Surface Water Quality Analysis on the Bauxite Mining Operations in Central Kalimantan

by Barlian Dwinagara

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Abstract. Environmental contamination, especially the degradation of surface water quality as an impact of bauxite mining activity becomes a severe problem for the environment in Central Kalimantan Province, Indonesia. One of the impacts of bauxite mining is red mud that causes the degradation of surface water quality. Therefore, the purpose of this research was to determine the effectiveness of environmental management activities in Central Kalimantan. Pollution Index retrieved from the surface water samples taken from Keruing River, Icik River, and Cempaga Hulu River was implemented as the analysis method in this research. The results of surface water quality analysis showed that the pollution index for Keruing River, Icik River, and Cempaga Hulu River were 2.64, 2.62, 2.66 respectively. The pollution index results between 1-5 indicated that all rivers were in the light pollution category. In conclusion, the environmental management in this area is still required to improve the surface water quality by creating a good management system for wastewater generated from mining activities.

INTRODUCTION

Recently, the environmental contamination as the effect of mining activities is becoming a highly noticeable issue. One of the issues is the degradation of surface water quality from the red mud waste. Red mud is the residue or waste materials derived from the processing of bauxite for alumina production. Red mud is usually produced from Bayer Process. Leachate that comes out from red mud carries elements and compounds, where these elements and compounds can be hazardous for environment if mixed with surface water.

One of the regions in Indonesia which has a relatively large bauxite reserve in Central Kalimantan Province. Exploration, exploitation, and processing activities of bauxite into alumina are mostly carried out in Central Kalimantan Province. Environmental management is done by some parties in Central Kalimantan Province to minimize environmental contamination. The environmental management conducted to reduce the contamination. i.e., waste treatment, remediation pond, etc. Therefore, this research is needed to identify the effectiveness of environmental management activities in Central Kalimantan Province.

LITERATURE REVIEW

Bauxite deposits ($Al2O3.3H2O$, with the mineral name 'gibbsite') among of the potential mineral resources in Indonesia. Regarding the processing of bauxite ore into alumina ($Al2O3$), one of the most critical concerns is the waste from the bayer process called red mud [1]. Red mud is the residue or waste material that comes from bauxite processing for alumina production. From 1 tonne of bauxite processing will produce about 0.8 - 1.5 tonnes of red mud.

As a solid waste, red mud well defined in the form of wet or dry mud, which is stored in a pond. The rapid development of the alumina industry globally makes red mud becomes one of the environmental problems, prominently due to its large number and strong alkaline properties with pH around 10 - 13 [2]. The Bayer process is the most reliable method until recent years to process alumina (Al2O3) from bauxite ore. The waste-derived from this process is in the form of red mud. However, if this sludge unmanaged in a planned manner, it can cause adverse environmental impacts [3]. The average red mud content of various bauxite industries in the world is as follows: Al2O3 10-22%, Fe2O3 14-35%, SiO2 3-10%, TiO2 7-15%, caustic soda 3-13%, lime (lime) 2-18% and minor elements (e.g.. Hg. Cd. U. and Th) [4]. High Na concentration and basicity in red mud are considered a critical note because it affects both in the short and long term. In the short term, the high solubility of Na affects the quality of red mud leachate if it is left untreated, has the risk of causing water and groundwater pollution [5]. The Pollution Index (PI) used for surface water characteristic analysis and to evaluate the pollution in the river where red mud was disposed. PI is a calculation method used to measure the stage of relative pollution to the permissible water standart parameters [6].

METHODOLOGY

The mining and processing sites for bauxite ore in Sudan Village and Keruing Village, Cempaga Hulu District, Kotawaringin Timur District, Central Kalimantan Province was selected for surface water sampling where environmental management activities had been done in these locations.

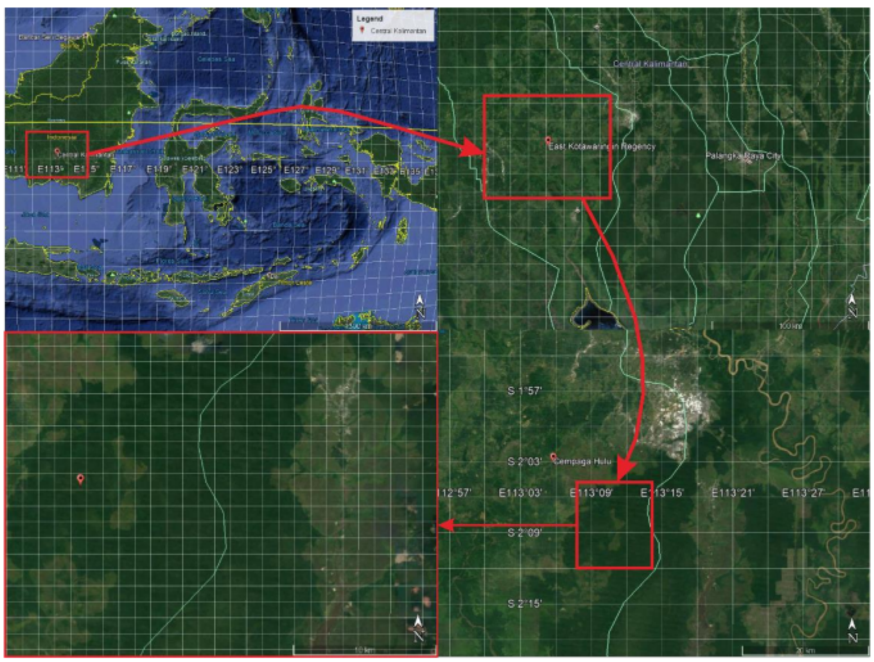

FIGURE 1. Research location

There were three samples taken from Keruing River, Icik River, and Cempaga Hulu River that shown in figure 2. Sampling was done by taking 3-liters water, which was divided into two bottles, each bottle contained of 1.5-liters water. The solution HNO_3 was added to one of the bottles until the pH turns acidic, namely at pH 2. It was intended to preserve the heavy metals in the sample. Samples then analyzed in Center for Environmental Health Engineering and Disease Control Yogyakarta Laboratory using Atomic Absorption Spectrophotometry method.

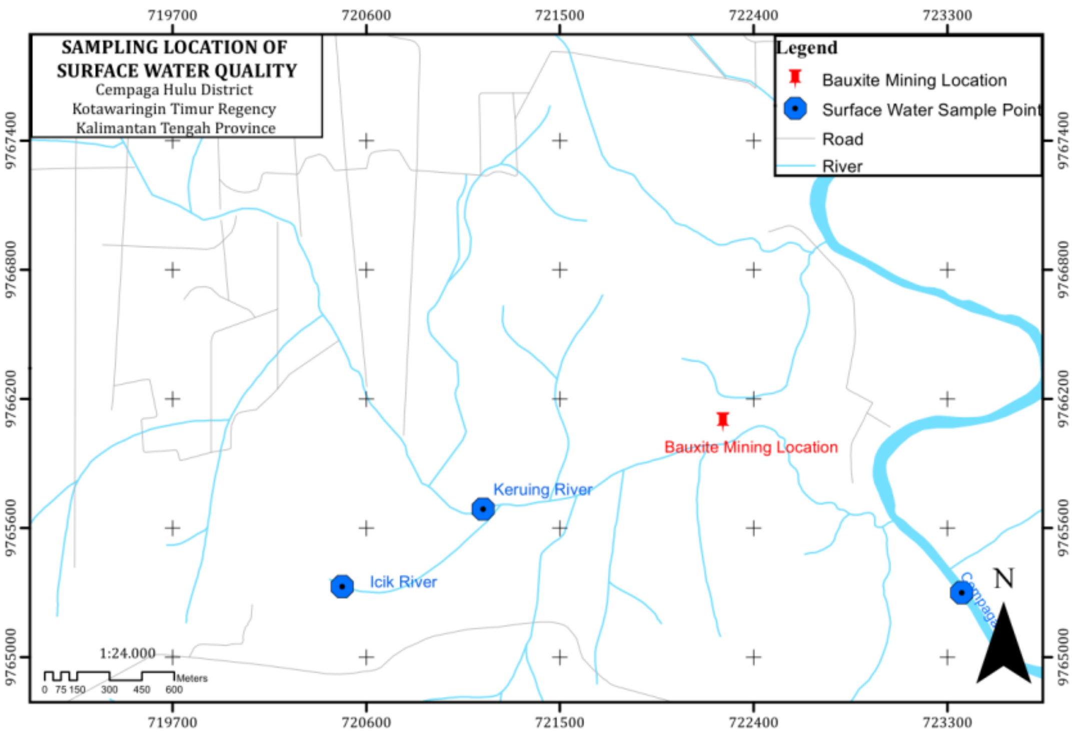

FIGURE 2. Water sampling location

The results of laboratory analysis were then analyzed using the PI calculation method. According to Ministerial Regulation of The Environment No. 115/ 2003, the PI is persevering for a reference and afterward it can be further developed for several uses related to all parts of a water body or a part of a river [7]. The decision-makers obtain insights to enable them to assess the characteristic of water bodies for a reference and plan to fix the water characteristic from the PI result whenever the degradation quality occurs due to the presence of polluting compounds. The PI formula is as follows:

$$\sqrt{\frac{\left(\frac{Ci}{Lij}\right)_M^2 + \left(\frac{Ci}{Lij}\right)_R^2}{2}}$$

Description: PI = Pollution index

$(Ci / Lij)_M$ = Maximum value of Ci / Lix

$(Ci / Lij)_R$ = Average value of Ci / Lix

Doubt arises if the two values (Ci / Li) are close to the reference value 1.0, for example C1 / L1j = 0.9 and C2 / L2j = 1.1 or the difference is very large, for example C3 / L3j = 5.0 and C4 / L4j = 10.0. In this model, the damage level of water bodies is complicated to be determined. The ways to overcome this difficulty are:

New (Ci / Lij) = 1.0 + P.log (Ci / Lij) measurement result

P is a constant and its value is determined independently and adjusted to the results of environmental observations and, or the desired requirements for a designation (usually the value is 5).

The PI value is then used to persevering water characteristic, with an evaluation of the PI value: $0 \leq PIj \leq 1.0$ meets quality standards (good condition) $1.0 < PIj \leq 5.0$ lightly polluted $5.0 < PIj \leq 10$ moderate polluted $PIj > 10$ heavily polluted. The environmental quality standard used for calculating the PI value is according to Government Regulations No. 82/2001 concerning level II Water Standart Management and Water Contamination Control [8].

RESULTS AND DISCUSSION

According to Indonesia Government Regulation (PP) No. 82/2001 [8] and the results of sampling carried out in 2019 and laboratory analysis, the results were obtained as in **TABLE-1** below:

TABLE 1. Surface Water Quality Test Result at the Sampling Location

No.	Parameter	Unit	Test results			BML
			Keruing River	Icik River	Cempaga Hulu River	PP 82/2001 Level II
1	pH	-	2.4	2.6	2.4	6.0-9.0
2	Biochemical Oxygen Demand (BOD)	mg / L	4.3	8.2	5	3
3	Chemical Oxygen Demand (COD)	mg / L	43.2	75.8	46.1	25
4	Dissolved Oxygen (DO)	mg / L	7.2	7.6	6.9	> 4
5	Total Phosphate (P)	mg / L	0.051	0.240	0.194	0.2
6	NO3 as N	mg / L	0.34	0.29	0.44	10
7	Arsenic (As)	mg / L	<0.005	<0.005	<0.005	1
8	Cobalt	mg / L	<0.0093	<0.0093	<0.0093	0.2
9	Selenium (Se)	mg / L	<0.0006	<0.0006	<0.0006	0.05
10	Cadmium (Cd)	mg / L	<0.0034	<0.0034	<0.0034	0.01
11	Chrome (VI)	mg / L	<0.0014	<0.0014	<0.0014	0.05
12	Copper	mg / L	<0.0069	<0.0069	<0.0069	0.02
13	Lead	mg / L	<0.0161	<0.0161	<0.0161	0.03
14	Zinc	mg / L	<0.0083	0.0128	<0.0083	0.05
15	Chloride (Cl)	mg / L	2.0	<0.6	2.0	600
16	Cyanide	mg / L	<0.0070	<0.0070	<0.0070	0.02
17	Iron (Fe)	mg / L	0.728	0.6594	0.6594	(-)
18	Manganese (Mn)	mg / L	0,0102	0,0102	0,0102	(-)
19	Nickel (Ni)	mg / L	0,0061	0,0061	0,0061	(-)
20	Fluoride (F)	mg / L	<0.0308	<0.0308	0.1076	1.5
21	Nitrite as N	mg / L	0.0026	0.0106	0.0049	0.06
22	Free chloride	mg / L	<0.03	<0.03	<0.03	0.03
23	Sulphur as H_2S	mg / L	<0.0046	<0.0046	<0.0046	0.002
24	Detergent as MBAS	μg / L	48.4	105.70	61.8	200
25	Phenolic Compounds as Phenols	μg / L	<0.0215	<0.0215	<0.0215	1
26	Temperature	° C	25.1	25.1	25.1	air temperature ± 3
27	Dissolved Residue (TDS)	mg / L	861	671	935	1000
28	Suspended Residue (TSS)	mg / L	10	13	9	50
29	Total Coliform	Amount / 100 mL	1600.10^1	21.10^1	$<1.8.10^0$	5000
30	Faecal Coliform	Amount / 100 mL	23.10^1	$<1.8.10^0$	$<1.8.10^0$	1000

Source: Laboratory for Environmental Health and Disease Control Engineering. 2019

The laboratory analysis results were then compared with the environmental quality standards according to PP No. 82/2001 for level II water designation [8]. In general, the river water conditions at the sampling location were in good condition since many parameters were still below the quality standard, however some parameters such as BOD and COD exceeded the environmental quality standard (BML). The BOD and COD values of river water can indicate the number of organic pollutants in the river water. BOD provides an overview of how much oxygen used by microbial activity during a specified time [9]. The greater the BOD value is, the greater the level of water pollution by organic matter will be.

Meanwhile, COD indicates all organic materials that are easy or that are difficult to decompose. COD and BOD values that exceed environmental quality standards in the Keruing River, Icik River, and Cempaga Hulu River are not affected by bauxite mining activities. According on Indonesia Regulation of the State Minister for the Environment No. 34/2009 concerning Wastewater Quality Standards for Bauxite Ore Mining Business and, or Activities in Attachment I and Attachment II, the parameters affected by bauxite mining and processing activities are as follows [10]:

TABLE 2. Wastewater Quality Standards for Bauxite Ore Mining Activities

No.	Parameter	Unit	Test results			BML
			Keruing	Icik	Cempaga Hulu	Permen LH 34/2009 Attachment 1
1	pH	-	2.4	2.6	2.4	6.0-9.0
2	TSS	mg / L	10	13	9	200
3	Fe	mg / L	0.728	0.6594	0.6594	5
4	Mn	mg / L	0.0102	0.0102	0.0102	2

TABLE 3. Wastewater Quality Standards for Bauxite Ore Processing Activities

No.	Parameter	Unit	Test results			BML
			Keruing	Icik	Cempaga Hulu	Permen LH 34/2009 Attachment II
1	pH	-	2.4	2.6	2.4	6.0-9.0
2	TSS	mg / L	10	13	9	200
3	Fe	mg / L	0.728	0.6594	0.6594	5
4	Cu	mg / L	0.0069	0.0069	0.0069	2
5	Ni	mg / L	0,0061	0,0061	0,0061	0.5
6	Mn	mg / L	0.0102	0.0102	0.0102	2
7	Pb	mg / L	0.0161	0.0161	0.0161	0.1

Based on **TABLE 2** and **TABLE 3** above, it proves that all parameters affected by mining and bauxite ore processing activities are still in good condition because they are still below the required quality standards. The results of laboratory analysis were then used to calculate the Pollution Index (PI) value. The results of PI calculations for Keruing River, Icik River, and Cempaga Hulu River were as follows:

TABLE 4. Pollution Index Calculation Results at the Research Location

No.	Parameter	Li	Analysis Results								
			Keruing			Icik			Cempaga Hulu		
			Ci	Ci/Li	New Ci / Li	Ci	Ci/Li	New Ci / Li	Ci	Ci/Li	New Ci / Li
1	TSS	50	10	0.200	0.200	13	0.260	0.260	9	0.180	0.180
2	TDS	1000	861	0.861	0.861	671	0.671	0.671	935	0.935	0.935
3	pH	6-9	2.4	3.400	3.657	2.6	3.267	3.571	2.4	3.400	3.657
4	BOD	3	4	1.433	1.782	8.2	2.733	3.183	5.0	1.667	2.109
5	COD	25	43.2	1.728	2.188	75.8	3.032	3.409	46.1	1.844	2.329
6	DO	4	7.2	0.650	0.650	7.6	0.700	0.700	6.9	0.613	0.613
7	Phosphate	0.2	0.051	0.255	0.255	0.240	1.200	1.396	0.194	0.970	0.970
8	Nitrate	10	0.34	0.034	0.034	0.29	0.029	0.029	0.44	0.044	0.044
9	Fluoride	1.5	0.0308	0.021	0.021	0.0308	0.021	0.021	0.1076	0.072	0.072
10	Lead	0.03	0.0161	0.537	0.537	0.0161	0.002	0.002	0.0161	0.537	0.537

11	Copper	0.02	0.0069	0.345	0.345	0.0069	0.345	0.345	0.0069	0.345	0.345
12	Chrome	0.05	0.0014	0.028	0.028	0.0014	0.000	0.000	0.0014	0.028	0.028
13	Cadmium	0.01	0.0034	0.340	0.340	0.0034	0.340	0.340	0.0034	0.340	0.340
14	Cyanide	0.02	0.0070	0.350	0.350	0.0070	0.350	0.350	0.0070	0.350	0.350
15	Nitrite	0.006	0.0026	0.433	0.433	0.0106	1.767	2.236	0.0049	0.560	0.560
Ci / Li average				0.78			1.10			0.87	
Maximum Ci / Li				3.66			3.57			3.66	
PI value				2.64			2.64			2.66	

The table above indicates that the PI value for the Keruing River is 2.64, the PI value for the Icik River is 2.64 and the PI value for the Cempaga Hulu River is 2.66. The PI value for all sampling locations is in the range of $1.0 < PI \leq 5.0$, which means it is included in the lightly polluted category. The condition of river water in industrial areas, especially the mining industry with a light-polluted category, it shows that the management has been carried out well.

CONCLUSIONS

The surface water conditions around the research location, namely the Icik River, Keruing River, and Cempaga Hulu River are still in good condition. This is indicated by the results of laboratory analysis where almost all the parameters tested were still below the quality standard. Besides, the calculation of the Pollution Index also shows good results, which is still below the value of 5, which means that river water around the research location is included in the light-polluted category. The still good condition of river water around the research location indicates that environmental management activities are running well. However, it is necessary to improve environmental management and conduct routin pollution monitor in the river so that the condition of river water in the research location can be even better.

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