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How Land Stripping Affects Quality of River in Pomalaa Nickel Mining, South East Sulawesi, Indonesia

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Abstract: Land stripping due to mining activity affects the river quality located in Pomalaa. An objective in this study is to analyze a change in water quality of rivers around Pomalaa nickel mining during and post-mining activity. The water samples were taken periodically from the rivers and developed data time series. The instrument to analyze Total Suspended Solid (TSS) was gravimeter. Meanwhile, the iron (Fe) parameter was analyzed by using spectrophotometric and Cr, Cr^{6+}, Cd, Zn, Cu, Ni, Co and Pb analyzed via atomic absorption spectroscopy (AAS) method. The pH determination was based on SNI 06-6989.11-2004 for evaluating water quality status. There are four class categories to determine water quality, where class A score is 0 (very good and has met the standard for quality), class B score is between –1 and –10 (mildly polluted), class C score is between -11 and -30 (moderately polluted), and class D score is ≥ –31 (severely polluted). The results showed that Huko-huko, Kumoro and Oko-oko rivers in Pomalaa were mildly polluted during the mining activity and moderately polluted as class II water. Total land stripping area between 2011 and 2016 was declining into 17,007 ha so that it was improving rivers quality.

Key words: Mining, land, nickel, river, Pomalaa.

Introduction

An abundant potential of metal mineral resources in Indonesia consists of ferrous and many other minerals (iron, nickel, cobalt, base metals and rare earth metals) (Nurdin et al., 2016 a,b). Pomalaa, in Southeast Sulawesi, is an area in which PT. Aneka Tambang (Antam) has mined and purified nickel since 1967 (Ilham et al., 2017). Antam is an integrated mining and metal company that explores, excavates, processes and markets minerals (Tafia et al., 2013).

In 2010, the government of Kolaka issued mining permits to 16 mining companies to mine and export nickel ore. Due to the increasing number of nickel ore export overseas, nickel ore mining has kept growing since then and thus, total land stripping area for nickel mining in Pomalaa is increasing vastly (Maryati, 2013). Several effects of mining include physical disturbance, land stability, erosion, sedimentation and flooding.

Being aware of how much damage mining causes to the environment and how little contribution nickel ore export to the national economy, Indonesian government

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issued some regulations where mining companies are obliged to build a smelter and prohibited nickel ore export to foreign countries. Based on the regulation, nickel mining for exports has stopped since 2014, causing 14 companies to stop mining and exporting nickel ore.

Nickel mining taking place in Pomalaa prior to 2014 resulted in vast land stripping area and declining river quality. After nickel mining for export was prohibited in 2014, the land stripping is decreasing and quality of the river is improving. The investigation of heavy metals in water and sediments could be used to assess the anthropogenic and industrial impacts and risks posed by waste discharges on the river in an ecosystem (Zheng et al., 2008; Yi et al., 2011; Saleem et al., 2015). Therefore, it is important to measure the concentrations of heavy metals in water and sediments of any contaminated river in an ecosystem (Mohammad et al., 2016).

The objective of the study was to analyze changing land stripping area and quality of water in the rivers located in Pomalaa nickel mining in South East Sulawesi, as a reference for improving the environment and ecosystem in the area.

Experimental Method

The study was conducted by analyzing land stripping map in Pomalaa nickel mining area and taking water from the rivers around the mining area as samples periodically between 2011 and 2016. The samples were analyzed in Health Laboratory of Kendari. The instruments to analyze Total Suspended Solid (TSS) were gravimeter, one to analyze iron (Fe) parameter was spectrophotometric, parameter for Cr, Cr^{6+}, Cd, Zn, Cu, Ni, Co and Pb analyses was the AAS method, and pH based on SNI 06-6989.11-2004 was the parameter for evaluating water quality status.

Based on the samples, taken periodically, STORET method was conducted to determine the water quality. A goal of STORET is to compare between the water taken from certain sites (sample) and standardized water quality, which has been adjusted to its designation. Using STORET as a method for analysis has been stated in the Minister of Environment Decree No. 115/2003 (Hefni et al., 2013). Procedures of the STORET analysis is as follow:

(a) Collecting data on water quality and debt periodically, developing time data series.
(b) Using each water parameter to make a comparison between the data and the standardized water quality parameter that matches the water class.
(c) When the standard is met (analysis result ≤ standardized quality), the score is 0.
(d) When the standard is not met (analysis result > standardized quality) Table 1 is used as a reference for scoring.
(e) All negative scores from all parameters are collected and based on the total scores, water quality can be determined.
(f) There are four classes that determine water quality, namely:
   1. Class A: Score is 0, categorized as very good and has met the standard for quality.
   2. Class B: Score is between –1 and –10, mildly polluted.
   3. Class C: Score is between –11 and –30, moderately polluted.
   4. Class D: Score is ≥ –31, categorized as poor (quality) and severely polluted.

Results and Discussion

Nickel mining in Pomalaa has caused changing land stripping area. Figure 2 shows total land stripping area around Pomalaa nickel mine in 2009, 2013 and 2016.

Table 1: Scoring system for water quality status

Number of parameter	*Score*	*Parameter*		
		Physical	*Chemical*	*Biological*
< 10	Maximum	-1	-2	-3
	Minimum	-1	-2	-3
	Average	-3	-6	-9
≥ 10	Maximum	-2	-4	-6
	Minimum	-2	-4	-6
	Average	-6	-12	-18

Source: Hefni et al. (2013)

Figure 1: Nickel mining area in Pomalaa, Indonesia as setting of the study.

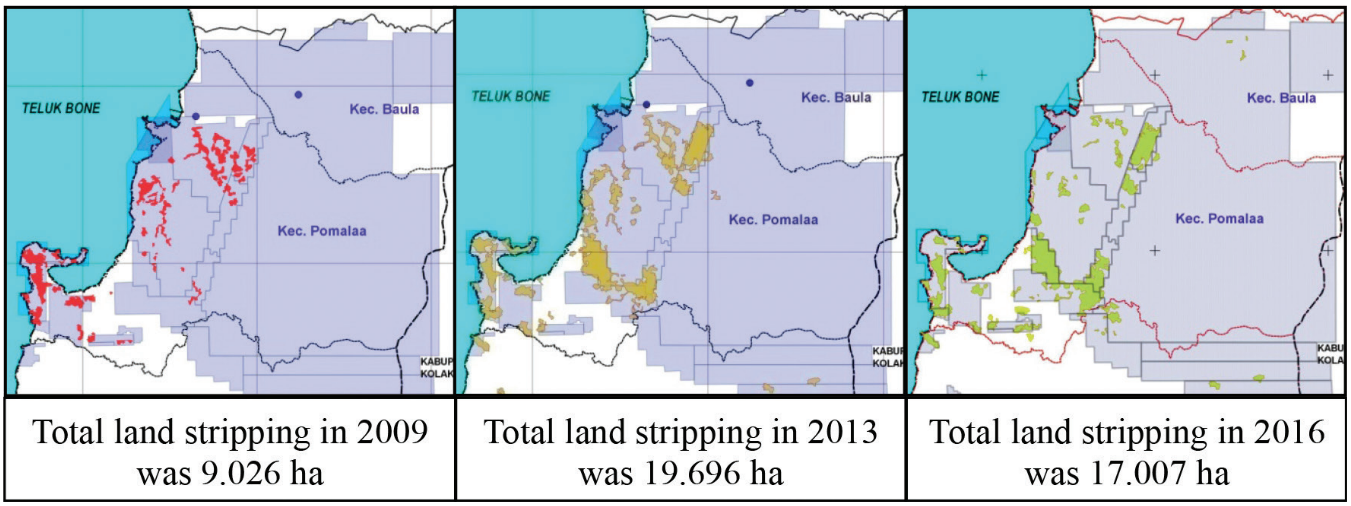

Figure 2: Changing land stripping area in 2009, 2013 and 2016.

Table 2: Water quality in rivers around Pomalaa nickel mining

Location	*Time*	*TSS (mg/L)*	*pH*	*Fe (mg/L)*	*Cr (mg/L)*	*$Cr^{(6+)}$ (mg/L)*	*Cd (mg/L)*	*Zn (mg/L)*	*Cu (mg/L)*	*Ni (mg/L)*	*Co (mg/L)*	*Pb (mg/L)*
Huko-huko River	12-Aug-12	35	7.8				0.03		0.01		0,2	
S: 04° 10′ 29.0″	26-Jun-13	44.2	7.4				0.052		0.017			
E: 121° 38′ 57.8″	02-Apr-14	14	7				0.03	0.11	0.015			0.003
	12-Mar-15	82	7.91				0.015	0.008	0.006			0.011
	11-Dec-16	190	7.98	0.54	0.0088	0.0065	0.0072	0.0239	0.0086	0.0296	0.0286	0.0016
Kumoro River	17-Dec-12	24	6.9				0.003		0.001		0.001	
S: 04° 11′ 43.9″	26-Feb-13	31	7			0.57	0.021		0.018			
E: 121° 35′ 58.0″	12-Dec-13	20	7			0.008	0.008		0.016			0.016
	11-Jun-14	7.5	6.5	0.063			0.01	0.14	0.24		0.022	0.017
	24-Dec-14	30	7.64	0.003			0.017	0.01	0.01			0.025
	26-May-15		6.9				0.003	0.003	0.012			0.048
	29-Jun-15	18	7.77	0.004			0.004	0.001	0.01			
	31-Jul-15	26	8.84				0.003	0.005	0.004			0.023
	29-Aug-15		7.3				0.01	0.001	0.003			0.001
	27-Oct-15	26	7.43					0.005	0.011			
	27-Nov-15	0.048	8.19				0.005	0.004	0.017		0.034	
	29-Dec-15	0.372	7.43				0.005	0.005	0.005			
	29-Jan-16	16	7.08				0.011	0.001	0.018	0.054	0.009	0.003
	11-Dec-16	43	7.99	0.4	0.0025	0.0021	0.0022	0.0096	0.0014	0.0128	0.0033	0.0008
Oko-oko River	21-Jan-11		8.4	0.15			0.001		0		0	0
S: 04° 17′ 41.9″	17-Feb-11		8.9	0			0		0.02		0.014	0
E: 121° 33′ 35.1″	14-Aug-12	48	6.9				0.01		0.01		0.02	
	26-Jun-13	20	7.2				0.075		0.016			
	26-Mar-14	54	7				0.021	0.47	0.019			0.007
	08-Jul-14	43	8.4	0.002			0.11	0.01	0.2		0.22	0.032
	12-Mar-15	88	8.04				0.01	0.005	0.028			0.024
	11-Dec-16	53	7.11	0.36	0.0106	0.0117	0.0105	0.0317	0.0085	0.031	0.0162	0.0012
Standardized quality during mining activities		200	6-9	5	0.5	0.1	0.05	5	2	0.5	0.4	0.1
Standardized quality of Class II water		50	6-9	0.3		0.05	0.01	0.05	0.02		0.2	0.03

Source: BLHK of Kolaka and the result of measurement, 2016

Land stripping area was increasing as nickel mining is growing but it is decreasing after the Decree number 4/2009 that prohibited nickel ore mining after 2014. After the decree, many nickel mining stopped their activities. The highest mining activities and fastest land stripping have occurred between 2010 and 2014. The total land stripping in 2009 was 9,026 ha, and it then increased more than twice into 19,696 ha in 2013 and slightly decreased into 17,007 ha in 2016.

Because of nickel mining in Pomalaa, the study analyzed water quality in the area periodically by identifying how polluted the river is because of land stripping. The rivers where samples were taken were Huko-huko, Kumoro and Oko-oko rivers. They were selected based on the standard of river water quality in mining and nickel industry area according to the Regulation of Minister of Environment No. 9/2006 on discharge standards for nickel ore business/mining activity (Rahmawati and Widyastuti, 2013), and Government Regulation No. 82/2001 on water quality management and water pollution control (Hefni et al., 2015). Table 2 describes the result of the analysis on water quality in the rivers around Pomalaa nickel mining between 2011 and 2016.

Quality Standard: Regulation of Minister of Environment No. 9/2006 on discharge standards for business/ore mining nickel activity. Government Regulation No. 82/2001 on Water Quality Management and Water Pollution Control.

Figures 3 to 7 describe several parameters identifying a change in water quality in the rivers during nickel ore mining and export between 2011 and 2014, as well as water quality in the rivers after the nickel ore mining and export in 2015 and 2016.

TSS concentration on the rivers located in Pomalaa nickel mining did not show significant change between the years when nickel mining took place and the years after it had stopped. Rainfall has a more significant influence towards TSS concentration in the river because it causes sediment (mudflow and fine sand into the river).

Effendi (2003) stated that TSS is suspended materials of which diameter is >1 μm retained on millipore sieve with a pore diameter of 0.45 μm. TSS is generally mud and fine sand and a variety of microorganisms, which is naturally caused by the erosion of soil and erosion into the body of water. Casali et al. (2010) described that sediment in runoff from forest land was strongly influenced by mining activities, where at the time of mining the amount of sediment in the water had increased.

Sediment quality has been used as an important indicator of pollution since they are considered as a major sink for various pollutants. In addition, sediments

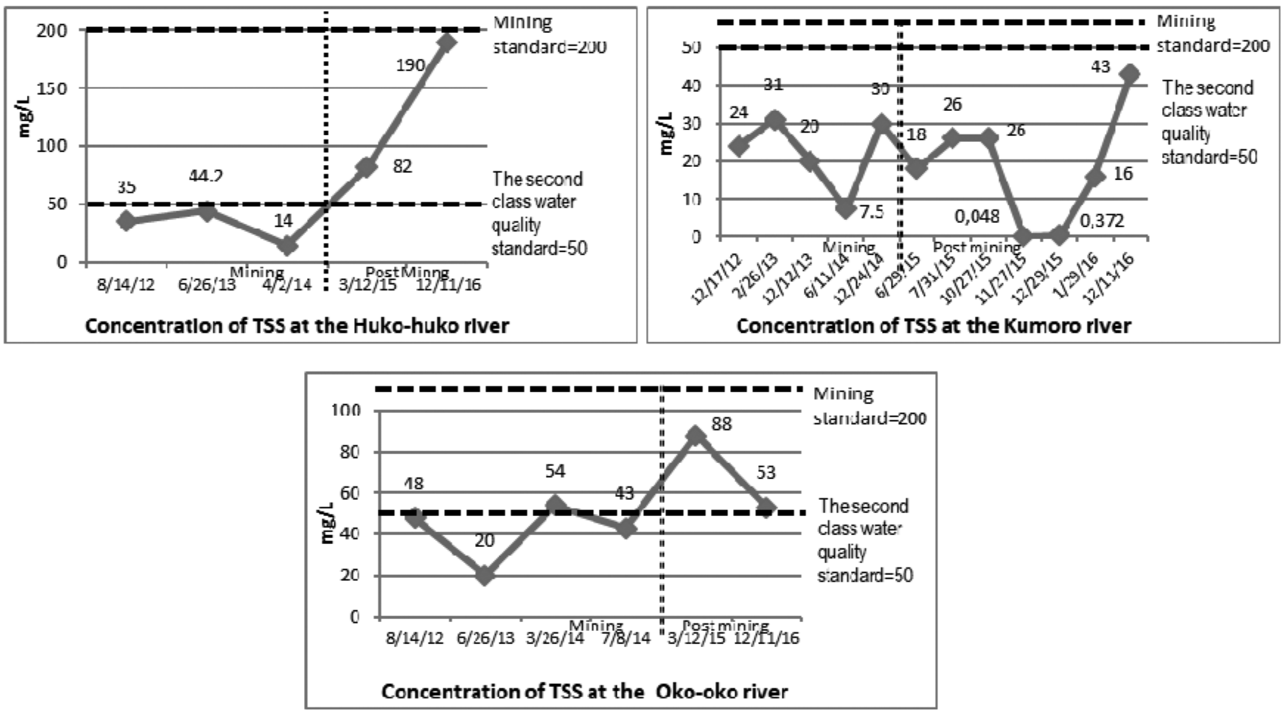

Figure 3: TSS concentration in Huko-huko, Kumoro and Oko-oko rivers.

are normally mixtures of several components and they can play a significant role in remobilization of contaminants in aquatic systems and interactions between water and sediments (Zarei et al., 2014). In the aquatic environment, sediments have been widely used as environmental indicators for the assessment of metal pollution in the natural water (Islam et al., 2015). The principal content of metals is a function of the suspended sediment composition and water chemistry in the natural water body (Mohiuddin et al., 2012).

Pomalaa nickel ore mining really influenced Cd concentration in the three rivers. The highest Cd concentration took place between 2012 and 2014 during the nickel ore mining, and later it decreased when the mining stopped in 2015. When the mining was taking place, Cd concentration in Huko-huko was between 0.03-0.052 mg/L and decreased into 0.0072 mg/L to 0.015 mg/L when the mining was over. In Kumoro river, Cd concentration when the mining took place was between 0.003 mg/L and 0.021 mg/L, and declined to 0.0022 mg/L to 0.011 mg/L when the mining was over. Cd concentration in Oko-oko river during the mining was between 0 mg/L and 0.11 mg/L and slightly changed to 0.01 mg/L when the mining was over.

Cadmium (Cd) is a type of heavy metal spread in nature. The importance of each source varied by metal; mine waste pile runoff contributed 70% of Cd, while mine drainage contributed 90% of Pb, and both sources contributed similarly to Zn loading (Laurel et al., 2014). Tarigan et al. (2003) explained Cd is poisonous and has a negative effect towards all living organisms including human being. Dissolved Cd in 1 ppm concentration can kill aquatic biota. Hefni et al. (2016) postulated that cadmium (Cd) is one of harmful heavy metals for human blood vessels and may accumulate in vital organs, especially in liver and kidney.

Zn concentration in the river is heavily influenced by Pomalaa nickel mining. When the mines were in operation, Zn concentration in Huko-huko river was 0.11 mg/L and decreased sharply to 0.008-0.0239 mg/L when the mines closed. Zn concentration in Kumoro river was between 0.01 mg/L and 0.14 mg/L when the nickel mines were in operation and declined between 0.001 mg/L and 0.0096 mg/L when the mines closed. A similar phenomenon took place in Oko-oko river in which there was declining Zn concentration post nickel mining. When the mines were in operation, Zn concentration in the river was between 0.01 mg/L and 0.47 mg/L and dived between 0.005 mg/L and 0.0317 mg/L when the mines closed.

In high concentration, Zn is poisonous but in lower concentration, it functions as co-enzyme for the organism (Tarigan et al., 2003). Although mining operations removed much of the metal ore, the mine waste material remains elevated in labile Zn, Pb and Cd, especially in fine particle size fractions (Schaider et al., 2007).

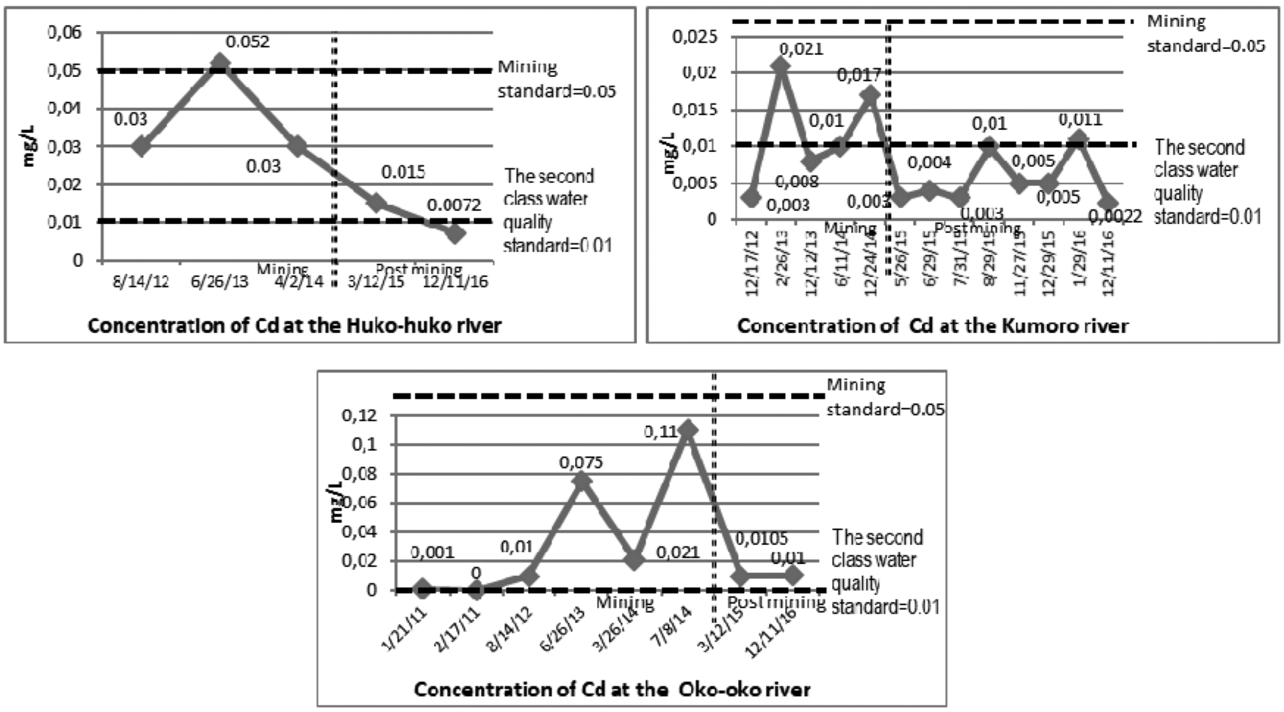

Figure 4. Cd concentration in Huko-huko, Kumoro and Oko-oko rivers.

Between 2011 and 2014 when the nickel ore mines were still operating in Pomalaa, the higher Cu concentration was found in Huko-huko, Kumoro and Oko-oko rivers. During the years, Cu concentration in Huko-huko river was between 0.01 mg/L and 0.017 mg/L, that in Kumoro river was between 0.001 mg/L and 0.24 mg/L, and that in Oko-oko river was between 0 mg/L and 0.2 mg/L. When the mines closed in 2015,

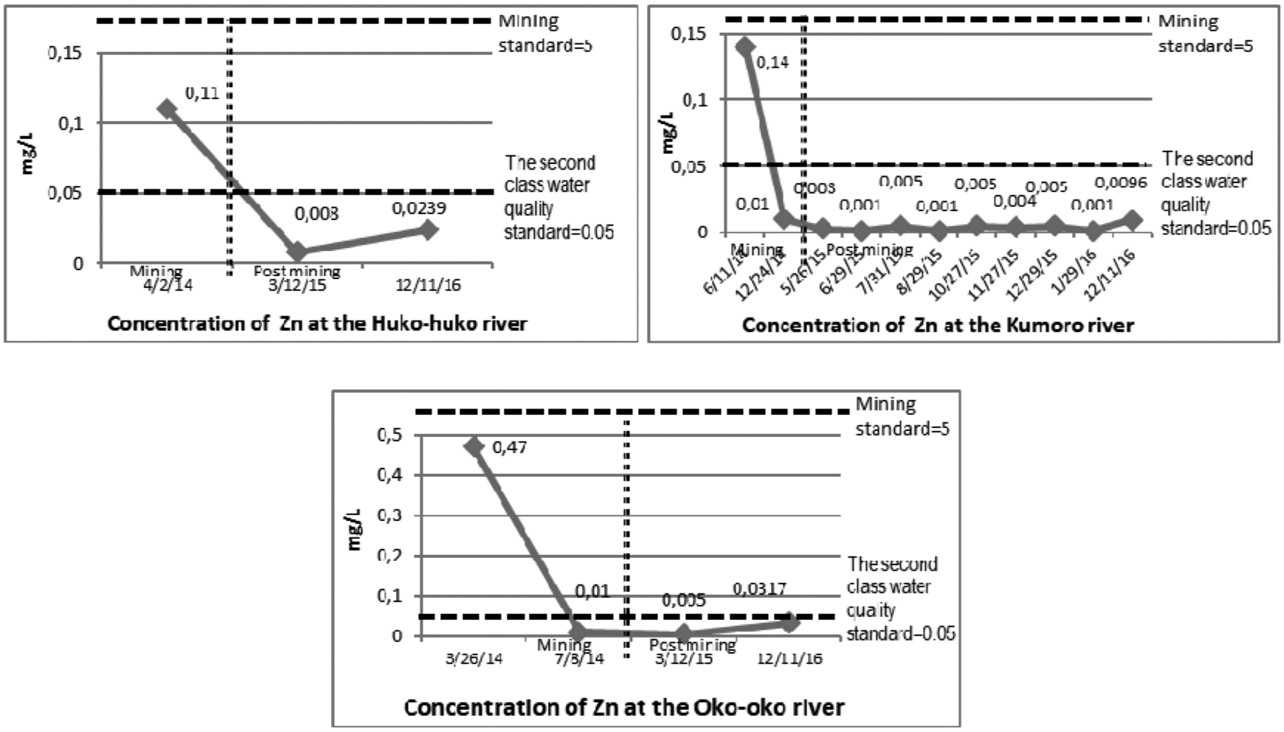

Figure 5: Zn concentration in Huko-huko, Kumoro and Oko-oko rivers.

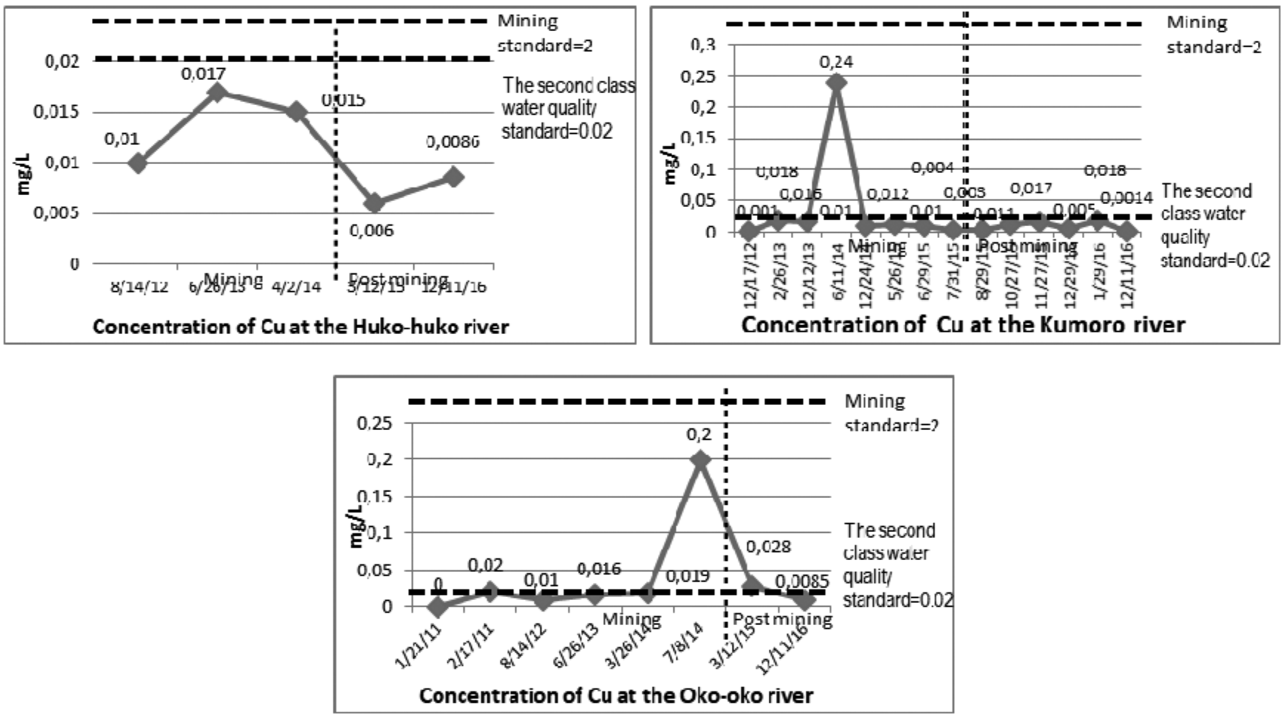

Figure 6: Cu concentration in Huko-huko, Kumoro and Oko-oko rivers.

Cu concentration in the rivers was decreasing. Cu concentration in Huko-huko river was between 0.006 mg/L and 0.0086 mg/L, that in Kumoro river was between 0.0014 mg/L and 0.018 mg/L, and that in Oko-oko river was between 0.0085 mg/L and 0.028 mg/L.

Copper (Cu) is one kind of heavy metal found in water and sediments (Anazawa et al., 2004). Cu is categorized as essential metal in which it functions as co-enzyme for metabolism for living organism in the low concentration; Cu is not poisonous unless it is found in high concentration (Rochayatun et al., 2003).

When the mines were still operating, Pb concentration in Huko-huko river reached 0.003 mg/L, that in Kumoro river was between 0.016 mg/L and 0.025 mg/L, and that in Oko-oko river was between 0 mg/L and 0.032 mg/L. When the mines closed in 2015, Pb concentration in the rivers was decreasing. Pb concentration in Huko-huko river was between 0.0016 mg/L and 0.011 mg/L, that in Kumoro river was between 0.0008 mg/L and 0.048 mg/L, and that in Oko-oko river was between 0.0012 mg/L and 0.024 mg/L.

In the three rivers, Pb concentration had exceeded standardized Pb concentration for class II water. However, it was still lower than standardized Pb concentration for mining water. One should pay close attention to Pb concentration in nature as, according to Hefni et al. (2016), Pb and As may cause the significant ecological effect on the sediment surface.

Heavy metals that leached out from these disposal points may contaminate the groundwater, as well as surface water resources around nearby areas, and could affect the health and livelihood of the local population (Tiwari et al., 2015).

The water samples from the three rivers were analyzed using STORET method to meet the requirement of the Decree of Minister of Environment No. 115/2003 on Guidelines for Determination of Water Quality Status.

Based on Table 3, between 2011 and 2014, the three rivers located in Pomalaa nickel mines area were mildly polluted. Using class II water standard, Huko-huko river was mildly polluted, Kumoro river was severely polluted and Oko-oko river was mildly polluted. Based on the 2015 and 2016 analysis, water from the three rivers had met the standardized quality of water for mining areas but when class II water standard was used as an indicator, the rivers were mildly polluted.

The nickel mining highly affects water quality in Huko-huko, Kumoro and Oko-oko rivers. The quality was improving when the nickel mines were no longer in operation. In addition, the total area of land stripping was also declining between 2015 and 2016.

Several kinds of literature cited the importance of water quality index application in determination of river water quality status. Water quality index plays a major role in water quality assessment of a given source as a function of time and other influencing factors (Poonam et al., 2013).

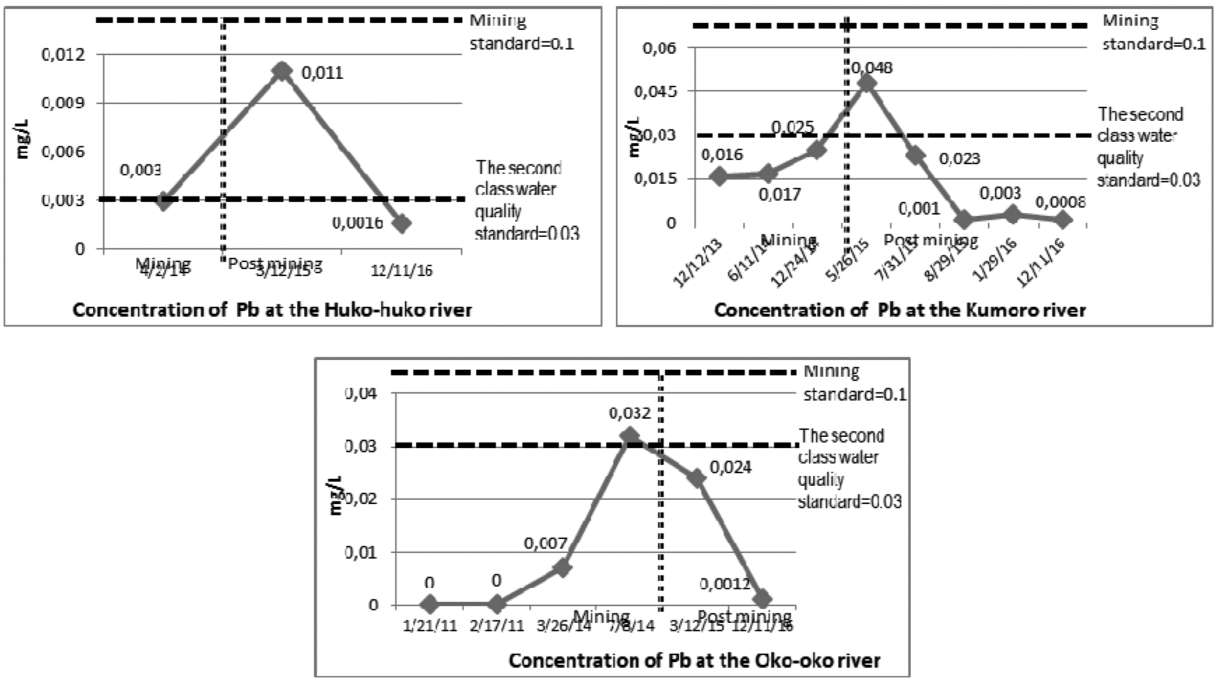

Figure 7: Pb concentration in Huko-huko, Kumoro and Oko-oko rivers.

Table 3: Water quality status in Pomalaa rivers

River Name	2011-2014				2015-2016			
	Mining		As Class II Water		Mining		As Class II Water	
	Score	Evaluation	Score	Evaluation	Score	Evaluation	Score	Evaluation
Huko-huko	-2	Mildly polluted	-10	Mildly polluted	0	Met the standard	-7	Mildly polluted
Kumoro	-8	Mildly polluted	-32	Severely polluted	0	Met the standard	-6	Mildly polluted
Oko-oko	-2	Mildly polluted	-28	Moderately polluted	0	Met the standard	-9	Mildly polluted

Source: The result of calculation, 2017

Conclusion

Changing land stripping area, as the cause of nickel mining, influences quality of water in the rivers located in Pomalaa. In 2013, the total land stripping area was 19,696 ha. Based on the standard of water quality in the mining area, Huko-huko, Kumoro and Oko-oko rivers are mildly polluted. On the other hand, using class II water standard as the indicator, Huko-huko river is categorized as class II water, Kumoro river was severely polluted and Oko-oko river is moderately polluted.

In 2016, the total land stripping area in Pomalaa decreases into 17,007 ha, improving the quality of three rivers. Based on the standardized quality for mining, Huko-huko, Kumoro and Oko-oko rivers have met the standard. On the other hand, using class II water standard as a parameter, Huko-huko, Kumoro and Oko-oko rivers are mildly polluted.

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