Heavy Metal Pollution in Sediments of Panreng River, Sidenreng Rappang Regency, South Sulawesi Province

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ABSTRACT

In Indonesia, small-scale rock mining is generally managed by traditional miners. For example, the andesite rock mining in Bulu Alakkuang has been exploited for approximately one hundred years. Mining waste is channeled directly into the Panreng River, located on the north side of the mining area. Rock mining waste contains sediment particles where the sediment plays an urgent role in the movement and accumulation of heavy metals that could lead to the cause of toxic effects on biota. The particular study aimed to analyze the levels and distribution of heavy metals Cu and Zn in the sediments of the Panreng River, Sidenreng Rappang Regency, South Sulawesi Province. The geochemical method was an Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICP-AES) analysis of 24 sediment samples taken systematically along the Panreng River. Then, data from the analysis of ICP-AES geochemical was analyzed for the Enrichment Factor (EF) and Geoaccumulation Index (I_{geo}). The metal of Cu tends to be high in the downstream area, while the metal of Zn tends to have an average value at all stations. The calculation result of EF showed the Cu content was in a range of 0,82-1,67, and the Zn content was in a range of 0,87-1,24. The result of EF was generally classified as minor enrichment. The calculation result of I_{geo} showed the mean of the I_{geo} Cu value was -0,27, and the mean of the I_{geo} Zn value was -0,52. The result of I_{geo} was generally classified as the unpolluted class of sediment.

Keywords: *Panreng River, Sediment, Heavy Metals, Enrichment Factor, Geoaccumulation Index.*

1. INTRODUCTION

The river is an important ecosystem where interactions occur between living things and the surrounding physical environment. Rivers play a role as a place for the hydrological cycle which become the key to the availability of water on earth, breeding grounds for flora and fauna in the river, water resources for human life and cultivation, such as agriculture, fisheries, industry, mining, transportation, and recreation [1]. Also, the river plays a role in accommodating the waste of these activities. The case also occurs with traditional mining in the Bulu Alakkuang area, Sidenreng Rappang Regency. In this area, two hills with trachytic-andesitic lava lithology have been mined for approximately one hundred years and have become the main source of livelihood for the local community [2]. Rock management is still classified as conventional and not equipped with a proper waste management process. Mining waste is channeled directly into the Panreng River, which is located on the north side of the mining area. It becomes a factor of the causes of increased sedimentation in the research area. As the impact, flooding in the area often occurs during the rainy season. Not only increase the sediment, but mining also increases the content of heavy metals and other elements carried with sedimentary material into the river system. The factor is that the sediment plays an urgent role in the movement and accumulation of heavy metals that could lead to the cause of toxic effects on biota [3]. Heavy metal pollution in river sediments caused by the mining management process can vary based on the distance of the river from the mining location. The closer to the mine, the higher the concentration of heavy metals found in river sediments [4].

The results of previous studies showed that the sediment of the Panreng River had the highest susceptibility value compared to the other three big rivers that also emptied into Sidenreng Lake, and it found a metal content of 0.04% Cu and 0.03% Zn in the Panreng River sediments [5]. The high value of this susceptibility indicates that the metal content is quite high in the sediments of the Panreng River. However, studies on sediment pollution of the Panreng River have never been carried out. Therefore, this study aimed to analyze the

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levels and distribution of heavy metals in the sediments of the Panreng River, especially for Cu and Zn metals.

Administratively, Sungai Panreng is located in the Allakuang Village and Teteaji Village, Tellu Limpoe District, Sidenreng Rappang Regency, South Sulawesi Province. Geographically, the study area is located at 3°58'15.12" -3°59'36.38" South Latitude and 119°47'15.22" -119°50'42.36" East Longitude (Figure 1) [6].

2. RESEARCH METHOD

2.1. Data Collection

Field data collection consisted of geological mapping, systematic sediment sampling for the content analysis of copper (Cu) and zinc (Zn), and measurements of temperature, acidity (pH), and total dissolved solids (TDS) in river water at each sample location point. Sampling was taken at 25 (twenty-five) locations (Figure 1). The river sediment samples were obtained at 24 (twenty-four) points on the Panreng River. Rock samples were taken at 1 (one) point in the mining area of the community. Three samples used as a control sample to analyze the Enrichment Factor (EF) and Geoaccumulation Index (I_{geo}). The control sample is a sediment sample assumed to have not been affected by mining activities [4]. This sample was taken in the Takkalasi area, from ST-1 to ST-3. There found neither mining nor processing of mining products. So, the sample is assumed to have not been contaminated by mining products. The Panreng River has various grain sizes of sediment, from coarse sand (0.4-1 mm) to fine-sized clay (<1/256 mm). River material, the clay-sized, will be suspended in river water [6]. The sample sediments have been accumulated and were deposited on the riverbed. Sediment samples were taken using non-metallic materials to avoid contamination of the sample.

2.2. Laboratory

A laboratory test for heavy metal concentrations in 24 sediment samples were carried out using the Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICP-AES) method. This analysis produces data on the value of heavy metal content in each river sediment sample in ppm (parts per million) [1]. The elements analyzed are Cu and Zn. The rock samples were subjected to petrographic analysis to determine the type of rock at the mining site.

2.3. Statistical Analysis and Data Interpretation

The results of the XRF analysis were statistically processed using Microsoft Excel and the Statistical Program for Social Science (SPSS) Statistics 25.

2.3.1. Enrichment Factor

The concept of enrichment factor (EF) is used to assess the level of contamination of an enrichment process in the analyzed metal elements and determine the possibility of anthropogenic impacts in sediments [9]. The equation formula in calculating the Enrichment Factor (EF) with following equation [8]

$$\text{EF } (\textit{Enrichment Factor}) = \frac{[metal]/[Al]_{sample}}{[metal]/[Al]_{kontrol}} \quad (1)$$

Then, the enrichment factor (EF) calculation is compared with the enrichment factor criteria that aims to determine the effect of an enrichment factor on the heavy metal content in the sediment sample [8]. Data normalization of metal using Aluminum (Al) as a conservative element has been widely used because Al analysis is easy, precise, and accurate [8].

2.3.2. Geoaccumulation Index (I_{geo})

The Geoaccumulation index is used to determine the possibility of metal enrichment in river sediments. The index is based on the relationship between the measured metal concentration and its reference value, with both normalized in terms of sediment sample granulometry using the fine fraction of the sample only [8]. I_{geo} is calculated using the following equation [8].

$$I_{geo} = \log_2 \frac{C_n}{1{,}5B_n} \quad (2)$$

I_{geo} = Geoaccumulation Index
Cn = Sediment Concentration
Bn = Concentration of Reference/background

3. RESULT AND DISCUSSION

3.1. Geology of Study Area

Based on the mapping of the study area, the study area was divided into 3 (three) rock units, namely the Tufa Unit, Andesite Lava Unit, and Alluvium Unit (Figure 1).

3.1.1. Tufa Unit

This unit consists of tuff and sandstone lithology. Tuff has a fresh blackish ash color and a weathered yellowish-brown color and consists of >50% rock fragments, 10% crystals, and 40% glass, poorly sorted and packed-open. The tuff is lithic [10] based on the fragment content. Sandstone has a fresh gray-white color, weathered brown color with rock position N 25 E/14° (Figure 2.a). The grain size of the sand is medium-fine sand, well-sorted, with poor permeability, and packed tightly. Based on the grain size, this rock is sandstone [9]. The thickness of this unit in the study area is approximately 30 meters. Based on the description of this unit, the Tufa Unit belongs to the Walanae Formation of the Late Miocene – Pliocene age [10]. This unit is located under the columnar joint of andesite lava in the study area [2].

3.1.2. Andesite Lava Unit

Andesite lava in the study area has a light gray fresh color and a brownish-gray weathered color. Its constituent minerals consist of 50% Plagioclase, 15% Biotite, 10% Pyroxene, 5% Quartz and 20% Glass. The rock structure was formed of columnar joints (Figure 2.b) with a trachytic texture (mineral alignment) and a degree of hypocrystalline crystallization. Based on these physical characteristics, the name of this rock is Andesite [12]. The thickness of this unit in the study area is about 80 meters. This unit belongs to the Pliocene Age of Parepare Volcanic Lava. Meanwhile, the stratigraphic relationship between the Walanae Formation and the Parepare Volcanic Lava Members is intertwined [11].

3.1.3. Alluvial Unit

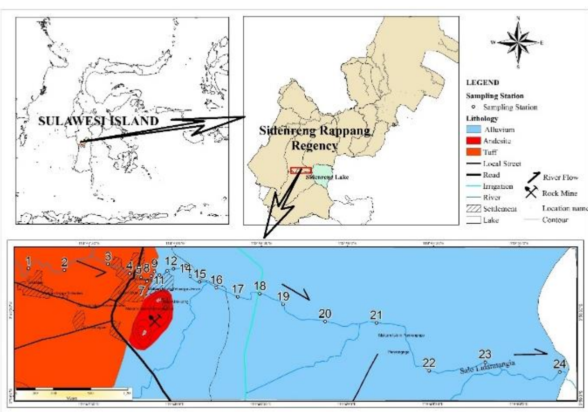

Figure 1. Map of study area and sampling point [6]

The unit has a Terrigenous Clastic Sedimentary with a predominance of yellowish-brown to gray-brown color. This unconsolidated material was dominated by coarse sand particles (0.5 - 1 mm) to clay (<0.004 mm) and spreads approximately 75% of the study area with a thickness of approximately 15 meters.

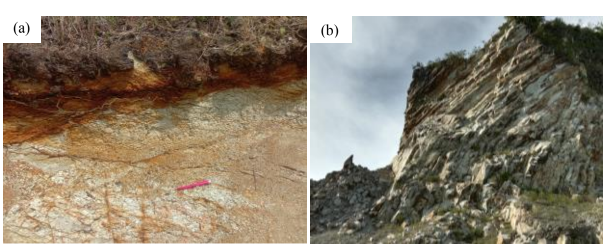

Figure 2. Location of the Bulu Alekkuang Rock Mining (a) Rock Contact between Sandstone and Tufa with Rock Position N 25 E/14° (Photo Taken Direction N126°E). (b) Andesite Lava Shows Columnar Joint Structure (Photo Taken Direction N332°E)

3.2. Temperature of River Water

River water temperature can indicate the tendency of chemical, biological and physical activity, such as thickening, vapor pressure, surface tension, and saturation values of solids and gases in water. If the temperature is high, the thickening will decrease while the sedimentation process increases with the estimated not being disturbed by current conversion [13]. The lowest temperature was 26.6°C at ST-1, while the highest temperature was 30.6°C at ST-16. The ambient temperature at the time of the sampling process was 30°C. So, referring to Government Regulation No.22 of 2021, the temperature quality standard in the study area with a deviation of 3° was 27°C -33°C. Therefore, the river water temperature that exceeds the minimum quality standard is ST-1. Apart from ST-1, the temperature in the study area is still a quality standard of the river water temperature.

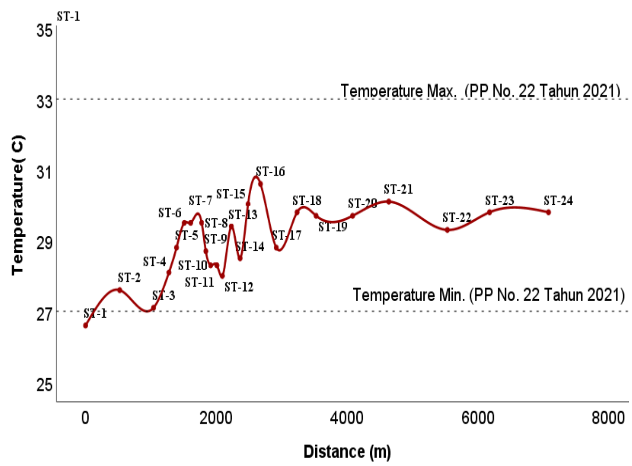

Figure 3. Graph of Temperature at Study Area Based on the Distance from Upstream to Downstream

3.3. The pH of River Water

The degree of acidity (pH) can affect the fertility level of the waters, the toxicity of a compound, and the increasing concentration of heavy metals [13]. Several factors affect the water temperature differences, including season, latitude, altitude above sea level, time of day, cloud cover, and water flow and depth [14]. The pH value tends to be average in each sampling area, which was the pH 6.7 – pH 7.2. The minimum pH was at ST-1, ST-8, and ST-17, and the maximum pH was at ST-22. Referring to Government Regulation No. 22 of 2021, the pH standard for river water is pH 6.5 – pH 9. So, it was interpreted that the pH of the study area meets the quality standards of river water.

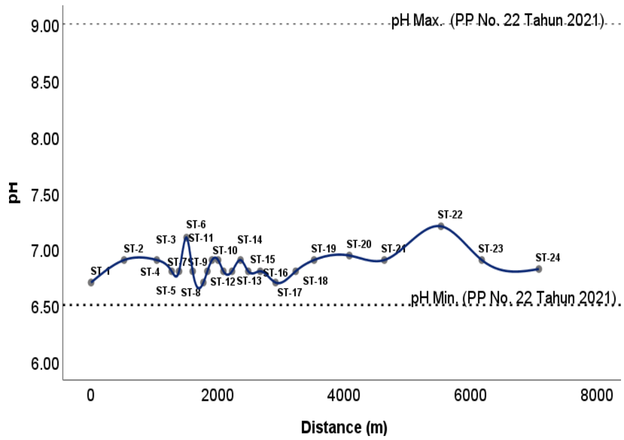

Figure 4. Graph of pH at Study Area Based on Distance from Upstream to Downstream

3.4. Total Dissolved Solid of River Water

TDS is the concentration number of cation ions and anion ions in water. TDS analysis might be used as a qualitative measurement of the number of dissolved ions [16]. When the TDS value increases, the water hardness also increases [13]. TDS values tend to decrease from ST-1 to ST-24. The minimum value was 94 mg/L at Station 22. The maximum value was 682 mg/L at ST-6, where this station is the outlet for the disposal of mining products. Referring to Government Regulation No. 22 of 2021, the TDS value of quality standard in river water is 1000 mg/kg. So, it was interpreted that the TDS of the study area still meets the quality standards of river water.

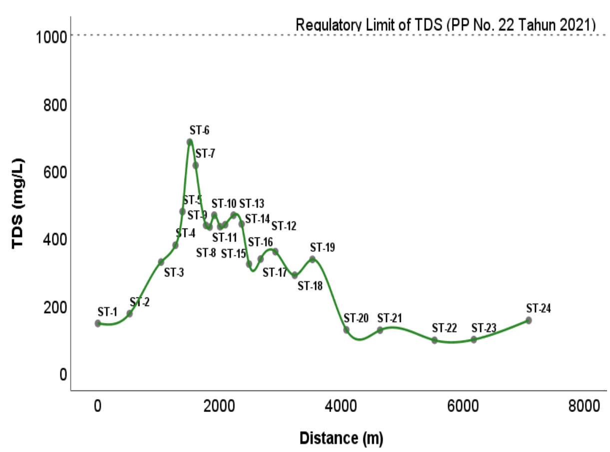

Figure 5. Graph of pH at Study Area Based on Distance from Upstream to Downstream

3.5. Cu and Zn Content in River Sediment

The Cu and Zn content results in river sediment samples ranged from 18.00 – 32.00 mg/kg, with a mean value of 26.77 mg/kg. The highest Cu level was at ST-22. In comparison, the lowest Cu levels was at ST-2. Based on Table 1, the levels of Zn in the sediment ranged from 65.00 – 78.00 mg/kg with a mean value of 70.88 mg/kg. The highest Zn levels was at ST-9, while the lowest was at ST-1, ST-7, and ST-21.

Control samples or reference samples, namely ST-1 to ST-3, had an average Cu content of 21.37 mg/kg and Zn 67.67 mg/kg. The value was used as the concentration of the control sample in the calculation of EF and I_{geo}.

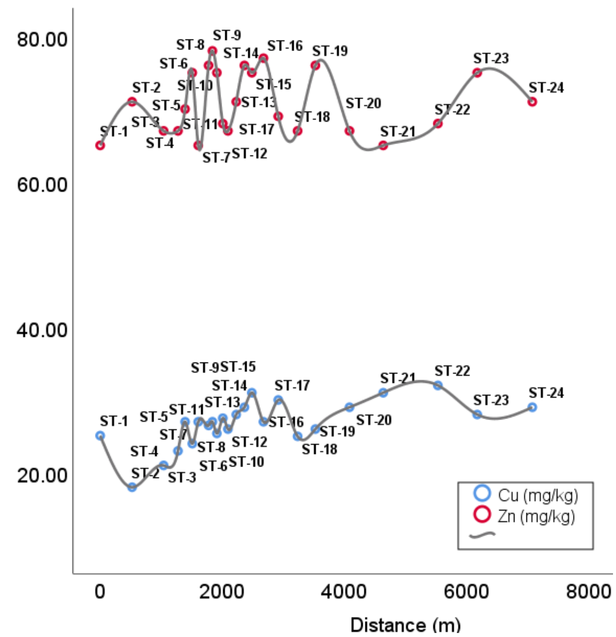

Figure 6. Graph of Cu and Zn Content in Sediment Samples of Panreng River

Based on Figure 6, the levels of Cu and Zn tend to increase insignificantly downstream. The high level of Cu and Zn in the downstream area indicated the accumulation of Cu and Zn metals in the area. It was caused by the sedimentation process, where sediment might be deposited in areas with low current velocities (<30 cm/s) [17].

3.6. Enrichment Factor (EF)

By using this Equation (1), it obtained the EF values for each Cu and Zn parameter. The calculation results of EF showed the Cu content has a minimum EF value of 0.82 at ST-2, and the maximum EF value of 1.67 at ST-21. The mean EF value of Cu was 1.31. Based on the criteria for Enrichment Factor (EF) [8], the Cu metal contained in the Panreng River sediment only has a minor enrichment, except at the ST-2 point, which was included in the criteria for no enrichment. It was interpreted as the absence of rock management in the area around ST-2. The pattern of EF values from upstream to downstream (Figure 7) showed that Cu metal enrichment in the Panreng River tends to increase insignificantly downstream of the Panreng River.

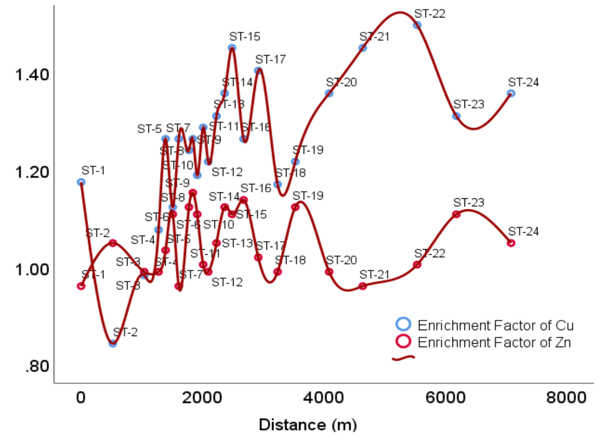

Figure 7. Graph of Cu and Zn Enrichment Factor (EF) Values

The EF value of Zn metal was a minimum EF of 0.87 at ST-7 and a maximum EF of 1.24 at ST-8 and ST-9. The mean EF value of Zn was 1.09. Based on Enrichment Factor's (EF) criteria [8], the Zn metal contained in the sediment of Panreng River only minor enrichment, except at points ST-1, ST-7, ST-17, and ST-18 that, included in the criteria for no enrichment. It was interpreted as a result of ST-1 being an area where there was no mining process of rock management. At the same time, ST-7 is a residential area that often occurs flooding during the rainy season. In short, Zn metal pollution in ST-7 was reduced due to suspended sediment in a flood. Meanwhile, ST-17 and ST-18 are sampling stations with a higher current velocity than other stations. It indicates that sediment in this area is difficult to deposit. Based on Figure 7, the EF value of Zn metal tends to be average at every point from the upstream to the downstream of the Panreng River.

3.7. Geoaccumulation Index

Using Equation (2), it obtained the value of the geoaccumulation index (I_{geo}) of each parameter in each sediment sample. The results indicated the minimum I_{geo} value of Cu metal was -0.83 at ST-2, and the maximum value was 0 at ST-22. The mean value of I_{geo} Cu was -0.27. Based on Figure 8, the I_{geo} value of Cu metal tends to increase insignificantly downstream of the Panreng river. This is directly proportional to the EF value in the study area. Based on the I_{geo} Class and Muller Sediment Quality (1979) in Eby (2004), the study area included in the class of unpolluted (I_{geo}<0) by Cu metal [18]. Although the study area was classified as unpolluted, the EF value interpreted that the study area was contaminated with low levels of Cu metal due to the effect of rock mining. Rock mining can cause changes in land morphology, and it is easier for rocks to break down physically and chemically than natural processes. Thereby, it increases the amount of loose material entering the river system [19].

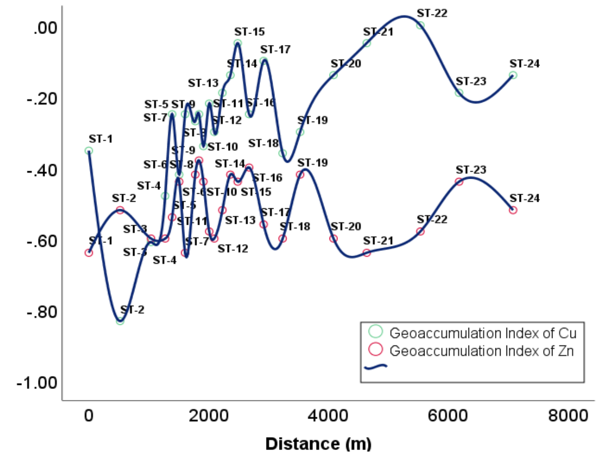

Figure 8. Graph of Cu and Zn Geoaccumulation Index (I_{geo}) Values

The minimum I_{geo} value of Zn metal was -0.64 at ST-1, ST-7, and ST-21. The maximum value was -0.38 at ST-9. The mean value of I_{geo} Zn was -0.52. Based on the I_{geo} Class and Muller Sediment Quality 1979 in Eby 2004, the study area included in the class of not polluted (I_{geo} <0) by Zn metal. Based on Figure 8, the I_{geo} value of Zn metal tends to be the average from upstream to downstream of the Panreng river. This pattern is directly proportional to the EF value in the study area. Based on the I_{geo} Class and Muller Sediment Quality 1979 in Eby 2004, the study area included in the class of unpolluted (I_{geo}<0) by Zn metal [18]. Although the study area was classified as unpolluted, the EF value interpreted that the study area was contaminated with low levels of Zn metal due to the effect of rock mining.

4. CONCLUSION

The study provides the status of heavy metal pollution from the sediments of the Panreng River. Cu metal tends to be high in the downstream area, while Zn tends to be an average value, both in the upstream and downstream areas. Based on the results of the EF calculation, Cu and Zn metals in the Panreng River sediment generally have minor enrichment. Meanwhile, the results of I_{geo}, the sediment in the study area was classified as unpolluted sediment. The category might be caused by the natural conditions of the study area, which are indicated as a mineralized zone [2]. The effect of land morphology changes that are caused by rock mining cannot be ignored because it increases the weathering process, both physically and chemically. Increased weathering can make it easier for minerals to be eroded and enter the river system. Although in an unpolluted condition, there found minor enrichment of Cu and Zn metals in the sediment of the Panreng River. In addition, reduced nutrients and heavy metals are also indicated as a dilution effect caused by frequent flooding in the study area [20].

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