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RESEARCH ARTICLE

Study of heavy metal in sediment of The Klagison River, Sorong City

Nurbia Nurbia[a], Samsuddin Affandi[b]

[a] Environmental Engineering, Universitas Muhammadiyah Sorong, Indonesia
[b] Master of Environmental Engineering, Institut Teknologi Adhi Tama Surabaya, Indonesia

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ABSTRACT

The Klagison River in Sorong City is used by the sand mining industry to dispose of liquid waste. Consequently, turbidity and sedimentation occurred. This study aimed to analyze the water quality, heavy metal concentrations in sediments, and the relationship between the two. The sampling points were determined using the purposive sampling method. Data analysis included the pollution load index (PLI), geoaccumulation index (Igeo), and correlation analysis. The TDS value of the Klagison River ranged from 126 to 168 mg/L and turbidity range of 19.98 to 724 NTU. The analysis results pollution load index showed that the sediment with a PLI value of 0.557 was neither polluted nor lightly polluted. Index geoaccumulation showed Cr and Cu values of 100% (Igeo < 0), while Mn and Fe were 80% unpolluted (Igeo < 0) and 20% unpolluted or mildly polluted (0 < Igeo < 2). The concentrations of Cr, Mn, and Fe had a negative correlation with the water quality parameters of TDS and turbidity. The concentration of Cu has a positive correlation with the water quality parameters, TDS, and turbidity.

Introduction

The growth and development of the industry in Sorong City has increased in recent years and has had a significant impact on river quality. The Klagison River is located in the city of Sorong, West Papua, and is one of the rivers that has been polluted. The source of this pollution comes from various domestic and industrial activities. Illegal sand mining activities around the Klagison River are increasing. Waste from washing sand that is disposed directly into the river tends to be without good waste management. This causes turbidity and sedimentation along the Klagison River towards the river mouth. The results of field and laboratory studies show that the water quality of the Klagison River is included in classes III-IV based on Government Regulation No. 82 of 2001 on Management of Water Quality and Control Over Water Pollution, and has a turbidity value of >1,000 NTU [1]. A high turbidity value indicates that the carrying capacity of the Klagison River decreased, and the river water became cloudy due to sedimentation.

Water quality monitoring can be performed to detect changes in water quality. River water is considered polluted if its parameters exceed the required quality standards, and an indication of pollution may appear as anthropomorphic activities increase along the river banks due to the increasing human population. In addition to the level of river water pollution that needs to be checked in monitoring river quality, sediment pollution in the river is also important. The nature of sediment that can bind persistent and toxic chemical pollutants, such as metals, can be problematic because sediment is a habitat for aquatic biota in an ecosystem balance and the survival of biological resources.

Heavy metal pollution in aquatic ecosystems is a global problem [2]. Sediment variability is influenced by coastal processes and sources of metals [3]. The Mahakam Delta is affected by anthropogenic activities and metal content in the dissolved and precipitated forms [4]. The increase in heavy metal concentrations due to anthropogenic influences from gold mining activities, especially for Hg and As metals, is already at low to extremely high levels in all research locations, which allows it to have a high ecological risk impact on these

Corresponding Author: Nurbia Nurbia nurbia11.11@gmail.com Environmental Engineering, Universitas Muhammadiyah Sorong, Indonesia.

environmental areas [5]. In a study [6] on the waters of Bangka Island, two different methods showed different results. Based on the pollution load index, not polluted by metals Pb, Cd, Cu, Zn, and Ni because the pollution load index (PLI) value <1, but based on the geoaccumulation index (Igeo) for Cd, it is included in the category of unpolluted (Igeo < 0), lightly polluted (0<Igeo<1), and moderately polluted (1<Igeo<2). Heavy metals can settle to the bottom layer of sediment, which is indicated by the significant correlation in each layer of sediment and the vertical distribution discriminant analysis; there is a high variation in heavy metals in the sediment [7].

Studies on heavy metal pollution in river sediments in Sorong City are generally limited compared to those on river water pollution. Therefore, it is necessary to conduct studies to obtain information regarding the concentrations of heavy metals in sediments. The purpose of this study was to identify the concentration of heavy metal elements in sediments of the Klagison River using the PLI, Igeo, and the relationship between metal concentrations in sediments and river water quality.

Material and Methods

Study Area

This study was conducted in Sorong City, West Papua, Indonesia. Sorong City is located at 131°51'E and 0°54'N. In general, the geological conditions of Sorong City are above the confluence of three tectonic plates: the Philippine, Eurasian, and Pacific plates. The soil conditions in Sorong City consist of alluvial soil, complex podzolic, and gray-brown soil with variations in effective soil depth between 0 to 25 cm, 25 to 50 cm, and 51 to 100 cm. The research location was selected from the banks of the Klagison River.

The Klagison River is approximately 9 km long, and its depth ranges from to 2 to 4 meters. The water velocity of the Klagison River is 1.81 m/s with an average discharge of 6.40 m^3/s [8]. The Klagison Basin is located in the following three administrative areas: Matalamagi Subdistrict, North Sorong District; Sawagumu Subdistrict, North Sorong District; Klasabi Subdistrict, Sorong Manoi District. The research location started at the headwaters of the river, which is located in Matalamagi Village and ends downstream or at the river mouth in Klasabi Village. The sampling locations for Klagison River sediments are showed in Figure 1 and Table 1, while Figure 2 showed the conditions of Klagison River at observation.

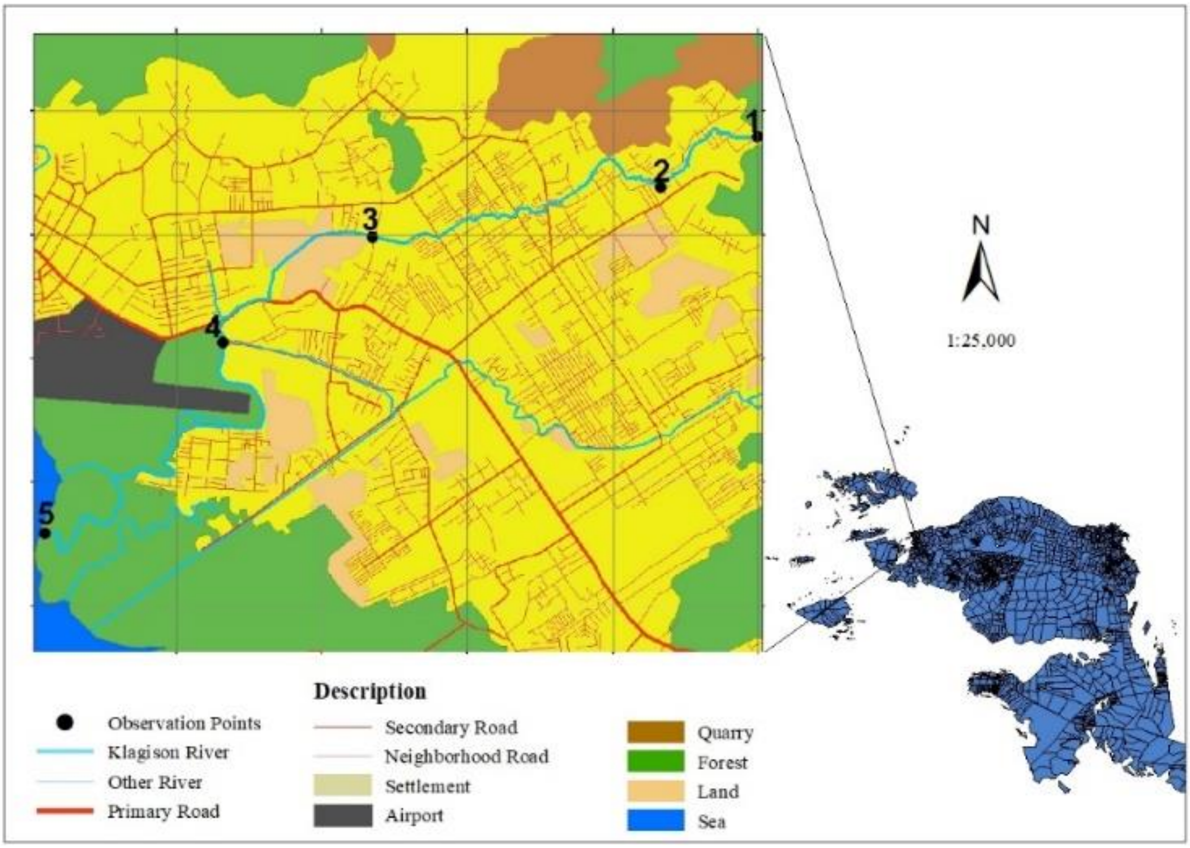


Figure 1. Research locations and observation points.

Table 1. Sampling station locations.

Station name	Description
St. 1	The upstream section with estimated of the river still in natural conditions. Water pollution comes from domestic waste.
St. 2	The middle part of the river with estimated water pollution comes from domestic waste, mining industry waste, and livestock waste.
St. 3	The confluence of the Klagison tributary from Malanu Village. Water pollution comes from domestic waste, food storage/processing warehouse waste, and mining industry waste.
St. 4	The confluence of the Klagison tributary from Klasabi Village. Water pollution comes from domestic waste, mining industry waste, and heavy equipment company waste.
St. 5	Downstream or Klagison river's mouth.

(a)

(b)

(c)

(d)

(e)

Figure 2. Conditions of Klagison River at observation; Station 1 (a) Station 2 (b) Station 3 (c) Station 4 (d) Station 5 (e).

Data Collection

The purposive sampling method was used to determine the location of the collection point and the sediment sampling tool using an Ekman grab. The samples studied were water and sediment from the Klagison River at five sampling points, and the distance between collection points varied. At each point, three samples were collected from the right, left, and middle sides of the river. The sample was placed in a plastic ziplock and a cooling container and then taken to the laboratory. The sediment samples were then homogenized and dried in an oven for 3 hours at 120 °C. The water quality testing method for TDS and turbidity parameters was performed in situ. Methods for determining metal concentrations using inductively coupled plasma optical emission spectrophotometry (ICP-OES). The quality standard used to determine the water quality is the Government Regulation of the Republic of Indonesia No. 22 of 2021 concerning the Implementation of Environmental Protection and Management. The quality standard used to determine sediment quality refers to the Ontario Ministry of Environment and Energy in the Guidelines for the Protection and Management of Aquatic Sediments. The Tomlison 1980 PLI is used to analyze the level of river pollution due to heavy metals using Equation 1 [9].

$$PLI = (CF1 \times CF2 \times CF3 \times \ldots\ldots. CFn)^{1/n} \quad (1)$$

$$CF = \frac{Cn}{Bn} \quad (2)$$

Where:

n : the number of metals.

CF : the pollution factor.

Cn : the concentration of metal elements in the sediment sample.

Bn : the concentration of metal n in the background sediment or reference value in Table 2.

Pollution load index values [9] are divided into six classes: class 0 = <1, not polluted; class 1 = 1 to 2 slightly polluted; class 2 = 2 to 4 moderately polluted; class 3 = 4 to 6 very polluted; class 4 = 6 to 8 very polluted to extremely polluted; and class 5 = 8 to 10 extremely polluted. While, the Muller 1979 geoaccumulation index was used to analyze the level of river pollution due to heavy metals using Equation 3 [10].

Table 2. Normal concentration value of metal elements.

Metal	Background (ppm)
Al	80,000
Fe	47,200
Cr	90
Cd	0.3
Cu	45
Mn	850
Ni	68
Pb	20

$$Igeo = \log 2 \left[\frac{Cn}{1.5 \times Bn}\right] \quad (3)$$

Where, Cn is the concentration of metal elements in the sediment sample. Bn is the concentration of metal n in the background sediment or reference value in Table 2. A factor of 1.5 is used because of the possibility of variations in values in the background such as anthropogenic influences.

The geoaccumulation index value [10] is divided into 6 classes with a class classification of 0 = <0 not polluted; class 1 = 0 to 1 moderately polluted; class 2 = 1 to 2 moderates to heavily polluted; class 3 = 2 to 3 heavily polluted; class 4 = 3 to 4 very polluted; class 5 = 4 to 5 very polluted to extremely polluted; class 6 > extremely polluted. Analysis of the relationship between heavy metal concentrations and water quality used a correlation analysis test with the Pearson coefficient [11] (equation 4). In this study, SPSS 25 was used to test the correlation analysis using Pearson's coefficient. The data included the results of water physics measurements and heavy metal concentrations in Klagison River water. The calculation results are then classified to determine the level of relationship with a very low correlation coefficient of 0.00 to 0.19, low 0.20 to 0.39, medium 0.40 to 0.59, and strong 0.60 to 0.79 [11].

$$r = \frac{n\sum_{i=1}^{n} X_i Y_i - \sum_{i=1}^{n} X_i \sum_{i=1}^{n} Y_i}{\sqrt{\sum_{i=1}^{n} X_i^2 - (\sum_{i=1}^{n} X_i)^2}\sqrt{\sum_{i=1}^{n} Y_i^2 - (\sum_{i=1}^{n} Y_i)^2}} \quad (4)$$

Where, n is the number of points of the variables X and Y. r is the correlation coefficient. x is independent variable (water quality parameters). y is the dependent variable (heavy metal concentration).

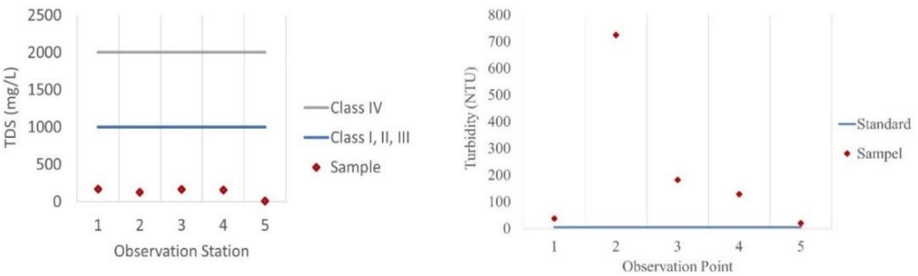
Results and Discussion

Water Quality Parameters

The results of field observations were obtained from five sampling stations with two parameters, TDS and turbidity, and compared to the water quality standards stipulated in Government Regulation No. 22 of 2021 concerning the Implementation of Environmental Protection and Management. This comparison determines the water quality of the Klagison River. The Klagison River is a river whose designation has not been determined in Sorong City, and based on Government Regulation of the Republic of Indonesia No. 22 of 2021, Class II water quality standards are stipulated as water quality standards in surface water bodies for rivers or water bodies whose designation has not been determined. Class II Water Quality Criteria are water that can be used for water recreation infrastructure, facilities, freshwater fish farming, animal husbandry, and water for irrigating plantations.

Total Dissolved Solids

Total Dissolved Solids (TDS) measurements in the water of the Klagison River showed different concentrations of dissolved solids at each observation station. Figure 3 shows the TDS value of the Klagison River ranged from 126 to 168 mg/L. This shows that the solids that enter the river are dominated by microsized solids or solids originating from organic waste. The Klagison River sediment has d50 grains with a diameter of 0.062 mm and d90 grains with a diameter of 0.073 mm, and the basic sediment classification is very fine sand [12]. Based on the results obtained, the TDS parameters of the Klagison River water at all observation stations were included in the Class II water quality standards category according to Government Regulation of the Republic of Indonesia No. 22 of 2021.



(a) (b)

Figure 3. (a) TDS and (b) Turbidity concentration in Klagison River water.

Turbidity

The results of water Turbidity measurements (turbidity) in the waters of the Klagison River showed a fluctuating concentration of turbidity at each observation station. The turbidity of the Klagison River water is in the range of 19.98 to 724 NTU. Observation station 2 the turbidity value reached 724 NTU, this is because at observation station 2 it is a source of river pollution from domestic waste, the sand mining industry and animal husbandry. At observation stations 1 to 5, the turbidity concentration of the Klagison River exceeded the limits of all classes of water quality standards according to Government Regulation of the Republic of Indonesia No. 22 of 2021 by 5 NTU.

Analysis of Heavy Metal Content in Sediments

The heavy metal content was analyzed to determine the concentration of heavy metals in the Klagison River sediments. The constituent elements of the Klagison River sediments were identified using the X-Ray Fluorescence (XRF) tool, as shown in Table 3 in the following percentages (%w/w). The metal constituents of Klagison River sediments include Al, S, Cl, Ti, K, Ca, V, Mn, Cr, Fe, Cu, Ni, Rb, Zn, Zr, and Sr. Metallic elements in the heavy metal category were obtained, namely Al, Mn, Cr, Ni, Fe, Zn, and Cu. Based on the results of the XRF analysis, the concentrations of heavy metals with a high degree of toxicity, namely Cr, Cu, Mn, and Fe, were selected for further observation. The concentrations of Cr, Cu, Mn, and Fe heavy metals obtained were then compared based on the sediment quality standard values from the Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario. Table 4 shows the Lowest Effect Level (LEL) showed the lowest effect level of heavy metals in sediments, and the Severe Effect Level (SEL) showed the level of severe effects of heavy metals in sediments.

Table 3. The content of the constituent elements of the Klagison River sediments contained in the 5 observation stations.

No.	Element	Concentration (%w/w)				
		1	2	3	4	5
1	Al	4.85	8.65	11.00	10.50	8.65
2	Si	16.00	40.00	34.50	26.00	27.00
3	P	0.71	0.93	0.77	0.61	-
4	S	0.26	0.41	0.10	0.36	2.30
5	Cl	27.70	1.70	2.90	3.35	17.80
6	K	1.70	15.35	22.25	8.78	9.81
7	Ca	5.04	5.23	2.85	2.20	3.76
8	Ti	2.05	1.60	2.01	2.27	1.75
9	V	0.11	0.08	0.07	0.10	0.07
10	Cr	0.16	0.06	0.05	0.29	0.44
11	Mn	0.61	0.50	0.26	0.49	0.20
12	Fe	39.85	24.30	21.35	43.40	27.35
13	Ni	0.06	0.04	0.03	0.28	0.07
14	Cu	0.24	0.27	0.27	0.32	0.23
15	Zn	0.09	0.07	0.08	0.12	0.09
16	Rb	0.07	0.31	0.56	0.30	0.29
17	Sr	0.17	0.26	0.23	0.23	0.23
18	Zr	0.08	0.11	0.57	0.35	0.24
19	Re	-	-	0.09	0.10	0.10

Source: [13]

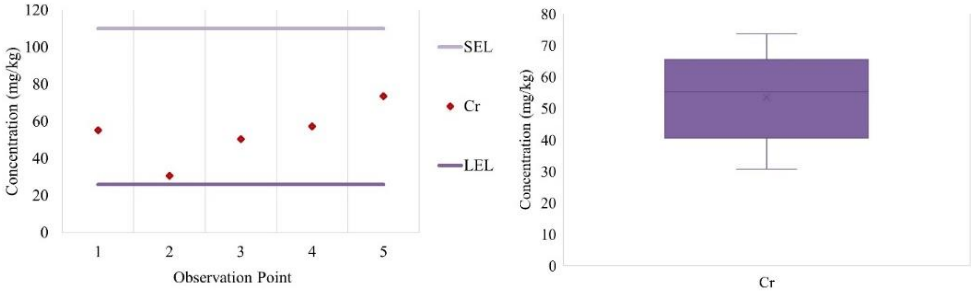
Table 4. Sediment quality standard values were determined according to the Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario.

Metal elements	No effect level	Lowest effect level Mg/g (ppm)	Severe effect level Mg/g (ppm)
Chromium (Cr)	-	26	110
Copper (Cu)	-	16	110
Manganese (Mn)	-	460	1,100
Iron (Fe)	-	20,000	40,000

Source: [14]

Concentration of Cr Elements

The results of the analysis of Cr metal obtained from the sediments showed varying concentration values at each observation station. Figure 4 shows the distribution of chormium in the sediments. The Cr metal ranged from 30.7 to 73.57 mg/kg. The highest Cr concentration was found at Observation Station 5 and the lowest was found at Observation Station 2. As shown in Figure 4, the Wishker box graph, the average Cr concentration in the Klagison River sediments was 53.422 mg/kg.

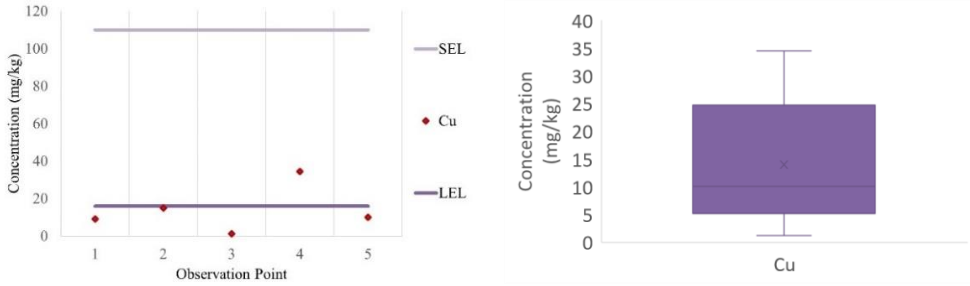


(a) (b)

Figure 4. (a) Chromium concentration; (b) Average chromium concentration values.

Concentration of Cu Elements

The results of the analysis of Cu metal obtained from the sediments showed varying concentration values at each observation station. Figure 5 shows the distribution of copper in the sediments. The Cu metal ranged from 1.20 to 34.47 mg/kg. The highest Cu concentration was found at Observation Station 4 and the lowest was found at Observation Station 3. As shown in Figure 5, the Wishker box graph, the average Cu concentration in the Klagison River sediments was 13,956 mg/kg.

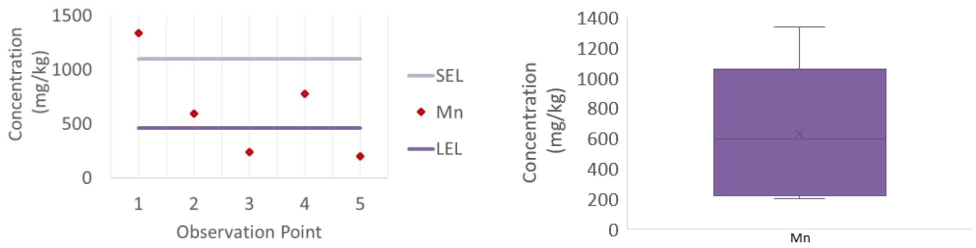


(a) (b)

Figure 5. Copper concentration (a) and Average copper concentration values (b).

Concentration of Mn Elements

The results of the analysis of Mn obtained from the sediment data showed varying concentration values at each observation station. Figure 6 shows the distribution of Mn in the sediments. The concentration of Mn in sediments ranged from 196.73 to 1,335.98 mg/kg. The highest Mn concentration was found at observation station 1 and the lowest at observation station 5. As shown in Figure 6 the wishker box chart, the average Mn concentration in Klagison River sediments was 629,024 mg/kg.

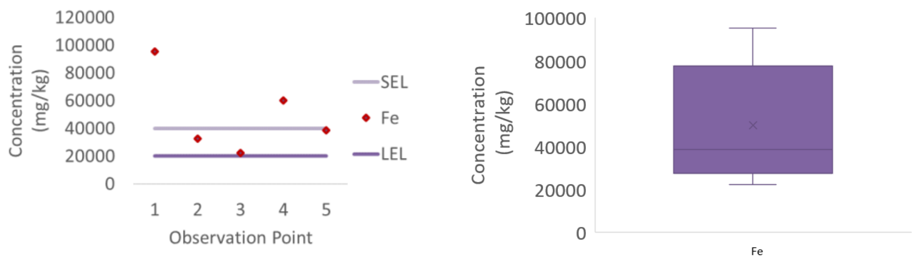


(a) (b)

Figure 6. Manganese concentration (a) and Average manganese concentration values (b).

Concentration of Fe Elements

The results of Fe metal analysis obtained data in sediments showed varying concentration values at each observation station. Figure 7 shows the distribution of iron data in the sediments. The concentration of iron metal in the sediments ranges from 22,400 to 95,400 mg/kg. The highest concentration of Mn was found at observation station 1 and the lowest concentration was found at observation station 3. As shown in Figure 7 the wishker box graph, the average iron concentration in the Klagison River was 49,800 mg/kg.



(a) (b)

Figure 7. Iron concentration (a) and Average iron concentration values (b).

Analysis of Heavy Metal Pollution Levels

The results of the analysis of heavy metal concentrations in the Klagison River sediments were then used to analyze the level of heavy metal pollution in sediments using the analysis method of pollution load index and geoaccumulation index.

Pollution Load Index

In calculate the pollution load index, the contamination factor (CF) is used. The results of the contamination factor calculation showed that the CF values for Cr and Cu in the Klagison River indicated that the contamination level was included in the low category CF < 1. The CF values for Mn and Fe showed moderate contamination levels of 1<CF<3. The PLI values obtained from the calculation ranges from 0.212 to 0.867 with an average of 0.557. This value was included in the unpolluted to slightly polluted areas because 0<PLI<2. Table 5 shows the results of calculating the contamination factor and pollution load index at the five observation stations. Sediment quality showed that it remained uncontaminated to moderately contaminated. In the findings for the Subtropical River, Gomti, Bangladesh, the quality of the sediment remained in conditions not contaminated with metal content with a value of CF < 1 and a value of 0<PLI<0.011 [15].

Table 5. CF and PLI values.

No.	Location	CF value				PLI
		Cr	Cu	Mn	Fe	
1	St. 1	0.613	0.202	1.572	2.021	0.792
2	St. 2	0.341	0.332	0.699	0.689	0.483
3	St. 3	0.560	0.027	0.284	0.475	0.212
4	St. 4	0.636	0.766	0.914	1.269	0.867
5	St. 5	0.817	0.223	0.231	0.822	0.432

Geoaccumulation Index

Geoaccumulation index calculation using background metal (Bn) from the global average share from Turekian and Wedepohl due to the absence of previous research at the research location or this research area. The results of calculating the geoaccumulation index showed that Cr and Cu metals at observation stations 1, 2, 3, 4, and 5 were 100% (Igeo < 0) in the unpolluted category, while Mn and Fe 80% were in the unpolluted category (Igeo < 0), and 20% were not polluted to lightly polluted (0<Igeo<2).

Table 6. Klagison River Geoaccumulation Index Value.

No.	Metal elements	Location				
		St.1	St.2	St.3	St.4	St.5
1	Cr	–1.290	–2.137	–1.422	–1.237	–0.876
2	Cu	–2.889	–2.174	–0.970	–0.970	–2.749
3	Mn	0.067	–1.101	–2.403	–0.714	–2.696
4	Fe	0.430	–1.123	–1.660	–0.241	–0.868

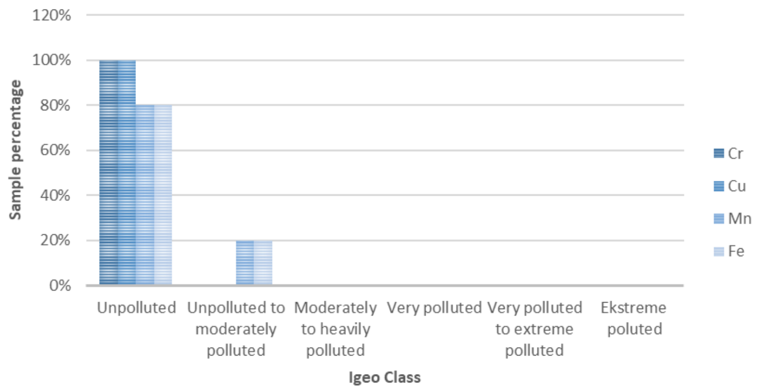


Figure 8. Classification index of metal geoaccumulation in sediments.

Table 6 shows the Igeo value of the Klagison River sediment and Figure 8 shows the level of heavy metal pollution in the sediment according to the Igeo class. In the sediments of the Biosphere Reserve, surface sediments are not contaminated to moderately contaminated with Pb, and are moderately to heavily contaminated with Cd [16].

Relationship Between Heavy Metal Concentration with TDS and Turbidity

Salidong et al. [17] evaluated the relationship between water pH and the physicochemical properties of water in influencing heavy metals and bacteriological factors on the surface of water and found that the physicochemical properties of water related to optimal pH and heavy metals were related to non-optimal pH. In this study, correlation analysis was used to determine the relationship between heavy metal concentrations in sediments and water quality parameters, TDS and Turbidity.

The correlation value with a positive sign (+) indicates the influence of the water quality parameter on increasing the concentration of metals in the sediment. Meanwhile, the correlation with a negative sign (–) indicates that the water quality parameter has no effect on the concentration of metals in the sediment. The results of the correlation analysis obtained in Table 7 showed that the concentrations of Cr, Mn, and Fe had a negative correlation with the water quality parameters of TDS and turbidity. The concentration of Cu has a positive correlation with the water quality parameters, TDS, and turbidity.

Table 7. Relationship between heavy metal concentrations in sediments with water quality.

Correlations					
Water Quality		Cr	Cu	Mn	Fe
TDS	Pearson Correlation	–0.544	+0.296	–0.266	–0.508
Turbidity		–0.897	+0.053	–0.110	–0.438

Conclusion

The TDS value of the Klagison River ranged from 126 to 168 mg/L and turbidity range of 19.98 to 724 NTU. The results pollution load index showed that the sediment with a PLI value of 0.557 tended to be not polluted or lightly polluted. Index geoaccumulation showed Cr and Cu values of 100% (Igeo < 0), while Mn and Fe were 80% unpolluted (Igeo < 0) and 20% unpolluted or mildly polluted (0<Igeo<2). The concentrations of Cr, Mn, and Fe had a negative correlation with the water quality parameters of TDS and turbidity. The concentration of Cu has a positive correlation with the water quality parameters, TDS, and turbidity.

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