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Contents

Environmental Impact of Au Artisanal Mining on Plampang River, Yogyakarta, Indonesia

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ABSTRACT

Tailing from artisanal gold (Au) processing activities using amalgamation in Kalirejo Village, Kulon Progo Regency, Yogyakarta, is recognized as a major issue on the environment. The mercury (Hg), media used as a separator of gold and other minerals, most likely contaminates the Plampang River and the surrounding ecosystems. Thus, this study aimed (i) to examine the concentration of mercury on abiotic and biotic components and (ii) to determine the contamination level. Stream water, sediment, and benthic macro-invertebrates samples were purposively collected based on the scattered location of mining activities around the river. The mercury content was then measured using a mercury analyzer. The results showed that the maximum mercury concentration in stream water, sediments, and benthic macro-invertebrates were 0.002, 0.135, and 0.106 mg/L, respectively. In conclusion, the status of water quality in the Plampang River still meets the standard of good quality (PI 0.73). The level of pollution in the sediments shows no contamination until sufficiently polluted (Igeo 0-1). The degree of pollution on the biotic component (benthic macroinvertebrates) categorized into low accumulation properties (BCF <100). Furthermore, the community perceptions of Kalirejo Village due to the gold mining activities on Plampang River and environmental management strategies were also discussed.

Keywords: Tailing, Mercury, Gold Mining, Environment, River Pollution

INTRODUCTION

Traditional gold mining activities are usually conducted in a technical and simple way. One of the traditional gold mining activities is located in the Village Kalirejo Kokap District Kulon Progo Regency of Yogyakarta Province. Mining progress attends vein quartz direction which contains gold processed by amalgamation using mercury (Hg) as a gold binder. The liquid waste from the amalgamation process is accommodated in the storage pond and flowed into the River. The amalgamation process in addition to producing gold amalgam also produces mercury residues that have the potential to cause river pollution.

Mercury compounds are highly toxic to living things when ingested. Waste containing mercury when wasted into the river is associated with a food chain system. Mercury enters the body of aquatic organisms and may be consumed by humans with food taken from waters contaminated by mercury. The main effect caused by mercury in the body is to block the action of enzymes and damage the membrane of the cell wall (membrane) cells, which can cause damage to the body's metabolism to cause death.

The waste of gold processing which still contains mercury is classified as hazardous and toxic waste. According to Government Regulation No. 101 of 2014, Chapter 1 of Article 1, the meaning of hazardous and toxic substances is defined as material by which its nature and or concentration and or amount, either directly or indirectly can pollute and or damage the environment, health, human survival, and other living things. The existence of waste that is deliberately disposed of on the river waters will be a threat if not done further management. Therefore, this study aimed to characterize the environmental impact of Au artisanal mining on Plampang River.

RESEARCH METHODS

Research Sites

The research sites are located in Kaiirejo Village, Kokap District, Kulon Progo Regency, Yogyakarta Province, Indonesia. Kalirejo Village has an area of 12.96 km^2. Since the discovery of gold minerals in Kalirejo Village in 1996, mining activities have been carried out by local residents as well as migrants around the distribution of the gold deposits. The points considered for this site selection are:

1. mining activities undertaken in Kalirejo Village are traditionally carried out and include Unlicensed Gold Mining (PETI) which has no license for mining;
2. processing activities have done simply by using the amalgamation method to separate gold with minerals followers;
3. the location of processing activities are generally located on the banks of the river, so that waste is easily disposed of in river waters.

Sampling Location

The sampling technique was done by a purposive sampling method based on the location of mining activities where tailings were disposed of. The sampling location referred to the Regulation of the Minister of Environment Number 01 of 2010 on the Controlling Procedure of Water Pollution. According to the regulation, mining activities including non-domestic waste sources with pollutant sources of water were sources (point sources). Sampling was

done as much as 6 (six) points covering upstream, middle, and downstream of the river by considering the last outlet of waste disposal.

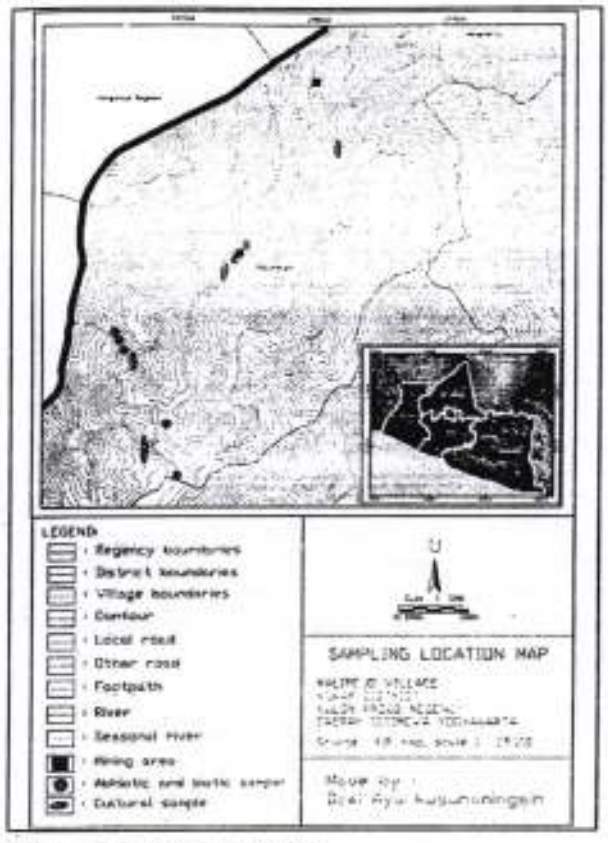

Fig. 1 Sampling Location Map

Analysis of Mercury Contaminants (Hg) Concentration

To achieve the objectives of this study, it is necessary to analyze the three components of the environment, which consists of abiotic, biotic and cultural components. The abiotic component in this research is the water quality of Plampang River which focused on mercury content (Hg) in water and river sediment. Water samples at the sampling point location were then further analyzed in the laboratory for known mercury metal content values. The value is then compared with Government Regulation No. 82/2001 on Water Quality Management and Water Pollution Control, with the aim to determine the level of pollution in each sampling location. Sediment samples at the location of the sampling point were also further analyzed in the laboratory for known mercury metal content.

The biotic component in this research is benthic macroinvertebrate. Samples from the research location were then taken to the Laboratory of Animal Systematics of Biology Faculty at UGM for the animal species identification process. After the animal species identification, then the sample was taken to the UGM Integrated Research and Testing Laboratory (LPPT) to know the mercury metal content.

The answer to each questionnaire has been directed and has certain weights. In addition, respondents were also given freedom of opinion in the form of reasons for each answer. Target respondents are residents around the mining activities and residents who live along the Plampang River along with mining business actors. Measurement results are then analyzed using two ways, both qualitative analysis, and quantitative analysis.

Environmental Pollution Level Analysis of Plampang River Waters

The amount of pollution level for river water quality is determined using the Pollution Index (IP) method based on the Minister of Environment Decree No. 115/2003 on Guidance of Water Quality Status. Evaluation of Pollution Index value based on the Ministry of Environment Decree Number 115, 2003 can be seen in Table 1.

The level of sediment quality in river waters is by using mercury geo-concentration analysis based on the equation expressed by Muller (1969), in Hasan et al (2003). Furthermore, Igeo's calculation results are classified into the Geo-accumulation Index (Igeo) classification table in Table 2.

Table 1 Evaluation of Pollutant Index Value (IP)

No	PI Value	Description
1	$0 \leq PIj \leq 1,0$	Quality standard (good condition)
2	$1,0 < PIj \leq 5,0$	Polluted mild
3	$5,0 < PIj \leq 10$	Polluted medium
4	$PIj > 10$	Severe pollutants

Source: Kepmen LH No. 115, 2003

Table 2 Classification of Geo-accumulation Index (*Igeo*)

I_{geo} Value	Class	Sediment Quality
<0	0	Not polluted
0 – 1	1	Not polluted until quite polluted
1 – 2	2	Fairly polluted
2 – 3	3	Fairly polluted until polluted
3 – 4	4	Polluted
4 – 5	5	Polluted until very polluted
>5	6	Very polluted

Source: Muller 1969 in Hasan et al 2003

The level of quality of the biotic components is done by the mercury bioconcentration factor analysis technique. The bioconcentration factor is defined as the ratio of heavy metal concentration in organisms and heavy metal concentration in sediments. According to Van Esch (1977) in Amriani (2011) there are 3 categories of BCF values, ie: (1) BCF values greater than 1000 are included in the category of high accumulation properties; (2) BCF values of

100 to 1000 are included in the category of moderate cumulative properties; (3) BCF values of less than 100 are categorized in low cumulative nature groups. Measurement of community perception of river water pollution caused by mining activities, using a number of questions given to respondents who have provided alternative answers. Answers from several respondents will be analyzed by giving the lowest total score and the highest so that the class interval can be calculated.

The public perception of traditional gold mining waste and its relation to the sustainability of Plampang River consists of 7 questions such as respondents' knowledge related to traditional gold mining activities, traditional gold mining waste, river water quality, river utilization, river environmental management. Here is a score that will be given based on respondents' answers:

1. public perception is low, if the index value <6;
2. perception of moderate society, if the index value 6-13;
3. the public perception is high if the index value >13.

RESULT AND DISCUSSION

Mercury Concentration In Plampang River Water

Water sampling is done in Plampang River at 6 sampling points and then taken into Laboratory for calculating the mercury content in the water sample. Test results from subsequent laboratory compared with the quality standard in Government Regulation No. 82 of 2001 on Water Quality Management and Water Pollution Control. In Plampang River, the class of water used is class II, with consideration of Plampang River used by the community for toilet, irrigation and animal feed.

The results of the research on water samples of Plampang River can be seen in Table 3 and Figure 2. The highest mercury (Hg) content was at point 4 of 0.0025 mg/l and the lowest was at 1, 2, 5 and 6 points <0.00006 mg/l. Based on this result there is a river water sample that is equal to the standard value determined by Government Regulation Number 82, 2001 class II of 0.002 mg/l. The rest at other locations, water samples are below the value of quality standards.

Table 3 Result Of Mercury Content In Plampang River Water In Kalirejo Village

No	Sample Location	Mercury Analysis Result (mg/l)	Quality Standard PP No 82, 2001
1	Point 1	<0.00006	0.002
2	Point 2	<0.00006	0.002
3	Point 3	0.001	0.002
4	Point 4	0.002	0.002
5	Point 5	<0.00006	0.002
6	Point 6	<0.00006	0.002

The analysis results indicate that point 3 and point 4 has a higher value compared to other points. Location point 3 is upstream of the mine at Sangon II Hamlet, the amount of mercury content obtained at this location is likely to occur naturally. At Location point 4 the value obtained is a waste disposal outlet from the processing of the Sangon II mine.

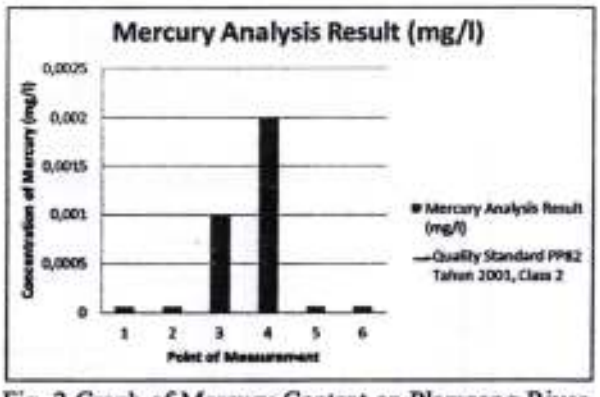

Fig. 2 Graph of Mercury Content on Plampang River Water

Mercury Concentration In Sediment of Plampang River

The sediment sampling location is the same as the water sampling location in Plampang River. Samples from the field were then taken to the Laboratory for known mercury content in river sediment samples. The results of the research on sediment samples of Plampang River can be seen in Table 4 and Figure 3. The highest mercury content was at point 4 of 0.135 mg/l and the lowest was at point 3 of 0.012 mg/l. The high mercury concentration at point 4 is due to the sampling location being at the waste disposal outlet at the mine site in Dusun Sangon.

The results of mercury content in the sediment of Plampang River in 2016 have decreased when compared with the condition in 2005. Based on the research that has been done by Setiabudi in 2005, the analysis of 90 sediment samples of the river showed levels> 0.1 ppm Hg, including 63 samples that have levels of 0.1-1.0 ppm Hg, and the remaining 27 samples of river sediment has levels > 1.0 - 97.48ppm Hg. All river sediment samples showing > 2 ppm Hg are from areas where there is a gold mining location or close to the gold mining site. The significant difference in mercury content in river sediments in 2005 compared to 2016 is due to the decrease in traditional gold mining activities conducted by mining business actors. In 2005 the location of traditional gold mining activity in the Village Kalirejo as many as 9 locations, while in the Year 2016 as many as 3 locations.

Table 4 Result Of Mercury Content In Sediment of Plampang River In Kalirejo Village

No	Sample Location	Mercury Analysis Result (mg/l)
1	Point 1	0.014
2	Point 2	0.040
3	Point 3	0.012
4	Point 4	0.135
5	Point 5	0.087
6	Point 6	0.024

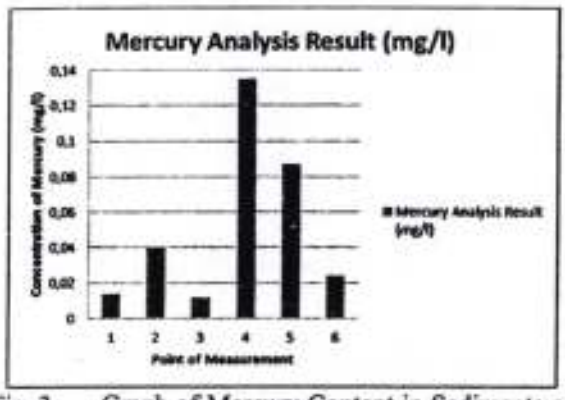

Fig. 3 Graph of Mercury Content in Sediments of Plampang River

The Concentration of Mercury Contaminant (Hg) Element In The Biotic Environment Component

The biotic sampling location is the same as the water and sediment sampling location in Plampang River. Based on the results of the research, benthic macroinvertebrate is obtained which consists of 5 families and 5 orders. Benthic macroinvertebrate types obtained in the study can be seen in Table 5 and Figure 4.

Table 5 Benthic Macroinvertebrate Type In Plampang River

Ordo	Familia	Feeding Group	Description
Ephemeroptera	Baetidae	Shredder (Sh)	Larvae of aquatic insect
Ephemeroptera	Heptageniidae	Scrapper-Grazer (S-G)	Larvae of aquatic insect
Trichoptera	Hydropsychidae	Filter Collector (F-C)	Larvae of aquatic insect
Plecoptera	Perlidae	Predator (Pr)	Larvae of aquatic insect
Odonata	Euphaeidae	Predator (Pr)	Larvae of aquatic insect
Isopoda	Euphaeidae	Shredder (Sh)	Crustacea: Isopoda

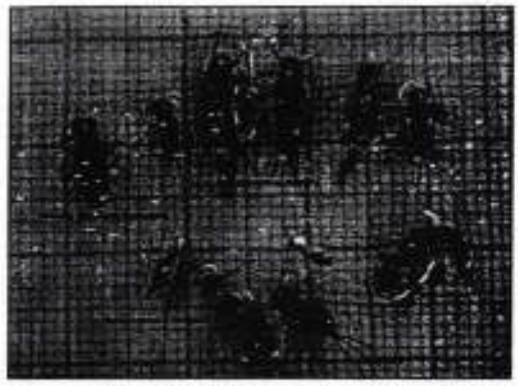

Fig. 4 Benthic Macroinvertebrate Sample at Point 1 on The Plampang River

The results of the study on sediment samples of Plampang River can be seen in Table 6 and Figure 5. The highest mercury content was at point 4 of 0.106 mg/l and the lowest was at point 1 of <0,000038 mg/l. The high mercury concentration at point 4 is due to the sampling location being at the waste disposal outlet at the mine site in Dusun Sangon.

Table 6 Result of Mercury Content on Benthic Macroinvertebrate on The Plampang River in Kalirejo Village

No	Sample Location	Ordo of Benthic Macroinvertebrate	Analysis of Mercury Result (mg/l)
1	Point 1	Ephemeroptera, trichoptera, plecoptera, isopoda	<0.000038
2	Point 2	Ephemeroptera, trichoptera, plecoptera, odonata	0.010
3	Point 3	Ephemeroptera, trichoptera	0.009
4	Point 4	Ephemeroptera, trichoptera, plecoptera	0.106
5	Point 5	Ephemeroptera, trichoptera, plecoptera	0.054
6	Point 6	Ephemeroptera, trichoptera, plecoptera, odonata	0.049

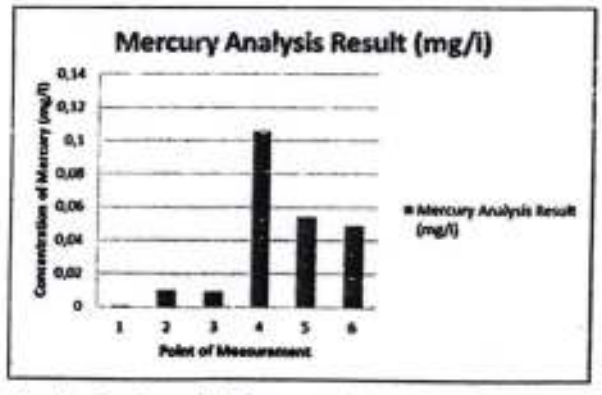

Fig.4 Graph of Mercury Content on Benthic Macroinvertebrate on the Plampang River

The result of mercury content analysis on sediment has a correlation with mercury content on benthic macroinvertebrate, the higher the mercury content in sediment, the higher the mercury content on benthic macroinvertebrate. This can be seen at point 1 of mercury content in 0.014 mg/l sediment, whereas mercury content in benthic macroinvertebrates <0.000038 mg/l. At point 2 the mercury content in the sediment was 0.040 mg/l, whereas the mercury content in benthic macroinvertebrates was 0.010 mg/l. At point 3 the mercury content in the sediment was 0.012 mg/l, whereas the mercury content in benthic macroinvertebrates was 0.009 mg/l. At point 4 the mercury content of the sediments is 0.135 mg/l, whereas the mercury content in benthic macroinvertebrates is 0.106 mg/l. At point 5 the mercury content in the sediment was 0.087 mg/l, whereas the mercury content in the benthic macroinvertebrate was 0.054 mg/l. At point 6 the mercury content in the sediment was 0.024 mg/l, whereas the mercury content in benthic macroinvertebrates was 0.049 mg/l. This situation is caused by benthic macroinvertebrate living animals attached to the substrate or river sediment.

Perceptions of locals to Plampang River due to mining activities

Based on observations in the field, it is known that the majority of respondents agree with the gold mining activities because it can help the people's economy (40%). Respondents who disagree as much as 10% on the grounds of gold mining activities are illegal or do not have permission. Related to the hazard of gold processing waste, the majority of respondents agree that the waste of mining activities produces hazardous waste because it contains mercury (59%), while as many as 9% of respondents do not know precisely the dangers of waste processing activities of gold.

Based on the perception of respondents on the quality of the waters of the Plampang River after the existence of traditional gold mining activities, the river waters become polluted and the quality decreases (50%). Some people assume that it is not polluted because the miners have done environmental management by making tailings pool (18%) and others not aware of the change in river water quality since there is no research result (18%).

Utilization of the Plampang River for the community in Kalirejo Village, the majority is used for daily use (54%), 14% do not use river water as a daily necessity. Against disease complaints resulting from river utilization, the majority of people do not have a disease complaint and thus give no reason (56%). As many as 35% of people complained of itching when using the river and 9% said there were no complaints about the disease.

Based on the observation in the field, it is known that the majority of respondents stated that mining business actors have done environmental management but not optimal (50%). As many as 14% of respondents said there is no form of environmental management by mining business actors. Based on input from respondents, respondents wanted gold mining waste management to be well managed (61%). Respondents expect socialization from mining business actors to the community in terms of preserving the environment (17%). The respondent who is "Pamong Desa" hopes that the migrant community who performs mining activities in Kalirejo village hand over the identity to Pamong Desa as regulation says (17%). So far there is no identity submitted to Pamong Desa Kalirejo from mining business actors, especially those who come from outside Kalirejo Village. As many as 5% of respondents want a profit-sharing from the sale of gold with the landowner.

Suggestions from respondents to the government, the majority of respondents want counseling session and guidance from the government related to gold mining activities (40%). Respondents expect the government to grant gold mining permits to the public (27%). A total of 20% of respondents want regular government supervision of gold mining activities conducted. There are respondents who do not want any traditional gold mining activities in Kalirejo Village (13%).

Perceptions of traditional gold mining business activities against Plampang River

Based on the observation in the field, it is known that the majority of respondents know the mechanism of waste disposal of traditional gold processing (88%). As many as 12% of respondents do not know the mechanism of waste disposal. Regarding the respondent's perception of gold mining waste hazard, 50% of respondents acknowledge the waste of processing of gold is dangerous because it contains mercury. Respondents stated that they do not know yet another method to separate gold with rocks other than by amalgamation method. Therefore, tailings ponds are created to minimize the impact that may occur. As many as 50% of other respondents said the waste of processing of gold is not dangerous. Respondents assume the use of mercury instead of harmful chemicals. If using other chemicals such as cyanide in separating gold, it is considered harmful to the environment.

Respondents' perceptions related to the impact of mining activities that affect environmental sustainability, the majority of respondents do not know the impact (50%). As many as 25% of respondents believe that mining activities cause river water to become cloudy when it rains. As many as 25% of other respondents thought that mercury used is not harmful to the surrounding environment.

Environmental management activities shall be undertaken by industry to minimize any negative

impacts that may occur. In the traditional gold mining activities in Kalirejo Village, respondents claimed to have no environmental management (38%). As many as 37% of respondents do environmental management by creating a waste storage pond.

Feedback from the respondent is needed to know what the respondent wants to the government. Feedback provided by respondents can be input to formulate an environmental management strategy. Based on field observations, respondents wanted the government to facilitate the people's mining permit (75%). As many as 25% of respondents want assistance from the government in the procurement of mining equipment so that mining activities can continue.

Level of Environmental Pollution

Determination of mercury contamination level in Plampang River water is done by using the Pollution Index method based on the Ministry of Environment Decree No. 115/2003 on Guidance on Determination of Water Quality Status. Based on the result of the calculation analysis of Pollution Index (PI), it is known that the PI value of River Plampang water with mercury test parameter is 0,73 which means that the condition of Plampang River has water quality status fulfill the standard of quality or good condition. This is supported by research conducted by Setiabudi (2005) in Dusun Sangon Kalirejo Village, the result of water sample analysis has a concentration <0.5 ppb Hg or <0.0005 ppm Hg. Thus it can be said that the quality of surface water in Kalirejo Village is still good.

The result of the chemical analysis of the mercury element in sediment samples of Plampang River showed a value of 0.012 - 0.135 mg/l. Test results are then calculated Igeo value to know the classification of pollution in the sediment. The calculation result of the geo-accumulation index (Igeo) on the sediment of Sungai Plampang with a parameter of mercury content can be seen in Table 7.

Table 7 Geo Accumulation Index Calculation Result (I_{geo})

Sample Location	Cn	Bn	I_{geo}	Sediment Quality
Point 1	0.01	0.07	-0.57	Not polluted
Point 2	0.04	0.07	-0.12	Not polluted
Point 3	0.01	0.07	-0.64	Not polluted
Point 4	0.14	0.07	0.41	Not polluted until quite polluted
Point 5	0.09	0.07	0.22	Not polluted until quite polluted
Point 6	0.02	0.07	-0.34	Not polluted

Laboratory results of the benthic macroinvertebrate aquatic biota show that mercury content is at a minimum content of <0.000038 mg/l in Location Point 1 and the maximum content of 0.106 mg/l in Location Point 4. The results from the laboratory then calculated the Bioconcentration Factor (BCF) value to determine benthic macroinvertebrate biota capability to accumulate heavy metals mercury (Hg). The result of the calculation of BCF value at the research location can be seen in Table 8. The calculation of bioconcentration factor (BCF) aims to see the magnitude of heavy metal accumulation of sediments occurring in benthic macroinvertebrates. This study shows that the accumulation of metals from sediments by benthic macroinvertebrates in the Plampang River belongs to the category of low accumulation.

Table 8 Value of Hg Bioconcentrate Factor on Benthic Macroinvertebrate

Sample Location	Corg	Csed	BCF	Category
Point 1	<0.00 0038	0.014	<0.00 271	Low accumulation
Point 2	0.01	0.04	0.250	Low accumulation
Point 3	0.009	0.012	0.750	Low accumulation
Point 4	0.106	0.135	0.785	Low accumulation
Point 5	0.054	0.087	0.621	Low accumulation
Point 6	0.049	0.024	2.042	Low accumulation

With a high level of public perception of the surrounding environment, it is possible to bring a positive impact on the implementation of environmental management programs. Based on observations, as many as 60% of people have a moderate perception of Plampang River water pollution resulting from traditional gold mining activities. Most respondents support the existence of traditional gold mining activities but there must be a form of good environmental management by mining actors considering the location of the mine is close to the river. This is because there are still many respondents who use river water for daily life. As many as 30% of people have a high perception, they know that gold mining waste can pollute river waters due to the use of mercury. As many as 10% of people have a low perception, they assume no harm to the use of mercury used by miners on the quality of river waters. Public perceptions on the waters of the Plampang River due to traditional gold mining activities can be seen in Table 9.

Table 9 Public Perception Against Pollution of Plampang River Waters Due to Traditional Gold Mining Activity

Public Perception	Respondents	Percentage (%)
Low (<6)	3	10
Medium (6-13)	18	60
Height (>13)	9	30
	30	100

Environmental Management Strategy

An environmental management strategy for traditional gold mining activities in Kalirejo Village, Kokap Subdistrict of Kulon Progo Regency, requires a synergy of management strategy with principles in the Law on Environmental Protection and Management Number 32, 2009. The strategy considers the planning, utilization, control, maintenance, supervision and law enforcement activities. Management strategies for river water pollution due to gold mining are as follows:

1. Preventing and controlling waste at the tailings pond site by making and/or expanding the waste collection pond, conducting periodic inspection and measurement of waste.
2. Environmental management is done by involving stakeholders. The parties involved are mining business actors, surrounding communities and related institutions.
3. Mining business actors and the government should socialize good mining practices both formally and/or informally to local communities. They also have to listen and accommodate good aspirations, demands, wishes, and expectations of the community around the traditional gold mining location.

CONCLUSION

Based on the results of the discussion some conclusions can be summarized as follows:

1. In terms of the abiotic component, the highest mercury content in water and sediment samples is at Point 4. The mercury content in water samples is 0.002 mg / l, while the mercury content in sediment samples is 0.135 mg / l. In terms of the biotic component, the highest mercury content in benthic macroinvertebrate samples was found at point 4, which was 0.106 mg / l. For information, point 4 is a gold processing waste disposal outlet located in Location II, namely Sangon II Hamlet. In terms of the cultural component, there are positive and negative perceptions of the local community towards traditional gold mining activities.
2. The level of environmental pollution when viewed from the abiotic component, the status of water quality in the Plampang River still meets the quality standards / good conditions (PI 0.73). While the level of environmental pollution in sediments shows that it is not polluted until it is sufficiently polluted (Igeo 0-1). In terms of the biotic component, the accumulation of mercury from sediments on benthic macroinvertebrates in the Plampang River is included in the category of low accumulation properties (BCF <100). In terms of the cultural component, 60% of respondents have a moderate perception of environmental pollution in the Plampang River.
3. The environmental management strategy for the pollution of the Plampang River waters due to traditional gold mining activities can be pursued by preparing best suitable mine planning by preventing and control waste at the tailings pond site by making and/or expanding the waste collection pond, and also by conducting periodic inspection and measurement of waste. Environmental management is carried out by involving stakeholders. The parties involved include mining business actors, surrounding communities and related institutions.

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REFERENCES

Yoga et al, 2009, Bioakumulasi Logam Merkuri pada Beberapa Tipe Kebiasaan Makan Fungsional Biota Air Di Sungai Cikaniki, Limnotek XVI, 167-179.

EPA, 2011, Regulatory Impact Analysis for The Final Mercury and Air Toxics Standards. U.S Environmental Protection Agency, Office of Air Quality, Planning and Standards, Health and Environmental Impact Division, Research Triangle Park, NC.

Louma, S.N and K.T. Ho., 1993, *Appropriate Uses Of Marine and Estuarine Sediment Bioassays.* Handbook Of Ecotoxicology, Vol.1 Oxford Blackwell Sci. Publ. London: 193-226.

Hasan AB, Kabir S, Reza AHMS, Zaman MN, Ahsan A, Rasid M., 2013, Enrichment Factor and Geo-accumulation Index of Trace Metals In Sediments Of The Ship Breaking Area Of Sitakund Upazilla (Bhatiary-Kumira), Chittagong, Bangladesh Journal Of Geochemical Exploration, 125, 130-137.

Amriani, Hendrarto, Hadiyarto., 2011, Bioakumulasi Logam Berat Timbal (Pb) dan Seng (Zn) pada Kerang Darah (Anadara granosa L.) dan Kerang Bakau (Polymesoda bengalensis L.) Di Perairan Teluk Kendari, Jurnal Ilmu Lingkungan, Vol.9, hal. 45-50.

Setiabudi, Tyahjono Bambang., 2005, Penyebaran Merkuri Akibat Usaha Pertambangan Emas di Daerah Sangon, Kabupaten Kulon Progo, D.I. Yogyakarta.