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Spatial Distribution of Mercury Pollution in the Mempawah River Watershed, West Kalimantan – Indonesia

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Abstract---*Mempawah River Basin (DAS) is a water resource for the people of Mempawah and Landak Regencies. The community uses the Mempawah River as the main medium for agricultural needs, plantations, and the rearing of fish for consumption. Awareness of health that comes from water with its various uses, there has been consumer anxiety when consuming air along with agricultural and fishery products that are relevant to water use in the Mempawah watershed. This phenomenon occurs because the water resources of this watershed area have been polluted by mercury as a result of unlicensed gold mining activities in its spatial extent. This research was conducted to analyze the level of mercury pollution in the river basin, due to illegal gold mining activities. The method applied was purposive sampling, through 29 water sample points located in the upstream, middle and downstream. The sample results were explained using the Atomic Absorption Spectroscopy (AAS) tool. Then, from a spatial perspective, the location of PETI activities was analyzed spatially using Spatial Dynamic Modeling Geographical Information System software with kriging interpolation techniques, to predict the distribution of mercury pollution. The results of the research show that in the middle part of the Mempawah watershed, there is mercury pollution from 0.0023mg/lt to 0.0083 mg/l and has exceeded the threshold determined by PP No. 22 of 2021. The upstream and downstream parts of the Mempawah watershed are not polluted by mercury, because the PETI activity point is only in the middle part of the Mempawah watershed. These findings provide suggestions that the allocation of Mempawah River water as the sole raw material for corporate entities and its use for growing fish communities should be more closely monitored, to avoid danger, due to the chain of heavy metal contamination in the form of Mercury.*
Keywords---*Mempawah River, mercury pollution, mercury, pollution distribution, Watershed (DAS).*

Introduction

Unlicensed Gold Mining Activities (PETI) are mining activities carried out by individuals, groups of communities, or lawful foundations undertaken without the permission of government agencies in accordance with the regulations of the applicable laws (Wahyudi, & Slamet 2017). PETI activities are illegal activities that have been regulated in the Mineral and Coal Mining Act No. 4 of 2009. Water pollution by Mercury occurs through small-scale gold mining,

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which uses the elemental type of mercury as a gold purifier in the amalgamation process. Mercury used in gold purification is disposed of in the river body, resulting in pollution of river water. Mercury pollution in the Tebaung River, Kapuas Hulu amounted to 0.0063 mg/l (Astika, 2017; Triana et al., 2012).
Mercury monitoring and evaluation as a result of PETI can be done with spatial analysis. The analysis of spatial data using the Geographic Information System (GIS) can be used to determine the spread of pollution from the point of origin of the contamination. The kriging interpolation method can be used as it gives a picture of pollution in an area as it can estimate values between data samples (Hidayat, 2020). The study aims to analyze and mapp spatially the water conditions of the Mempawah River, which is the main water source for the people in Mempawha district exposed to Mercury pollution due to gold mining activities without permission (PETI) (Andilala, 2017; Armid & Takwir, 2020; Basmi, 1999).

Research Method

Location and Time of Research

The research was conducted in September 2020-January 2021 in the Hulu, middle, and suburbs of the Mempawah DAS, West Kalimantan.

Data Collection Methods

The determination of the water sampling point is done using the purposive Sampling method with the sample collection divided according to the lower DAS section, i.e. there are 11 sample points in the lower part, 7 samplings in the middle part, and 10 samplers in the upper part (Cahyaningsih & Harsoyo, 2010; Darmono, 1995; Effendi, 2003). The sample taking of water is carried out using the grab sampler method referring to SNI 03-7016-2004 Sample Samplings Method in the framework of water quality monitoring in a river-flowing area (Loh et al., 2012; Heliani et al., 2020).

Data Analysis Methods
Mercury Pollution Analysis

The samples of river water that have been obtained were then analyzed in the Laboratory of the Pontianak Industry Research and Standardization Hall (ESRI, 2020; Hadi & Asiah, 2015; Harseno & Tampubolon, 2007). The analysis was carried out to measure the level of accumulated heavy metal content (Hg) due to the impact of PETI activity in the Mempaw River. Measurement of Hg levels using Indonesian National Standard SNI No. 06-2462-1991 on the method of testing of mercury levels (Hg) in water and water with cold automation spectrophotometer. Scope of testing SNI 06-2462-1991 which has a concentration range of 0.6 µg Hg/L up to 15 µgHg / L (Karssenberg, 2002; Kemp, 1992; Kristanto, 2002; Yulis 2018).

Mercury Pollution Spatial Mapping Analysis

Sampling point coordinates are recorded by the cellular Global Positioning System (GPS) (Hylander & Goodsite, 2006; Budnik & Casteleyn, 2019). The results of chemical analysis (average sample values) are then used as input data in ArcGis 10.5. Sampling locations are integrated with water data for the creation of spatial distribution maps (Lauselang, 2019; Matějíček et al., 2003; Palar, 1994).

DAS Mercury Pollution Analysis Down

Laboratory analysis using the AAS method is used to determine pollution values based on river water intake points (Prasasti et al., 2005; Reid, 1961; Romiyanto et al., 2015). The substantial pollution outcome in the downstream DAS will be compared with the mercury contamination threshold in PP No. 82 of 2001 on Water Quality Management and Water Pollution Control (Boening, 2000; Lin et al., 1999).

Result and Discussion

The rainwater that falls into the DAS is divided into three sections according to the topographical height of the entire section of the DAS, i.e. the area of the top, the middle, and the latter (Fernández-Martínez et al., 2019; Li et al., 2009). The sources of rainwater falling to the DAS are flowing from the top to the bottom of DAS in Kuala Mempawah, due to the height difference of each section of DAS. The DAS has an area of 3.260 km2 whose use in the land is dominated by the fields, plantations, and plantations mixed from various horticultural commodities such as coconut, palm oil, tomatoes, onions, peppers, to fruits. The use of the water space is used for the cultivation of fish breeding in Keramba Jaring Apung (KJA), and as a raw material for drinking water treatment by the Drinking Water District Company, Mempawah District (Suharyadi, 2004; Widodo, 2008; Widowati et al., 2008; Wismarini & Khristianto, 2016). The results of land use mapping are known, that the ancient and central areas are occupied by communities with low density, with locus only areas that are close to the body of the river. This is due to historic factors of ease of accessibility and use of water for various provisions by the community (Sancayaningsih et al., 2010; Setiabudi et al., 2007; Subanri, 2008).

Described, the results of laboratory analysis using the AAS method on the sample of water from the back and bottom of DAS Mempah showed Mercury's condition did not pass the quality standards already specified in PP No. 82 of 2001. While the analysis of the mercury content of the waters of DAS Mempah below the central part marked with traces of former PETI activities in the land, there are areas whose waters are contaminated with Mercury. Map of land use of DAS Down, can be seen in Figure 1:

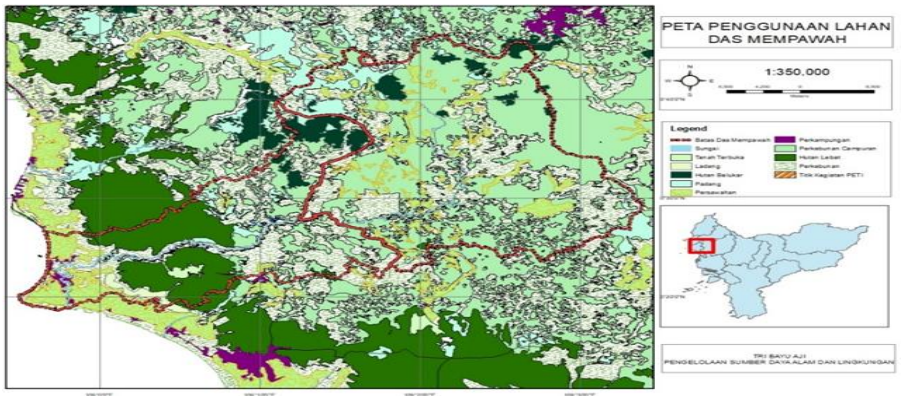

Figure 1. Map of DAS land meltdown

Information about the results of Mercury content analysis in the Hulu Bottom DAS section can be found in Table 1:

Table 1
Results of Mercury Content Analysis of DAS

No	Latitude	Longitude	Mercury pollution (mg/lt)	Description
1	0,466438	109,333777	0,0002	Not contaminated
2	0,479653	109,345013	0,0002	Not contaminated
3	0,485582	109,356767	0,0004	Not contaminated
4	0,507034	109,370622	0,0002	Not contaminated
5	0,513923	109,376397	0,0002	Not contaminated
6	0,554922	109,375493	0,0002	Not contaminated
7	0,566886	109,.36343	0,0003	Not contaminated
8	0,577136	109,348644	0,0002	Not contaminated
8	0,606381	109,342725	0,0002	Not contaminated
10	0,612347	109,332827	0,0002	Not contaminated

Lower Hulu is a mountainous area that is used for various land allocations, mainly as a planting area, food crops farming, and annual horticulture, as well as a population settlement area in the forests of limited production (Jaiswal et al., 2015; Das et al., 2019). At the top of the bottom of the DAS there is a sample that has a greater mercury

content than the other sample from this section of DAS, i.e. 0,0004 mg/l. This is supposed to be due to a natural cycle in nature that naturally forms mercure. Furthermore, the bottom of the DAS is dominated by Sawit plantations and mixed plantations, so the use of mercury-containing disinfectants can be the cause of the Mercury content in the sample points. Mercury can spread in the environment from agricultural material (Alfian, 2006).

In the suburbs of the Mempawah district, which is an urban area, 12 water samples were collected. Laboratory results show the content of Mercury as follows:

Table 2
Results of mercury content analysis of DAS

No	Latitude	Longitude	Mercury pollution (mgl-1)	Description
1	0,324	108,969	0,0002	Not contaminated
2	0,3653	108,962887	0,0002	Not contaminated
3	0,388039	108,96603	0,0002	Not contaminated
4	0,389074	108,967789	0,0002	Not contaminated
5	0,38568	108,969039	0,0002	Not contaminated
6	0,381626	108,979168	0,0002	Not contaminated
7	0,390992	108,99839	0,0002	Not contaminated
8	0,393	108,006	0,0002	Not contaminated
9	0,398176	109,005514	0,0002	Not contaminated
10	0,401353	109,014525	0,0002	Not contaminated
11	0,401353	109,014525	0,0002	Not contaminated
12	0,402031	109,024816	0,0002	Not contaminated

The laboratory results showed that the waters in the Hilir section of the DAS are not contaminated with Mercury. This is indicated with mercury content not exceeding the threshold of the standard quality set by the Act No. 82 of 2001. The area is covered by the density of residential and business areas, as well as fishing ports with various attributes of community activities, along with its economic activity, which is based on the water resources that exist in the body of the river DAS Mempawah. This density occurs as a consequence, the area is the capital of the district.

A sample of DAS water at the bottom of the middle section was taken from seven water samples. Identification and mercury content of such samples can be seen in Table 3:

Table 3
Results of DNA Mercury Analysis Downtown

No	Latitude	Longitude	Mercury content (mg/l)	Description
1	0,427	109,092	0,0002	Not contaminated
2	0,427	109,093	0,0002	Not contaminated
3	0,419	109,094	0,0002	Not contaminated
4	0,455988	109,178845	0,0083	Polluted
5	0,453	109,182	0,002	Polluted
6	0,456	109,19	0,0023	Polluted
7	0,458	109,198	0,0002	Not contaminated

The results of the AAS test showed that in the middle area of the DAS below there were contaminated samples of Mercury with mercury values ranging from 0,0002 mg/L to 0.0083 mg/ L located at the samples points 15, 16 and 17. The analysis of the sample in the laboratory indicated that the mercure content exceeded the threshold of raw quality specified in PP No. 82 Year 2001. The central part of the Lower D.A. is dominated by plantation areas, mixed plantations, and limited production forests. Land usage in the middle of the Lower D.A. refers to Figure 2:

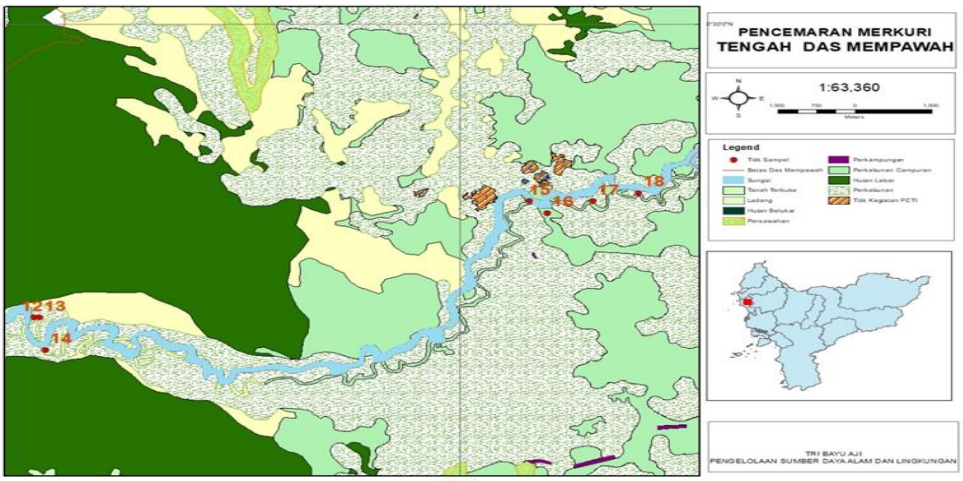

Figure 2. Sample Point Map and Land Usage Down Downtown DAS

The pollution at the sampling point number 15, 16, and 17 is due to the existence of several PETI activity points. PETI activities in the middle area of the Mempawah DAS have an area of 54 Ha which is divided by 7 PETI action points. The largest Peti activity point is 21.91 Ha.

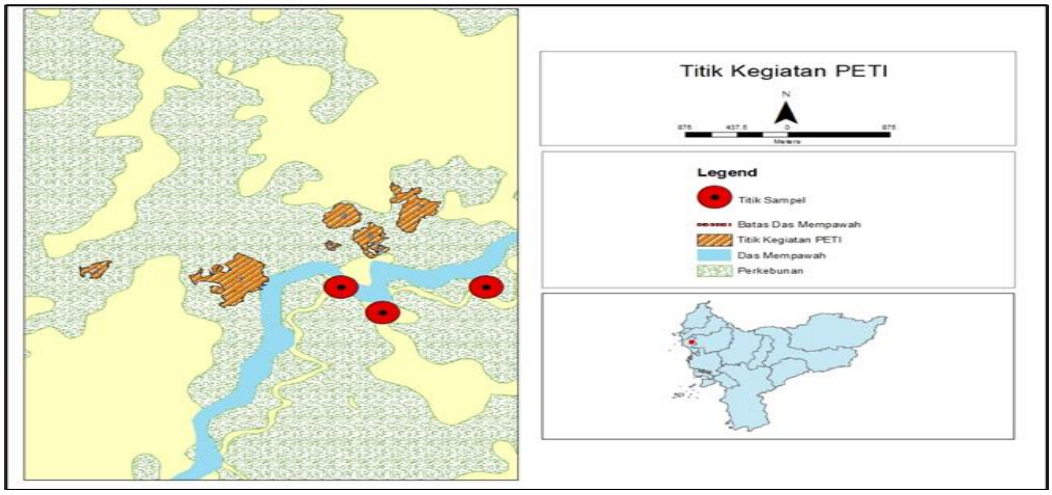

Figure 3. PETI Activity Point Map

The PETI activity area is the main source of mercury pollution in the Mempawah DAS. The results of the map analysis are shown in Figure 4:

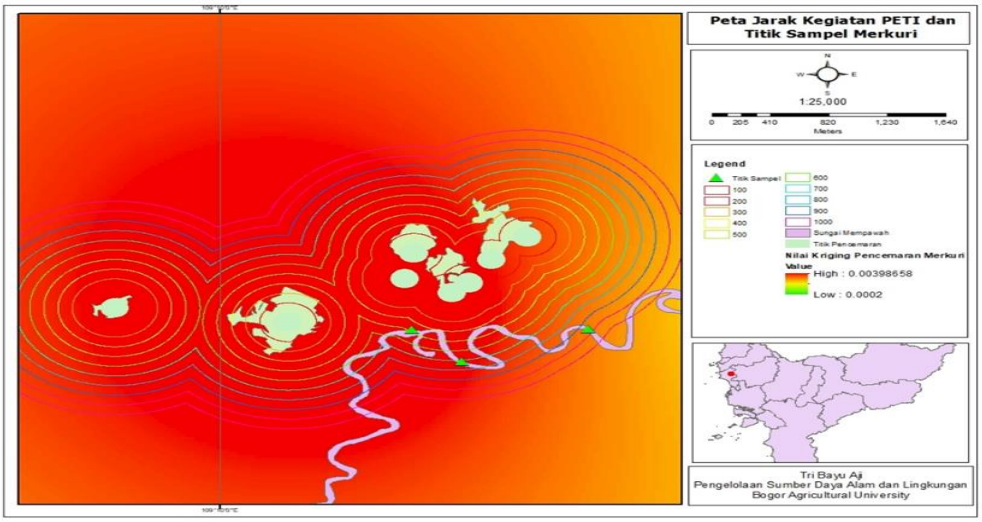

Figure 4. PETI activity distance map and sample point

The distribution of Mercury around the River Mempawah is near the highest point of PETI activity in a radius of about 400 M to 800 M. At the 400 M radius of the PETI point of activity, the mercury content is 0.0083 mg/l, then at the 700 M radius the mercure content is 0,002 mg/ l, while at the 800 Meter radius the content of mercure is 0.023 mg/L. These heavy metals have characteristics that are difficult to describe by the environment. The heavy metals that enter the water body will settle and accumulate in the sediment and part of it will enter the living organisms. (Shukla et al., 2007). The results of kriging interpolation are presented in Figure 5 below:

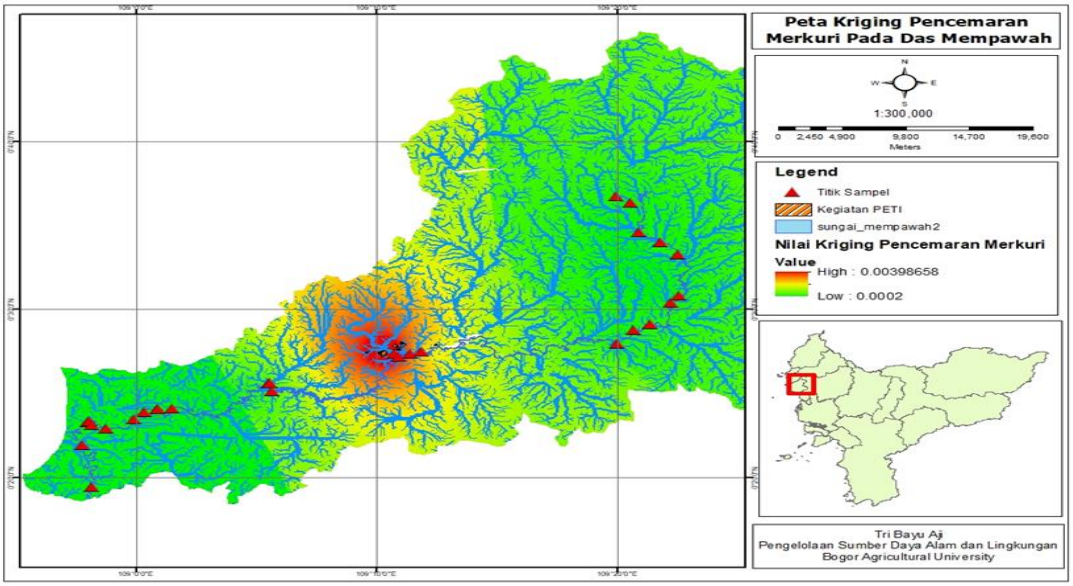

Figure 5. Mercury Pollution Circulation Map on DAS Down

The results of the mapping carried out using the kriging interpolation method showed the color differences of each area of the study according to the intensity of Mercury concentration from the lowest to the highest in the sampling area which would ultimately make it easier to read and understand the map. The map in Figure 5 shows the distribution of Mercury classified by color gradients from green to red. The green color indicates an area that is not exposed to mercury contamination with a mercure content of 0,0002 mg/l. The area covers the downstream of the Downstream and the upper edge of the Upperstream. Mercury originating from the amalgamation process has high concentrations so that its mobility in the water bodies is reduced Gerson et al. (2018), thus resulting in high mercury concentrations in the area of PETI activity. Mercury derived from the amalgamation process in PETI activities is

discharged into the environment with high concentrations and can damage the environment. Mercury entering the water body will accumulate in the soil. Mercury, which is in the aquatic environment as a result of human activity, has a limited spread, because it is a liquid heavy metal with a larger weight than water, so that its concentration in the water body is not far from the point of contamination. The pollutants that are in the waters are affected by the speed of the flow of the river, which, as the flow is slowed down, leads to the accumulation of the pollutant in one contaminated area (Yulianti et al., 2018). The topography of the Lower D.A. affects the flow rate of river currents in the area. The top area of the Mempawah DAS is an area that has a higher altitude than the middle area and is below the DAS, so Mercury is not detected in the top area. Pollution in river water is affected by water slope (Bugis, 2003). This indicates that there is a huge difference in the concentration of Mercury in the three parts of the Downstream.

The mercury used in the amalgamation process will be discharged into the river body and will survive in the environment and accumulate in the food chain in the form of Mercury Methyl. This Merkury methyl contaminates and damages organisms by entering the food supply chain through plankton (Lino et al., 2019). Plankton, which consists of phytoplankton and zooplancton, can absorb mercury directly from the water body, compared to zooplanton, absorbing more Mercury in the aquatic body than it does to the phyto-plankton (Fisher & Hook, 2002; Tsui & Wang, 2004). This will affect the health of the people who depend on their daily water requirements and also for the community who consume the fish from this Downfall DAS.

The PDAM district of Mempawah uses its own water from the DAS to use the raw water that will eventually be consumed by the community. In this study, samples were also taken from the Wastewater Treatment Plant (IPAL) and water distribution PDAM that showed mercury contamination of 0.0024 mg/L and 0.0039mg/L. Mercury pollution in drinking water management processes is very potentially hazardous to public health. According to the Act No. 82 of 2001 on the Management of Water Quality and Control of Water Pollution, there is a classification of water quality established in 4 classes, where the first class used for raw drinking water with a raw quality content of Mercury exceeding 0,001 mg/L. This shows that water on the DAS Down at some points of absorption can harm the community that uses it. In the same law on the classification on water quality in the third class that is used for the cultivation of freshwater fish, farms, water for irrigation of plants also indicates that the water on DAS Down cannot be used for freshwater fishing. Mercury accumulated in the water will be absorbed by aquatic organisms. Heavy metals in the water are the cause of damage to community structures, genes, food tissues, behavior, and physiology of aquatic organisms (Yazhini et al., 2018). Heavy metal such as Mercury in the waters will enter the body of aquatics and accumulate in the organs of the organism. In a study conducted by Haque et al. (2019); Selvanthan et al. (2013); Sambo et al. (2020), suggested that fish exposed to Mercury have damage to the insects, because the insect organs are organs that have been in contact with the inserts in toxic environments. The liver's organs are very susceptible to exposure to Mercury because the liver is the primary target organ of toxic substances through liver portal veins. (Bakos et al., 2019).

Conclusion

The results of the analysis of Mercury pollution in the waters of the D.A.P.Bow showed that there are areas where the water source is contaminated with Mercure, the level of which exceeds the threshold established in PP No. 82 of 2001, on Water Quality Management and Control of Water Pollution. The fact of this mercury contamination was found in the central area of DASBow with a mercure content, between 0,0002 mg/L – 0,0083 mg/ L. The results from the spatial mapping of SIG stated, that the distribution of mercure contamination in the DASPowers showed the presence of Mercure content around the site of the PETI activity with the mercy content exceeding the limit, of 0.0023 mg/l to a distance of 800 Meters. This fact gives a signal, that the management of water resources with its use, such as for the fishing activities carried out by the community along the Mempawah River and as a raw material of Water Treatment by the Company of the District of Drinking Water of Mempowah District, need to get special treatment, so that its existence does not endanger public health in the various areas affected on the space referred to in this study.

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