season, the concentration of mercury in the bottom sediments is very high in around the tailings, the lower it is to the estuary. Although the current condition is still safe, control efforts still have to be considered further so that there is no minus value or exceed its capacity.

The level of diversity is caused by the level of ore concentration in the rock, the level of ore quality, the amount of mercury for refining gold, and the practice of reclaiming the mercury used (Gulley, 2017). Veiga, Angeloci-Santos, & Meech (2014) said that the amalgamation method allows mercury to be wasted in the environment, as much as 1000 - 1600 tons every year. The environmental impacts of mercury depend on the amount of mercury lost during the gold refining process. The gold mining activity in Pancurendang Village has only been going on for four years so that mercury pollution is still below the quality standard. However, control efforts are needed to prevent further impacts.

One form of mercury pollution control is by replacing mercury with other reagents in the amalgamation process (Veiga, Nunes, Klein, Shandro, Velasquez, & Sousa, 2009) or treating its waste with various technology options (Chalkidis, Jampaiah, Aryana, Wood, Hartley, Sabri, & Bhargava, 2020). The amalgamation process allows miners to extract ore at a relatively low cost. Seeing this phenomenon, the alternatives offered to replace amalgamation must be more profitable for miners than those offered by other processing methods (Veiga & Fadina, 2020).

V. CONCLUSION AND FURTHER RESEARCH

The carrying capacity of the pollution load in the river in Pancurendang Village has not exceeded its capacity. However, efforts to control mercury pollution still have to be considered further so that the river ecosystem is maintained according to environmental quality standards that have been set by the government. Alternative amalgamation materials and various gold mine waste processing technologies open up opportunities for further research.

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