Aceh Int. J. Sci. Technol., 9(1): 29-39
April, 2020
doi: 10.13170/aijst. 9.1.15267

Aceh International Journal of Science and Technology
ISSN: p-2088-9860; e-2503-2398
Journal homepage: http://jurnal.unsyiah.ac.id/aijst

Water and Sediment Quality Index Due To Gold Mining in The Downstream of Krueng Kluet Sub Watershed, Aceh Selatan Regency

Ichwana Ramli[1,2,3*], Syahrul [1], Mutia Rizka Lestari [1]
[1]Department of Agricultural Engineering, Agriculture Faculty, Universitas Syiah Kuala, Banda Aceh
[2]School of Environmental Management, Universitas Syiah Kuala, Banda Aceh
[3]Research Center for Environmental and Natural Resources, Universitas Syiah Kuala, Banda Aceh
**Corresponding Author Email: ichwana.ramli@unsyiah.ac.id*

Received: December 12, 2019
Accepted: May 11, 2020
Online : May 11, 2020

Abstract – Increasing population growth, economic and industrial development will lead to the utilization of natural resources effected on water pollution. One of those activities related to natural resource utilization is gold mining. Mining activities cannot be separated from the use of chemicals that are harmful to living things; for example, it is mercury. This study aims to determine levels of mercury (Hg) that accumulate in water and sediments. The tools that will be used in this research are QGIS 2.18.27 software and Global Positioning System (GPS). The material used is water and sediment samples. Water and sediment samples were analyzed at the Industrial Standardization Research Institute Laboratory (BARISTAND) to obtain several potential parameters such as hydrogen (pH), mercury (Hg), Lead (Pb), Iron (Fe) and Copper (Cu). These potential parameters are further analyzed using the Pollution Index (PI) method and Sediment Quality Guidelines (SQGs). The results showed that the water quality in downstream of Krueng Kluet sub-watershed in the year 2019 using the Pollution Index (PI) method for the drinking water (Class I) with the value is 6.2036, classified as moderately polluted water quality criteria and for the agricultural water (Class IV) with the value is 6.0796, classified as fairly polluted water quality criteria. The quality of sediments in the downstream of Krueng Kluet sub-watershed using the sediment quality guidelines method with the value is 0.2343 is classified as an adverse effect for the biota of heavy metals on medium value. This shows that neither the water quality nor the sediment in the downstream of Krueng Kluet sub-watershed does not accord with the water and sediment quality standards. Pollution Index can assess the quality of water bodies and becomes a consideration in taking actions to improve water quality. At the same time, SQGs show chemical concentrations that have biological effects on aquatic biodata.

Keywords: Mercury, Gold Mining, Pollution Index (P I), Sediment Quality Guidelines (SQGs).

Introduction

Water pollution arising from urbanization and industrialization has become a serious concern throughout the world (Tam and Wong, 2000; Li et al., 2007). Gold mining is one of the leading causes of environmental pollution. Mercury pollution in Aceh is closely related to gold mining activities and become a severe polemic issue. Aceh Provincial Government and the Community are taking more concern due to gold mining activities as we know that mercury is difficult to dissolve in water (Adlim, 2016). One of the gold mines in the South Aceh Regency is in Central Kluet District. Many gold miners exploit gold and risen through Kecamatan Kluet Tengah since 2009. The process of extracting gold often ignores procedures so that many miners ignore the required land area that is permitted as a designation. Water quality monitoring and assessment are essential to be carried out for the sustainability of water surface for human life (Boyd, 2015; Wu, et al., 2018).

Binding heavy metals from industrial products will tend to absorb and accumulate in fine-grained particles, which eventually move to the deposition area (Gao et al., 2012). The existence of mercury metals in waters and sediments is a problem because it can adversely affect all organisms in the waters and can be accumulated in the food chain. Heavy metals that flow in the waters will be removed from the body of water through several processes, namely deposition, and absorption by aquatic organisms. Heavy metals that are absorbed by suspended sediment will settle to the deposit and cause the concentration of heavy metals in the water to be lower than the concentration in the sediment. The height of heavy metals in sediments can harm organisms that live in aquatic biota because they can come into the digestive system, the consequences will be very detrimental to humans who consume water biota that has been contaminated by heavy metals (Chapman et al., 1998; Machado et al., 2002; Islam and Tanaka, 2004; Roussiez et al., 2011).

Irrigation water containing pollutants such as Hg can affect the quality of agricultural production. The use of heavy metal polluted water for agriculture can lead to contamination of plants by heavy metals that can disrupt plant growth and human health that consumes the results. These heavy metals, when they get into the body through food, will accumulate continuously and, in the long term, can cause nervous system disorders, paralysis, decreased intelligence of children, and premature death (Almiqrhi, 2018).

The rainfall also can bring mercury into the river, so that mercury can be accumulated in sediments or drift with water downstream of the river. According to Rochyatun et al. (2006), heavy metals initially dissolved in the river were absorbed by suspended solids and carried by the river into estuaries. High levels of heavy metals are found near the coastal area, and down toward the sea. River currents in the estuary meet with tidal ones, and when current wave flow conditions are in steady-state, heavy metal dilution running slowly. Heavy metal accumulation occurs in deposits in the aquatic environment, which are toxic to organisms and fish that live in sediments, which results in death, reduced growth, or damage to reproduction and lower species diversity (Praveena et al., 2007). The effect causes the river is polluted with mercury and can endanger the society health around the river (Tepe and Cebi, 2017). To find out the water quality in river flow, it can be done with a water quality index to facilitate the identification of the diluted classification in an area—the Calculation of water quality index with the National Sanitation Foundation Water Quality Index (NSF-WQI). There is no assessment of metal elements (Ichwana, 2016). Therefore, from this problem, it is necessary to do the identification of heavy metal content in the Krueng Kluet Hilir Sub-watershed using the Pollution method Index (PI) for river water and Sediment Quality Guidelines (SQGs) for river sediments.

Materials and Methods

Materials

This research was conducted in Central Kluet Subdistrict, South Aceh District. This research was conducted from June to August 2019 (Figure 1).

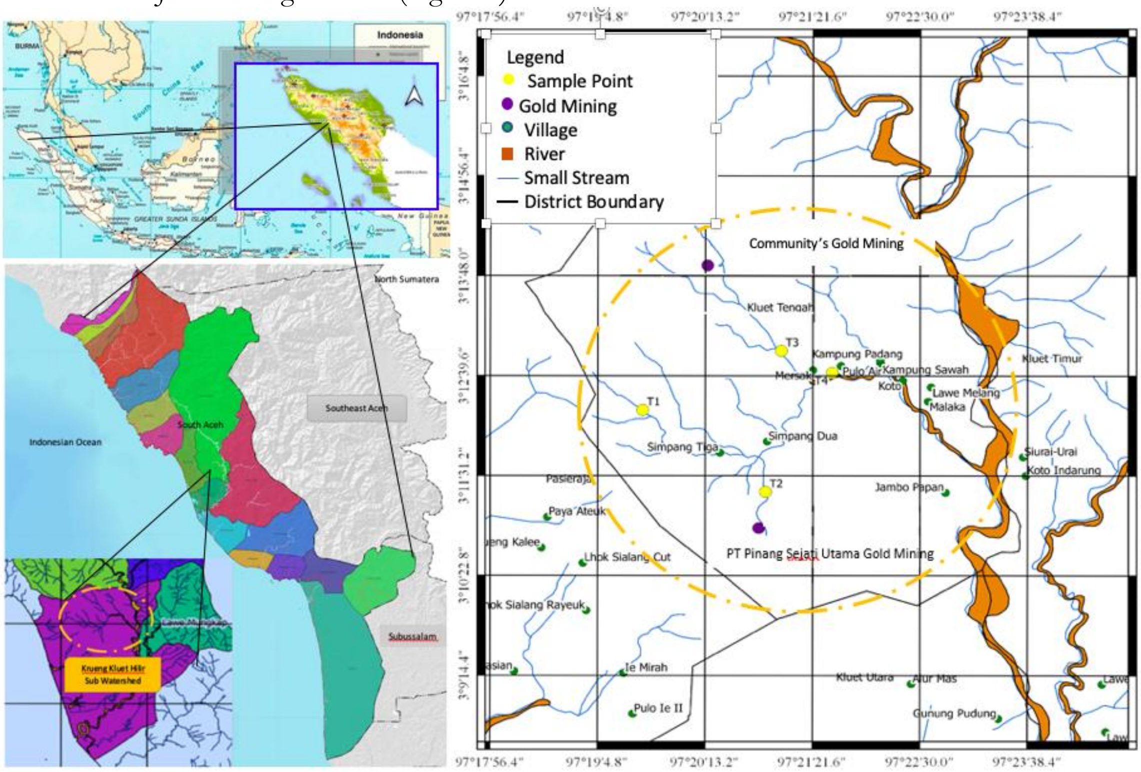

Figure 1. Map of Sample Point at The Research Location

Data collection

The primary data collection was conducted by inserting the water and river sediment samples with the parameters used, namely the potential of hydrogen (pH), mercury (Hg), lead (Pb), iron (Fe), and copper (Cu). The secondary data was taken from the downstream of Krueng Kluet sub-watershed map data obtained from the Regional Development Planning Agency (BAPPEDA), Banda Aceh. Water quality standards are assessed based on Government Regulation of the Republic of Indonesia decree number 82 in 2001 concerning Water Quality Standards, Management, and Water Pollution Control (Table 1). Class I is water whose designation can be used for drinking purposes. Class IV can be used to irrigate crops and or other uses that require the same water quality as the purpose. Water quality requirements as benchmarks are determined based on Water Quality Standards in Indonesia.

Table 1. Water Quality Standards in Indonesia

Parameter	Unit	Class			
		I	II	III	IV
pH	-	6-9	6-9	6-9	5-9
Mercury (Hg)	mg/L	0.001	0.001	0.001	0.005
Lead (Pb)	mg/L	0.03	0.03	0.03	1
Iron (Fe)	mg/L	0.3	0.3	0.3	0.3
Cupper (Cu)	mg/L	0.02	0.02	0.02	0.2

Source: Government Regulation of the Republic of Indonesia decree number 82 in 2001

Data Analysis

The water quality index can be calculated by using the Pollution Index (PI) method, which can be determined in the following way (Nemerow and Sumitomo, 1970) and Table 2, criteria of Pollution Index (PI).

$$Plj = \sqrt{\frac{\left(\frac{Ci}{L_{ij}}\right)_M^2 + \left(\frac{Ci}{L_{ij}}\right)_R^2}{2}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Explanation :

Pl_j = Pollution Index

C_i = Concentration of Water Quality Parameters obtained from the Laboratory (mg/L)

L_{ij} = Concentration of Water Quality Parameters listed in the quality standard of allotment water (mg/L)

M = Maximum value of (C_i/L_{ij})

R = Average Value of (C_i/L_{ij})

Table 2. Criteria of *Pollution Index* (PI)

No	Criteria of ***Pollution Index*** (PI)	Explanation
1.	$0 \leq PI \leq 1,0$	Good
2.	$1,0 \leq PI \leq 5,0$	Slightly Polluted
3.	$5,0 \leq PI \leq 10$	Fairly Polluted
4.	$PI \geq 10,0$	Heavily Polluted

Source: Decree of the Minister State LH No. 115, 2003

The sediment quality index can be calculated by using the Sediment Quality Guidelines (SQGs) method, which can be determined by using the following formula (Fairey et al., 2001) and criteria of Sediment Quality Guidelines (SQGs) (Table 3).

$$PEL - Qi = \frac{contaminant}{PEL} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

$$SQG - Q = \frac{\sum_{i=1}^{n} PEL - Qi}{n} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Definition	:
Contaminant	= Polluter parameter (mg/kg)
PEL	= Quality standard established by CCME (mg/kg)
n	= Number of parameters
PEL-Qi	= The calculated result from the contaminant concentration measured by its PEL value
SQG-Q	= Sediment pollution index

Table 3. Criteria of *Sediment Quality Guidelines* (SQGs)

No	Criteria of ***Pollution Index*** (PI)	Explanation
1.	SQG-Q<0,1	The negative effect of heavy metals on low biota
2.	0,1< SQG-Q<1	The negative effect of heavy metals on medium biota
3.	SQG-Q≥1	The negative effect of heavy metals on high biota

Source: Fairey et al., 2001

Results

Central Kluet Subdistrict is one of the sub-districts in the South Aceh Regency. Central Kluet District has an area of 54.83 Km^2 with geographical location 03⁰19'12,1" South Latitude and 97°37'12,1" East Latitude. The downstream of Krueng Kluet Sub-watershed is a tributary of the Krueng Kluet watershed located in the Central Kluet District. The downstream of Krueng Kluet Sub-watershed is a watershed sub-adjacent to the gold mining location in Central Kluet District. The research location was in the Lawe Manggamat River in Simpang Tiga Village and Lawe Simpang dua River in Mersak Village. The distance of the sampling point was not determined. The coordinate points for each sample point are listed in Table 4.

Table 4. Coordinate Points and Altitude of Research Location

No	Sample Points	village	Coordinate Points	Altitude (above sea level)
1.	T1	Simpang Tiga	N= 3°12'17.07" E= 97°19'32.91"	163
2.	T2	Simpang Tiga	N= 3°11'21.14" E= 97°20'51.38"	134
3.	T3	Mersak	N= 3°12'56.61" E= 97°21'01.28	71
4.	T4	Mersak	N= 3°12'42.02" E= 97°21'33.46"	50

Table 5. The Result Water Quality of Sub-watershed in downstream Krueng Kluet in the Laboratory

No	Sample Points	Parameters Assessment				
		pH	Hg (mg/L)	Pb (mg/L)	Fe (mg/L)	Cu (mg/L)
1.	T1	7.75	0.0005	0.0001	0.1677	0.0008
2.	T2	7.86	0.0005	0.0001	11.6608	0.3269
3.	T3	7.80	0.0005	0.0001	4.8110	0.0008
4.	T4	7.66	0.0005	0.0001	12.5676	0.1137

Source: Laboratory of BARISTAND Banda Aceh, 2019

The sample point (T1) used as the control point is located in Lawe Manggamat River, Simpang Tiga Village, and it is far from residential areas. The road to reach the T1 location is bumpy and gravel. The height of the site reaches 163 m above sea level. The surrounding conditions still look natural with a variety of vegetation, such as areca nut plants and so forth. The location of the T2 sample point is on the Manggamat River in Simpang Tiga Village, not far from the PT Pinang Sejati Utama gold mine. 2.980 km away from sample point T1 with a height of 134 m above sea level. The color of the river is slightly yellowish. The location of the T3 sample point is on the Lawe Simpang dua River, Mersak Village, located not far from the community's gold mining area. 3.043 km away from sample point 2 with an altitude of 71 m above sea level. The color of the river is slightly yellowish. Vegetation around the river is bamboo trees, areca trees, etc.

The location of the T4 sample point is on the Lawe Manggamat River in Mersak Village. The location of this sample point is close to residential areas with an approximate distance is 1.118 km from the sample point T3. This location has a height of 50 m above sea level. The color of the river looks slightly murky brown—vegetation around the river: areca trees, etc. The water from the Lawe Manggamat River continues to flow into the Krueng Kluet River.

The laboratory test parameters in this study were five parameters, namely; pH, mercury, lead, iron, and copper. After testing five water samples taken from each point, quantitative data was obtained (Table 5). The data is analyzed by using a predetermined method, namely, the Pollution Index (PI) method. The calculation result of PI_j for agricultural use Class I are listed in Table 6 with the graph shown in Figure 2. Based on the PIj graph (Figure 2), it is stated that the calculation results are only the location of sample point T1 that fulfills the quality standards that designate drinking water with a value of 0,4361. Whereas at the site of sample point T2, sample point T3 and sample point T4 were obtained values of 6.7603, 5.0894, and 6.7610, which is classified as fairly polluted.

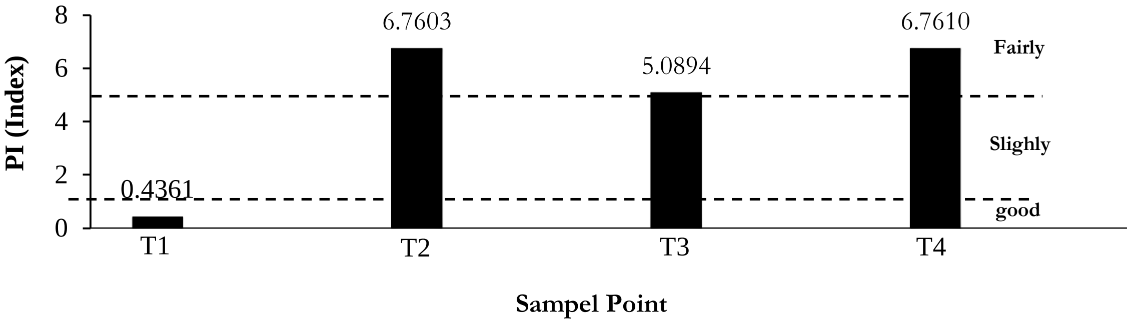

Figure 2. The Value of Pij Calculation Result for drinking Water (Class I)

Table 6. The Calculation of *Pollution Index* (PI_j) Each Parameter for Class I Quality Standard of Drinking Water

Sample Point	Parameter	Lij	Ci	Ci/Lij	Ci/Lij New	Average	Pij	Criteria PI
		Standard Quality I	Parameter Water Quality Laboratory					
1	pH	6-9	7.75	0.2000	0.2000	0.2605	0.4361	Fulfill Standard Quality
	Mercury (Hg)	0.0010	0.0005	0.5000	05000			
	Lead (Pb)	0.03	0.0001	0.0033	0.0033			
	Iron (Fe)	0.3	0.1677	0.5590	0.5590			
	Copper (Cu)	0.02	0.0008	0.0400	0.0400			
2	pH	6-9	7.86	0.3158	0.3158	3.3668	6.7603	Fairly Polluted
	Mercury (Hg)	0.0010	0.0005	0.5000	0.5000			
	Lead (Pb)	0.03	0.0001	0.0033	0.0033			
	Iron (Fe)	0.3	116608	38.8693	8.9480			
	Copper (Cu)	0.02	0.3269	16.3450	7.0669			
3	pH	6-9	7.80	0.2500	0.2500	1.5638	5.0894	Fairly Polluted
	Mercury (Hg)	0.0010	00005	0.5000	0.5000			
	Lead (Pb)	0.03	0.0001	0.0033	0.0033			
	Iron (Fe)	0.3	4.8110	16.0367	7.0256			
	Copper (Cu)	0.02	0.0008	0.0400	0.0400			
4	pH	6-9	7.66	0.1194	0.1194	2.9014	6.7610	Fairly Polluted
	Mercury (Hg)	0.0010	0.0005	0.5000	0.5000			
	Lead (Pb)	0.03	0.0001	0.0033	0.0033			
	Iron (Fe)	0.3	12.5676	41.8920	9.1107			
	Copper (Cu)	0.02	0.1137	5.6850	4.7737			
Conclusion							6.2036	Fairly Polluted

Based on the PIj graph listed in Figure 3, the calculation results showed that it is not much different from the previous one. Sample point T1 obtained a PIj value of 0.4603, which was classified as water quality standards for agriculture. Sample point T2 obtained a PIj value of 6.5461 that was classified as fairly polluted, sample point T3 obtained a value of PIj of 5.0887 that was classified as fairly polluted, and sample point T4 received a PIj value of 6.604 which was classified as fairly polluted. The calculation results of Pij for agricultural use Class IV are listed in Table 7.

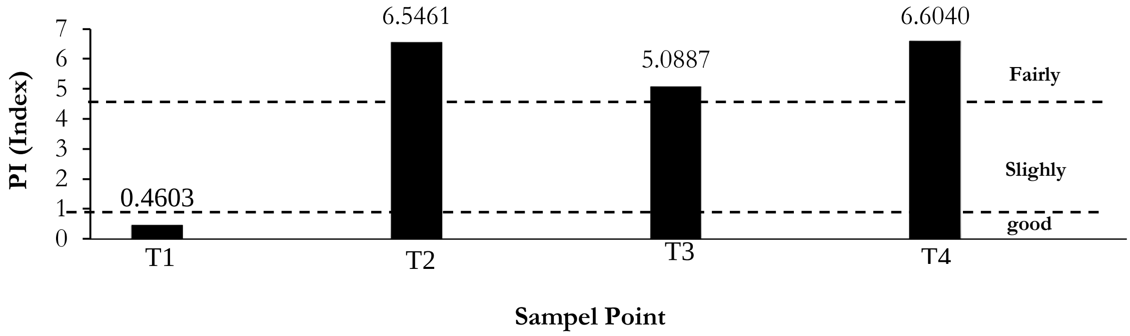

Figure 3. The Value of Pij Calculation Result for Agriculture (Class IV)

Table 7. The Calculation of *Pollution Index* (PI_j) Each Parameter for Class IV Standard Quality of Agriculture Water

Sample Points	Parameter	Lij	Ci	Ci/Lij	Ci/Lij New	Average	Pij	Criteria PI
		Quality Standard IV	Parameter of Laboratory Water Quality					
1	pH	5-9	7.75	0.6000	0.6000	0.2526	0.4603	Fulfill Standard Quality
	Mercury(Hg)	0.0050	0.0005	0.1000	0.1000			
	Lead (Pb)	1	0.0001	0.0001	0.0001			
	Iron (Fe)	0.3	0.1677	0.5590	0.5590			
	Copper (Cu)	0.2	0.0008	0.0040	0.0040			
2	pH	5-9	7.86	0.7544	0.7544	2.3739	6.5461	Fairly Polluted
	Mercury(Hg)	0.0050	0.0005	0.1000	0.1000			
	Lead (Pb)	1	0.0001	0.0001	0.0001			
	Iron (Fe)	0.3	11.6608	38.8693	8.9480			
	Copper (Cu)	0.2	0.3269	1.6345	2.0669			
3	pH	5-9	7.8	0.6667	0.6667	1.5593	5.0887	Fairly Polluted
	Mercury(Hg)	0.0050	0.0005	0.1000	0.1000			
	Lead (Pb)	1	0.0001	0.0001	0.0001			
	Iron (Fe)	0.3	4.8110	16.0367	7.0256			
	Copper (Cu)	0.2	0.0008	0.0040	0.0040			
4	pH	5-9	7.66	0.4925	0.4930	2.0546	6.6040	Fairly Polluted
	Mercury(Hg)	0.0050	0.0005	0.1000	0.1000			
	Lead (Pb)	1	0.0001	0.0001	0.0001			
	Iron (Fe)	0.3	12.5676	41.8920	9.1107			
	Copper (Cu)	0.2	0.1137	0.5685	0.5690			
Conclusion							6.0796	Fairly Polluted

This is primary data where sediment sampling is done on the river bank. In this study, the parameters of the laboratory test were four parameters; mercury, lead, iron, and copper. After testing four sediment samples taken from each point, the quantitative data were obtained (Table 8).

Table 8. The Result of Sediment Quality Testing at the downstream of Krueng Kluet sub watershed in Laboratory

No	Sample Point	Parameter of Testing			
		Hg (mg/L)	Pb (mg/L)	Fe (mg/L)	Cu (mg/L)
1.	T1	0.1056	0.0001	695.1945	0.0008
2.	T2	0.6465	9.8430	881.6166	0.0008
3.	T3	0.6006	9.8667	923.6560	0.0008
4.	T4	0.4892	0.4459	851.6999	0.0008

Source: Laboratory of BARISTAND Banda Aceh, 2019

The calculation result of SQG-Q with graphic format is shown in Table 9 Figure 4. Sample point T1 obtained an SQG-Q value of 0.0503 which was classified as a heavy metal negative effect on low biota, sample point T2 obtained an SQG-Q value of 0.3372 belonging to the negative impact of heavy metals on medium biota, sample point T3 obtained an SQG value -Q of 0.354 which is classified as an adverse effect of heavy metals on medium biota, and sample point T4 obtained SQG-Q value of 0.2343 which is the negative effect of heavy metals on medium biota.

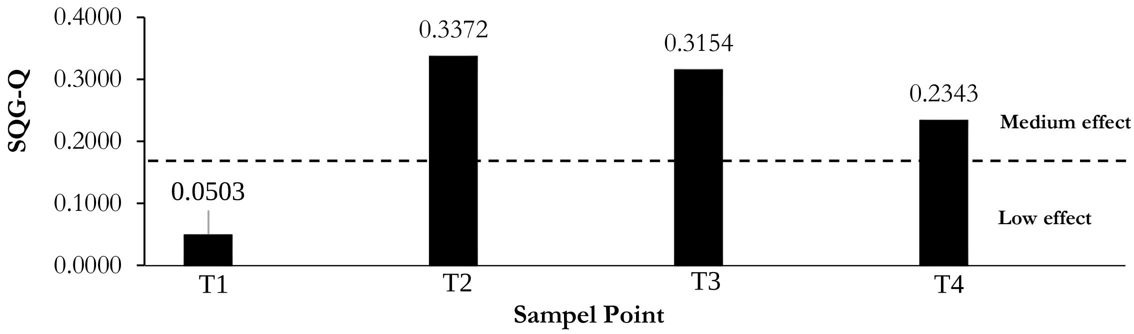

Figure 4. The Value of Calculation Result SQG-Q

Table 9. The Calculation Criteria of *Sediment Quality Guidelines* (SQG-Q)

Sample Point	Parameter	Contaminant	PEL	PEL-Qi	SQG-Q	Explanation
1	Mercury (Hg)	0.1056	0.7	0.1509	0.0503	heavy metal negative effect on low biota
	Lead (Pb)	0.0001	112	0.0000		
	Copper (Cu)	0.0008	108	0.0000		
2	Mercury (Hg)	0.6465	0,7	0.9236	0.3372	heavy metal negative effect on medium biota
	Lead (Pb)	9.8430	112	0.0879		
	Copper (Cu)	0.0008	108	0.0000		
3	Mercury (Hg)	0.6006	0.7	0.8580	0.3154	heavy metal negative effect on medium biota
	Lead (Pb)	9.8667	112	0.0881		
	Copper (Cu)	0.0008	108	0.0000		
4	Mercury (Hg)	0.4892	0.7	0.6989	0.2343	heavy metal negative effect on medium biota
	Lead (Pb)	0.4459	112	0.0040		
	Copper (Cu)	0.0008	108	0.0000		
Conclusion					0.2343	heavy metal negative effect on medium biota

Discussion

Pollution Index is a value that represented the final decision in expressing the absolute size of relative pollution levels to specify particular parameters of water quality (Nemerow and Sumitomo, 1970). Unlike other calculation approaches that measure only from one parameter, Pollution Index is used to calculate the parameters concerned to measure the level of pollution in specific uses, for example for drinking water quality, or intended for water recreation, agriculture purposes, so that it can propose control of pollutants in water.

Base on Figure 2 and Table 6, the result from the Pij calculation is stated that the quality criteria of the downstream of Krueng Kluet Sub Watershed river for drinking water standards (Class I) are classified as fairly polluted except for sample point T1. The location of sample point T4 is the main river that drains water from rivers that have mining activities nearby. Rain falling can bring iron (Fe) and copper (Cu) into the river that is close to the mining area. Iron (Fe) and copper (Cu) that get into water cause high values obtained for the Calculation of Ci/Lij. Water that has high concentrations of iron (Fe) and copper (Cu) will be dangerous if consumed as drinking water. Iron and copper poisoning can lead to genetic abnormalities in chromosomes that affect the failure of iron metabolism.

Moreover, it can damage food digestive cells, heart failure, kidney and liver damage, and death. River water treatment is essential before the water is consumed so that it can filter out the high metal concentrations in water. An example of river water treatment is by purifying water with a filter material as an absorber of metal elements so that it can simultaneously eliminate color and odor.

The calculation results of PIj for agricultural use are Class IV (Figure 3). They have fulfilled the quality standard was placed at the location of sampling point T1, namely upstream of the river, because it is located at upstream of the river and higher than the mining area so that the location of sample point T1 is possible away from the impact of gold mining activities. The site of sampling point T4 is a vast river that drains water from the location of sample points T1, T2, and T4 to the rice field area of Desa Paya Dapur. Gold mining at PT Pinang Sejati Utama uses an open-pit system. Mining systems used human power or small tractors. All activities are carried out conventionally: excavation, loading, and transportation. Mining, smelting, burning fossil fuels, and steel production are sources of mercury that can increase their presence in nature; the mining system will provide an ecological track record of water quality and sedimentation (Fernando, 2017). Surface water runoff will bring the remaining particles of mining results along the river, which causes water quality and sedimentation classified poorly, especially in the dry season (Hasrul et al., 2015).

The conclusions obtained through the calculations listed in Table 7 are the criteria in the downstream of Krueng Kluet subwatershed for agriculture (Class IV) classified as fairly polluted. Determined Pollution Index can be able to assess the quality of water bodies and take action to improve water quality if there is a decrease in quality due to the presence of pollutant compounds. The higher the Pollution Index level indicates, the worse the water quality is analyzed.

Fairey et al. (2001) propose a guideline and equation that can be employed for assessing contaminated sediments, namely Sediment Quality Guidelines (SQGs). This equation compares the concentration of sediment contaminants with the appropriate quality guidelines. It evaluates the extent to which the chemical status of sediment is negatively related and might be affected by aquatic organisms. SQGs are designed to support in interpreting sediment qualities.

Base on the Analysis shows that sample point T1 has a concentration of mercury (Hg) of 0.1056 mg/kg, sample point T2 has a concentration of 0.6465 mg/kg, sample point T3 has a concentration of 0.6006 mg/kg and sample point T4 has a concentration of 0.4892 mg/kg (Table 8). The sediment quality standard based on the Canadian Council of Ministers of the Environment (CCME, 2001) quality standard, which is 0.13 mg/kg. When compared with (CCME, 2001), the mercury parameter (Hg) for sample point T1 still meets the sediment quality standard, but exceeds the quality standard for sample points T2, T3 and T4. Sediment quality conditions can be due to the large number of mining activities that increase the concentration of mercury that already exists in nature.

The Increasing levels of heavy metals in the water that needed for various metabolic processes can turn into poisons for aquatic organisms. Heavy metals will accumulate in sediments and biota through the gravity process. Besides, the stream is an essential factor in the distribution of heavy metals in the waters. The stream speed is influenced by the depth and width of the river; the stream will be faster if the waters are narrower and shallower. The stream speed can also affect sediment textures where the strong stream is dominated by coarse particles such as sand, whereas finer mud particles dominate the slower stream. Sediment with mud texture will be easier to bind heavy metals. The deposition of heavy metals in suspended sediments will affect the quality of sediments in the bottom waters and also the surrounding waters (Harikumar et al., 2010).

Heavy metals will accumulate in sediments and biota through the process of gravity, besides the current is an essential factor in the distribution of heavy metals in water. The current velocity is influenced by the depth and width of the river. The flow will be faster when the waters are increasingly narrow and shallow. Current velocity can also affect the texture of sediments where strong currents are dominated by coarse particles such as sand, whereas for slower currents dominated by finer mud particles. Sediment with mud texture will be easier to bind heavy metals. The deposition of heavy metals in suspended sediments will affect the quality of sediments in the bottom and the surrounding.

The conclusions obtained through the calculations listed in (Table 9 and Figure 4) are the criteria for the sedimentation of the downstream of Krueng Kluet Sub-watershed classified as the negative effects of heavy metals on medium biota. The accumulation of heavy metals in sediments causes the concentration to be always higher than the concentration of metals in water. Sediments are easily suspended due to the movement of water mass, which will dissolve the metal they contain back into the water so that the sediment becomes a potential source of pollutants at a specific time scale. The Canadian Council of Ministers for the Environment (CCME, 2001) has not yet established quality standards for Fe, so it cannot be used in the Calculation of sediment quality standards using the SQGs method. Still, according to Helen et al. (2016), the standard quality of ferrous metals in sediments is 30 ppm, iron metal levels above 30 ppm, can cause hemochromatosis that is iron from food will be absorbed excessively and cannot be removed from the body.

The river can be used for irrigation with precautionary measures, but extensive care is needed before it is used for domestic use to prevent adverse public health effects. The presence of heavy metals in waters directly or indirectly endangers the life of the organism and human health (Tepe & Cebi, 2017). This relates to the properties of heavy metals that are difficult to degrade so that they are quickly accumulated in the aquatic environment, and their presence is naturally difficult to decompose.

Sediment contamination in estuaries, beaches, and coastal areas act as receivers of heavy metals through adsorption by suspended material and subsequent sedimentation contamination (Chapman et al., 1998). Sediment quality guidelines (SQGs) provide comparative values to evaluate the risk of contamination in aquatic ecosystems (Ke et al., 2017). The solution to the use of water containing pollutants that is the land has been contaminated with heavy metals can be managed by the phytoremediation method, namely the planting of several types of plants that absorb pollutants such as *mendong* plants, *paitan* and puzzles. The solution to clean water sediments polluted by heavy metals is by planting water hyacinth in the river area. Roots and leaves of water hyacinth can absorb heavy metals so that within a particular time, this can be solved.

Conclusion

River water quality in the downstream of Krueng Kluet Sub Watershed in the year 2019 has the value of the Pollution Index (PI) 6.2036 for the designation of drinking water is (Class I), and value of 6.0796 for agricultural purposes is (Class IV) classified as reasonably polluted. This is due to the concentration of ferrous metals (Fe) in the downstream of Krueng Kluet Sub Watershed is high. It showed that the water in the downstream of Krueng Kluet Sub Watershed did not fulfill the quality standard. The quality of river sediments in 2019 downstream of Krueng Kluet Sub Watershed used the Sediment Quality Guidelines (SQGs) method with a value of 0.2343 is classified as an adverse effect of heavy metals on medium biota. This is due to the concentration of iron (Fe) and mercury (Hg) in the sediments of the downstream of the Krueng Kluet Sub Watershed river. It showed that the sediment in the downstream of Krueng Kluet Sub Watershed did not fulfill the quality standard.

Mercury (Hg) for sample point T1 (Simpang Tiga) still meets the sediment quality standards, but for sample points T2 (Simpang Tiga), T3 (Mersak), and T4 (Mersak), it exceeds the quality standard. Locations T1, T2, and T4 are near to the rice field area in Desa Paya Dapur. Therefore, further preventive actions are needed to improve water quality and clean up sedimentation of water contaminated with heavy metals. Thus, it will not cause harmful effects to human health and the surrounding ecosystems in the near future.

Acknowledgments.

The authors would like to thank the editors and the reviewers for their helpful comments and suggestions. We thank Syiah Kuala University and the Ministry of Research, Technology, and Higher Education, Indonesia, for supporting and funding this research.

References

Adlim. 2016. Mercury pollution in water and the characteristics: mini review Depik, 5(1): 33-40 ISSN Cetak: 2089-7790 ISSN Elektronik: 2502-6194 DOI: http://dx.doi.org/ 10. 13170/ depik.5.1.3968.

Almiqrhi, A.A. 2018. Determination of heavy metals (Pb, Zn, Cd, Cu) in coastal sediments and fish urban area of Semarang, Indonesia. Journal of Environmental & Analytical Toxicology, 8(2): 1-9.

Boyd, C. E. 2015. Water quality: An introduction. http://dx.doi.org/10.1007/ 978-3-319-17446-4.

Chapman, P.M., Wang, F., Janssen, C., Persoone, G., and Allen, H.E. 1998. Ecotoxicology of metals in aquatic sediments binding and release, bioavailability, risk assessment, and remediation. Can. J. Fish. Aquat. Sci, 55: 2221–2243.

Decree of the State Minister for the Environment No. 115 of 2003 concerning Guidelines for Determination of Water Quality Status, Jakarta.

Fairey, R., Long, E.R., Roberts, C.A., Anderson, B.S., Phillips, B.M., Hunt, J.W., Puckett, H.R., and Wilson, C.J. 2001. An evaluation of methods for calculating mean sediment quality guideline quotients as indicators of contamination and acute toxicity tamphipods by chemical mixture. Environmental Toxicology and Chemistry, 20: 2276-2286.

Fernando P.C. 2017. Mining industry and sustainable development: time for change. Food and Energy Security; 6(2): 61–77 DOI: 10.1002/fes3.109.

Gao, X.L., and Li, P.M. 2012. Concentration and fractionation of trace metals in surface sediments of intertidal Bohai Bay, China. Mar. Sci. Bull, 64: 1529– 1536.

Government Regulation of the Republic of Indonesia decree number 82 in 2001 concerning Water Quality Standards, Management, and Water Pollution Control.

Hasrul H. H., Nor R. J., and Norfadilah, A. 2015. Water quality index and sediment loading analysis in Pelus River, Perak, Malaysia International Conference on Environmental Forensics 2015 (iENFORCE2015) ScienceDirect. Procedia Environmental Sciences, 30: 133 – 138.

Harikumar, P.S., Prajitha, K., and Silpa, S. 2010. Assessment of heavy metal contamination in the sediments of a river draining into a Ramsar Site in the Indian Subcontinent. Journal of Advanced Laboratory Research in Biology, 1: 120-127.

Helen, D., Vaithyanathan, C., and Pillai, A. R. 2016. Assessment of heavy metal contamination and sediment quality of thengapattinam estuary in kanyakumari district. International Journal of Chemical and Physical Sciences, 5: 11.

Ichwana, Syahrul, and Wirda, N. 2016. Water quality index by using national sanitation foundation-water quality index (NSF-WQI) method at Krueng Tamiang Aceh, International Conference on Technology, Innovation, and Society, Padang, ITP Press, 978-602-70570-4-3.

Islam, M.S., and Tanaka, M., 2004. Impacts of pollution on coastal and marine ecosystems, including coastal and marine fisheries and approach for management: a review and synthesis. Mar. Pollut. Bull, 48, 624–649.

Ke, X., Gui, S., Huang, H., Zhang, H., Wang, C., and Guo, W. 2017. Ecological risk assessment and source identification for heavy metals in surface sediment from the Liaohe River protected area, China. Chemosphere, 175, 473–481. http://dx.doi.org/10.1016/ j.chemosphere.2017.02.029.

Li, Q.S., Wu, Z.F., Chu, B., Zhang, N., Cai, S.S., and Fang, J.H. 2007. Heavy metals in coastal wetland sediments of the Pearl River Estuary. China. Environ. Pollut. 149: 158– 164.

Machado, W., Silva-Filho, E.V., Oliveira, R.R., and Lacerda, L.D. 2002. Trace metal retention in mangrove ecosystems in Guanabara Bay, SE Brazil. Mar. Sci. Bull, 44: 1277–1280.

Nemerow, N.L., and Sumitomo, H., 1970. Benefits of Water Quality Enhancement, Syracuse University, New York.

Praveena, S.M., Radojevic, M., Abdullah, M.H., and Avis, A.Z. 2007. Factor-cluster analysis and enrichment study of mangrove sediments – an example from Mengkabong Sabah, Malays. J. Anal. Sci. 11: 421–430.

Rochyatun, E., M. T., Kaisupy, and Rozak. A. 2006. Distribution of heavy metals in water and sediments in the waters of the Cisadene River estuary. Jurnal Makara Sains, 10: 38.

Roussiez, V., Ludwig, W., Radakovitch, O., Probst, J., Monaco, A., Charriere, B., and Buscail, R. 2011. Fate of metals in coastal sediments of a Mediterranean flood-dominated system: an approach based on total and labile fractions. Estuar. Coast. Shelf Sci, 92: 486–495

Tam, N.F.Y., and Wong, Y.S., 2000. Spatial variation of heavy metals in surface sediments of Hong Kong mangrove swamps. Environ. Pollut. 110: 195–205.

Tepe, Y., and Çebi, A., 2017. Acrylamide in environmental water: A review on sources, exposure, and public health risks. Exposure and Health. http://dx.doi.org/ 10.1007/s12403-017-0261-y.

Wu, Z., Wang, X., Chen, Y., Cai, Y., and Deng, J. 2018. Assessing river water quality using water quality index in Lake Taihu Basin, China. Science of the Total Environment, 612: 914–922. http://dx.doi.org/10.1016/j.scitotenv.2017.08.293.