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Distribution and Concentration of Pb, Cd, and Hg Metals Due to Land Use Influence on Sediment in Malili River, East Luwu Regency

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ABSTRACT

This research was conducted in the waters of Malili River, East Luwu Regency, with 4 observation points in Malili River East Luwu Regency, namely: (a) Southeast Sulawesi Sub Das (Point 1) namely Pongkeru village bridge, Coordinate point 12126.69‘8°” E; (b) Larona Sub Das Karebbe basin bridge (Point 2), Coordinate point 12115.09‘9°” E; (c) The meeting point of Larona sub-dash and Pongkeru sub-dash (Point 3), coordinate point 12159.64‘8°” E; (d) Upper Malili River, Malili village, Malili bridge (Point 4), Coordinate point 12147.20‘5°” E. Metal concentration and distribution were analyzed descriptively with the help of images (maps), graphs, and tables. Differences in Pb, Cd, and Hg metal concentrations in sediments between point locations were tested using analysis of variance (ANOVA) through the SPSS version 22 program. The relation between grain size, organic matter, and Pb, Cd, and Hg metal concentrations was tested using linear correlation. The results showed that the sediment content of Pb and Cd metal concentrations at each point location did not exceed NOAA (1999) quality standards. In the sediment, Hg metal concentration exceeds the quality standards of NOAA (1999) at each point, namely point 1. Pongkeru 0.590 $\mu g.g^{-1}$, point 2. Karebbe 0.229 $\mu g.g^{-1}$, point 3. Kawasule 0.514 $\mu g.g^{-1}$ and point 4. Malili 0.358 $\mu g.g^{-1}$. The relation between sediment size and Pb, Cd, and Hg metal concentrations at each point location has a weak correlation. The relation does not significantly affect the content of heavy metals in the sediment. It may be due to other factors, such as the source of heavy metal pollutants in each different point location. The relation between organic matter and the concentration of Pb, Cd, and Hg metals at each point location has a weak correlation. The relation does not significantly affect the content of heavy metals in the sediment because it may be due to other factors, such as different sources of heavy metal pollutants in each point location.

INTRODUCTION

River water quality can be polluted if there are activities that impact river water quality, but if there is public awareness and active participation, river water quality can be maintained. One of the areas known for its waters is Malili. It is a water area that has experienced the biggest impact due to mining activities, namely in Sorowako mining activities of PT Vale, and in Pongkeru, there is the mining of PT CLM and several southeast Sulawesi companies. Not only that, along the river flow, there are also many forest land conversion activities into pepper plantations, illegal logging, and residential settlements (Prawita et al. 2008).

According to Government Regulation No. 38/2011 on Rivers, several things must be considered in managing rivers, one of which is river boundaries. The government has regulated that river borders should not be planted with plants other than grass, and buildings should not be erected (Yogafanny 2015). Pollution and sedimentation are high due to supplies from the watershed, especially by mining activities, agriculture, and household waste, especially supplies from the Salonoa River, Angkona River, and Malili River (Ayyub et al. 2018). The Malili River estuary is experiencing an increase in sediment in the estuary (Lanuru & Syafyudin 2018).

The higher the population activity along the watershed, the higher the possibility of pollutants in the river. The content of Hg, Pb, and Cd is very dangerous if it is in water. The number of activities around the river is the cause of polluted river waters. Pollution in the waters can be in the form of organic and inorganic compounds. Inorganic components can be heavy metals such as Pb, Cu, Zn, Cr, Ni, Hg, etc. The presence of heavy metals in the environment is considered dangerous because of their non-degradable nature. However, they are still often used in human activities, so their production is also increasing (Sumekar et al. 2015).

The presence of heavy metals in water can negatively impact human health, accumulating in body tissues. It can cause poisoning for humans if they exceed tolerance limits and accumulate in sediments and biota through bioconcentration, bioaccumulation, and biomagnification by aquatic organisms. According to Mahardika et al. (2012), heavy metals enter the waters as part of the suspension system in water and sediment through the process of absorption, deposition, and ion exchange. Heavy metals can accumulate in solids in waters, such as sediments. Sediment quality testing, especially on heavy metal parameters, is an important stage in assessing the quality of the aquatic environment.

Heavy metals from human and natural activities are distributed on sediment particles of different sizes. The distribution of heavy metals in various particle sizes is influenced by the formation of sediments both naturally and non-naturally. Particle size plays an important role in the distribution of heavy metals in sediments (Maslukah 2013). The many activities of land use change activities such as nickel ore mining exploitation, namely at PT Vale from the upper Larona sub-dash (Sorowako) and PT CLM and Southeast Sulawesi companies from the upper Pongkeru sub-dash (Southeast Sulawesi) and the existence of forest land conversion activities into pepper plantations, illegal logging, and residential settlements are vulnerable to river pollution in Malili, East Luwu district which can cause siltation, degradation of water quality, endanger aquatic biota and human health. This is the background for the research on "Distribution and Concentration of Pb, Cd and Hg Metals Due to the Effect of Land Use on Sediments in Malili River, East Luwu Regency."

MATERIALS AND METHODS

Research Area

This research was conducted in the waters of Malili River, East Luwu Regency, with 4 observation point locations in Malili River, East Luwu Regency, namely: (a) Southeast Sulawesi Sub Das (Point 1) namely Pongkeru village bridge, coordinate point 121°8'26.69" E; (b) Larona Sub Das Karebbe basin bridge (Point 2), coordinate point 121°9'15.09" E; (c) Larona Sub Das and Pongkeru Sub Das meeting point (Point 3), coordinate point 121°8'59.64" E; (d) Upper Malili River, Malili village, Malili bridge (Point 4), coordinate point 121°5'47.20" E.

Sample Preparation and Method

Sediment sampling was carried out using an Eckman Grab with a depth of ± 10 cm with the valve teeth left open. After the tool reaches the bottom, the weight is released, which causes the valve to close tightly so that the substrate that has been trapped in the Eckman Grab cavity will not be released again. Then the tool is pulled up to the surface. Then a sediment sample was taken as much as 250 grams using a plastic spoon. To avoid contamination, only the center of the sediment in the Eckman Grab was taken to analyze heavy metal content in the laboratory. The temperature and pH of the sediment were measured immediately at the time of collection. The collected sample material was put into polyethylene plastic bags, stored in an ice box, and immediately brought to the laboratory. Wet samples were air-dried for 3 days. The dried sediment samples were crushed using a porcelain mortar and pestle. Samples that have been finely weighed as much as 0.2 grams are dissolved in concentrated HNO_3 to a volume of 10 mL and added $HClO_4$ as much as 0.5 mL, then heated in a water bath with a temperature of 80°C for 30 min, cooled and diluted with aquabidest to a volume of 50 mL, filtered with Whatman 42 filter paper, and then analyzed with an ICP machine (Afifah et al. 2019).

Hg, Pb, and Cd Concentration Measurement

Hg, Pb, and Cd concentrations $\mu g/g = \frac{(D-E)\ x\ Fp\ x\ V}{W}$

Where:

D = sample concentration $\mu g/I$ from the ICP reading result

E = concentration of sample blank $\mu g/I$ from the ICP reading result

Fp = dilution factor

V = Final volume of sample solution prepared (mL), must be in units of liters.

W = sample weight (g)

Measurement of Total Organic Matter in Sediments

BOT content was analyzed using the Loss On Ignition (LOI) method. Sediment samples were dried using an oven for 2×24 h/sample to dry at 105°C. Weigh the weight of the porcelain cup (Bc). Weigh the weight of the sediment sample in the oven as much as ± 5 grams and record it as the initial weight (Baw). The cup is in the oven to ensure that there is no residual water content in the cup so that during the high-temperature exposure, the cup does not break. Heating a porcelain cup containing 5 grams of sediment samples using a furnace at 550°C for approximately 3.5 h. After reaching

3.5 h, the sediment sample in the cup was removed from the furnace. Weigh back the sample in the cup in the furnace as the final weight (Bak).

The following formula was used to calculate the organic content of sediments (Lanuru 2004).

$$\text{Organic matter (\%)} = \frac{initial\ weight\ (g) - weight\ after\ ashing\ (g)}{initial\ weight\ (g)} \times 100\%$$

Data Analysis

The concentration and distribution of metals will be analyzed descriptively with the help of images (maps), graphs, and tables. Heavy metal concentrations at each point location will be compared with the 1999 NOAA standard (*Sediment Quality Guidelines developed for the National Status and Trends Program)*. Differences in Pb, Cd, and Hg metal concentrations in sediments between point locations are tested using analysis of variance (ANOVA) through the SPSS version 22 program. The relation between grain size, organic matter, and Pb, Cd and Hg metal concentrations was tested using linear correlation (Steel & Torrie 1991).

RESULTS AND DISCUSSION

Land Use

The following results of the land use analysis in the Malili River basin of East Luwu Regency are presented in Fig. 1.

Land use in the Malili river basin of East Luwu district has many human activities, as seen in point 1. Southeast Sulawesi sub-basin, precisely the bridge of Pongkeru Village, activities around the waters are dry land farming, forests, and mining at point 2. Larona Sub-dash, to be precise, the Laskap Karebbe bridge, activities around the waters are settlements, forests, and dry land farming at point 3. Meeting of Larona Sub-Dash and Southeast Sulawesi Sub-Dash precisely in Kawasule Village, activities around the waters are rice fields, plantations, forests, and sand mining activities that cannot be read on the map at point 4. Upper Malili River, activities around the waters are residential areas, rice fields, dry land farming, plantations, and ponds.

The fact is that the use of land maps is closely related to various purposes, including watershed management, forestry engineering, soil and water conservation, settlement architecture, road networks, reclamation of degraded lands, and many other activities that require land information. This land use map shows what activities affect the surrounding river bodies so that pollution in the waters occurs.

Land use is very important for the government to know the land used by the community where the central and regional governments will know the most potential income

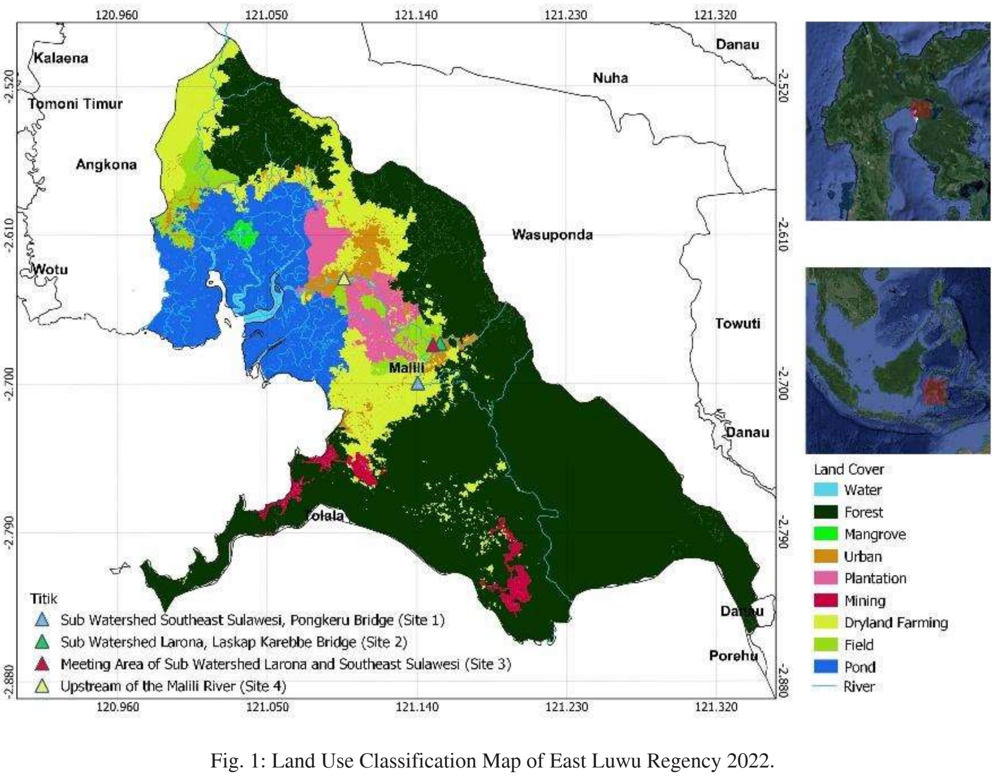

Fig. 1: Land Use Classification Map of East Luwu Regency 2022.

Table 1: Average concentration of heavy metal Pb at each location point.

No.	Point (Repeat)	Concentration [μg.g^{-1}] Pongkeru	Karebbe	Kawasule	Malili
1.	1.1	1.195	2.847	2.812	4.419
2.	1.2	4.560	2.567	2.497	4.612
3.	1.3	5.701	1.672	2.639	4.479
	Average	3.819	2.362	2.694	4.503
	Quality Standard	ERL 46.7 μg.g^{-1} and ERM 218 μg.g^{-1}			

Source: Primary Data, 2023

in each region. The results obtained by using GIS in geo-governance studies, analyzing regional administrative maps, and combining data can be used to solve the critical environmental, social, and economic situations involved in land use management in each region.

Concentration of Pb, Cd, and Hg Metals in Sediments

Based on the results of the analysis of Pb, Cd, and Hg metals carried out at four points by conducting three replicates in the field can be seen in the discussion below by looking at the 1999 NOAA quality standards (*Sediment Quality Guidelines developed for the National Status and Trends Program)*.

Heavy metal lead (Pb): Results of Pb metal testing in Malili river waters with four location points are presented in Table 1.

Based on Table 1. The average concentration of Pb metal at each point shows a concentration that does not exceed the quality standard, namely at Pongkeru 3,819 μg.g^{-1}, Karebbe 2,362 μg.g^{-1}, Kawasule 2,694 μg.g^{-1} and Malili 4,503 μg.g^{-1}. It can be said that heavy metal Pb has not fully polluted each point and is still far from the quality standard threshold limit of 46.7 μg.g^{-1}. The difference in each location point of heavy metal Pb can be seen in Fig. 2:

The highest result of Pb metal in each location point is in Malili, as much as 4,503 μg.g^{-1}. This Pb metal pollution is closely related to the many community activities, such as residential settlements located on the banks of the river and the existence of sales activities whose waste is discharged into the river, causing the high content of Pb in Malili. This is in accordance with the opinion of Ahmad et al. (2021), which states that heavy metal Pb pollution to the environment occurs due to a process that is closely related to the use of these metals in human activities and intentionally or unintentionally discharges various wastes containing heavy metals into the environment.

The high content of Pb in Malili is also due to the dense shipping activities of fishermen, such as painting ships on the riverbank and ships passing by also affect the high content of Pb metal in Malili. Zulfikar (2016) found that the highest value was obtained at the point 2 location with

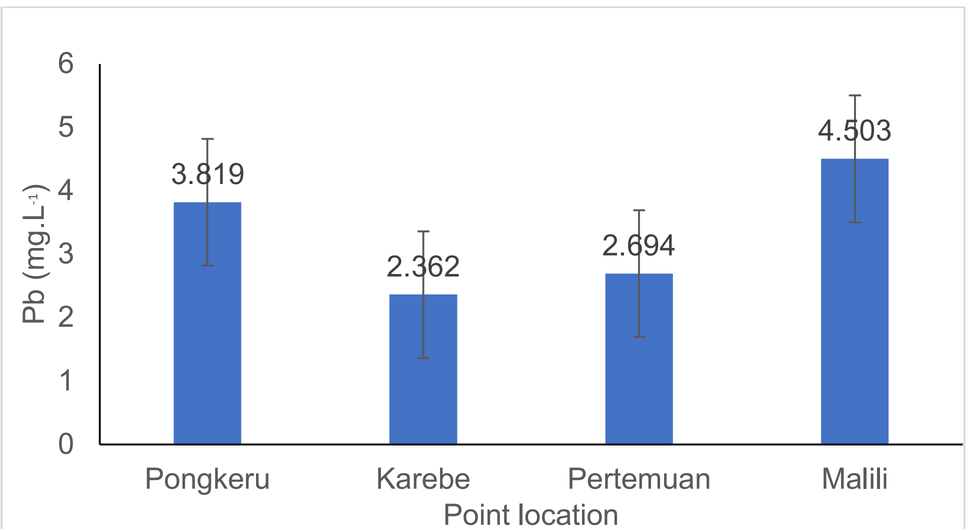

Fig. 2: Diagram of heavy metal Pb at each point.
Source: Primary data, 2023

an average Pb metal content of 22.96 $\mu g.g^{-1}$ due to ship and port activities, such as ship painting, ship refueling, and port waste that produces non-essential metals containing Pb elements from ship engines accidentally discharged into water bodies. According to Sumekar et al. (2015), the Pb content of the Dead River estuary is a place for fishermen who use motorized boats that may emit Pb-containing gases. Pb metal is often used as a mixture in fuel to increase octane value, although its use is starting to be reduced.

In Malili and Pongkeru, the results of Pb metal are not much different, namely 4,503 $\mu g.g^{-1}$ and 3,819 $\mu g.g^{-1}$. It can be said that the activities in Malili, namely residential areas and the number of fishing boats passing by to go to the sea, and in Pongkeru, namely the number of mining activities, are not significantly different. Based on the research of Budiastuti et al. (2016), the analysis of lead metal measurement results in Babon River sediments ranged from 4.17 $mg.kg^{-1}$ - 7.256 $mg.kg^{-1}$ of lead levels in sediments with no significant difference between sediment lead at sampling points in industrial areas and sampling points in residential areas. This is due to the nature of heavy metals that easily precipitate so that heavy metal lead has settled at the bottom of the waters. According to Putri et al. (2014), contamination from heavy metals in sediments will persist for a long period, even when the source of pollution is gone. Based on heavy metal data in sediments, past conditions can be studied and estimated the number of heavy metals accumulated in sediments.

The Pb metal content in Karebbe is low compared to other points at 2,362 $\mu g.g^{-1}$. The high dissolved oxygen at the location of point 2 is 6.2 ppm. The level of dissolved oxygen in the water strongly indicates pollution. Low DO values affect the toxicity of lead metal (Pb) (Budiastuti et al. 2016). In Karebbe and Kawasule, the results of Pb metal in Kawasule are also not much different, namely 2,694 $\mu g.g^{-1}$, because the distance between the waters of point 2 and point 3 is not too far. According to Wulandari et al. (2008), the current speed also affects the distribution of Pb and Cd metal concentrations.

Heavy metal cadmium (Cd): Based on the results of Cd

Table 2: Average concentration of heavy metal Cd at each location point.

		Concentration [$\mu g.g^{-1}$]			
No.	Point (Repeat)	Pongkeru	Karebbe	Kawasule	Malili
1.	1.1	0.021	0.044	0.020	0.040
2.	1.2	0.044	0.038	0.023	0.036
3.	1.3	0.068	0.031	0.019	0.043
	Average	0.044	0.038	0.021	0.040
	Quality Standard	ERL 1.2 $\mu g.g^{-1}$ and ERM 9.6 $\mu g.g^{-1}$			

Source: Primary Data, 2023

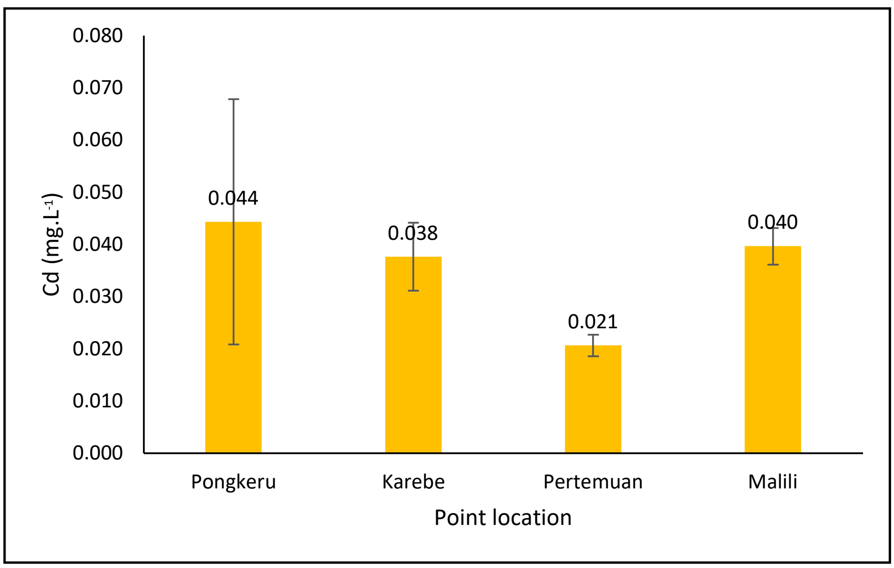

Fig. 3: Diagram of heavy metal Cd at each point.
Source: Primary Data, 2023

metal testing in Malili river waters with 4 location points, the concentration values can be seen in Table 2.

The average concentration of Cd metal at each point location shows a concentration that does not exceed the quality standard, namely at Pongkeru 0.044 $\mu g.g^{-1}$, Karebbe 0.038 $\mu g.g^{-1}$, Kawasule 0.021 $\mu g.g^{-1}$ and Malili 0.040 $\mu g.g^{-1}$. It can be said that each point has not been fully polluted by Cd heavy metal and is still far from the quality standard threshold limit of 1.2 $\mu g.g^{-1}$. The difference in each location point of heavy metal Cd can be seen in Fig. 3.

The results of Cd metal at each location point have relatively the same content and are below the quality standard. The highest Cd content at each point location is at Pongkeru, which is 0.044 $\mu g.g^{-1}$. This Pongkeru point is a mining stream, dry land agriculture such as plantations, and changes in land use from forest to pepper plantations which are thought to increase heavy metal Cd. The existence of dry land agriculture around the river using fertilizers can enter the body of water, which is thought to be the cause of the Cd metal factor. This is in line with the statement of Rachmaningrum et al. (2015), which states that phosphate fertilizers, garbage deposits, and waste from coal and oil can cause cadmium. River water and irrigation for agriculture containing cadmium (Cd) will accumulate in sediments and mud (Sudarmaji et al. 2006).

Karebbe and Malili have the same average Cd content of 0.038 $\mu g.g^{-1}$ and 0.040 $\mu g.g^{-1}$. It can be seen from the land use map Fig. 2. around the location of this point. Many residential areas, sales activities, and Malili platforms are tours around the river, causing domestic waste such as laundry detergents, plastic waste, and fecal waste from people living around the river, causing Cd content in sediment waters. The results obtained by Wulandari et al. (2008) conducted research on the Cd content in the Babon River sediment at the point 6 location, which is 0.042 ppm. The high Cd content is due to activities around the Babon River from domestic waste, such as settlements, restaurants, and hotels. The presence of Cd in the aquatic environment can come from community activities, for example, market waste and household waste, repair, and painting of fishing boats (Alisa et al. 2020).

At Malili point, the Cd content of 0.040 $\mu g.g^{-1}$ is watering adjacent to fishery ponds that can have a dangerous impact. Based on Government Regulation No. 82 of 2001, the standard value of Cadmium heavy metal for fisheries is 0.01 $mg.L^{-1}$. According to Rachmawatie et al. (2009), the content of Cadmium parameters in the 2nd and 3rd locations, namely 0.025 $mg.L^{-1}$ and 0.075 $mg.L^{-1}$ in the estuary of the Porong River, exceeds the standard, so that the condition of these waters is not suitable for fisheries activities and marine biota habitat. The existence of fishing and harbor shipping activities around the waters causes high Cd content in the waters. This is in accordance with the opinion of Syaifullah et al. (2018) suggest that fishing port activities, and the manufacture and repair of fishing boats, are thought to be the cause of the high Cd metal content in the waters.

The low Cd content in Kawasule is 0.021 $\mu g.g^{-1}$; many sand mining activities do not affect the Cd content. This is not in line with the research of Rachmawatie et al. (2009), suggesting that the highest Cd content is found at point 3, which is 0.075 $mg.L^{-1}$ because this location is close to the sand mining area. Although the Cd metal content at each point location is low and does not exceed the quality standards, it can be toxic if accumulated in large quantities. It can have an impact on human health and aquatic organisms. According to Emilia et al. (2013), human activities can cause an increase in the amount of pollutant discharges, including heavy metal pollution such as cadmium which is a threat to the environment because it can accumulate in the body of living things through the food chain level to the highest tropical level such as humans.

Heavy metal mercury (Hg): Based on the results of Hg metal testing in Malili river waters with 4 location points, the concentration value can be seen in Table 3

The average concentration of Hg metal at each point shows concentrations that exceed the quality standard, namely at Pongkeru 0.590 $\mu g.g^{-1}$, Karebbe 0.229 $\mu g.g^{-1}$, Kawasule 0.514 $\mu g.g^{-1,}$ and Malili 0.358 $\mu g.g^{-1}$

Table 3: Average concentration of heavy metal Hg at each location point.

No.	Point (Repeat)	Concentration [$\mu g.g^{-1}$]			
		Pongkeru	Karebbe	Kawasule	Malili
1.	1.1	0.507	0.348	0.378	0.390
2.	1.2	0.563	0.213	0.335	0.364
3.	1.3	0.699	0.125	0.829	0.320
	Average	0.590	0.229	0.514	0.358
	Quality Standard	ERL 0.15 $\mu g.g^{-1}$ and ERM 0.71 $\mu g.g^{-1}$			

Source: Primary Data, 2023

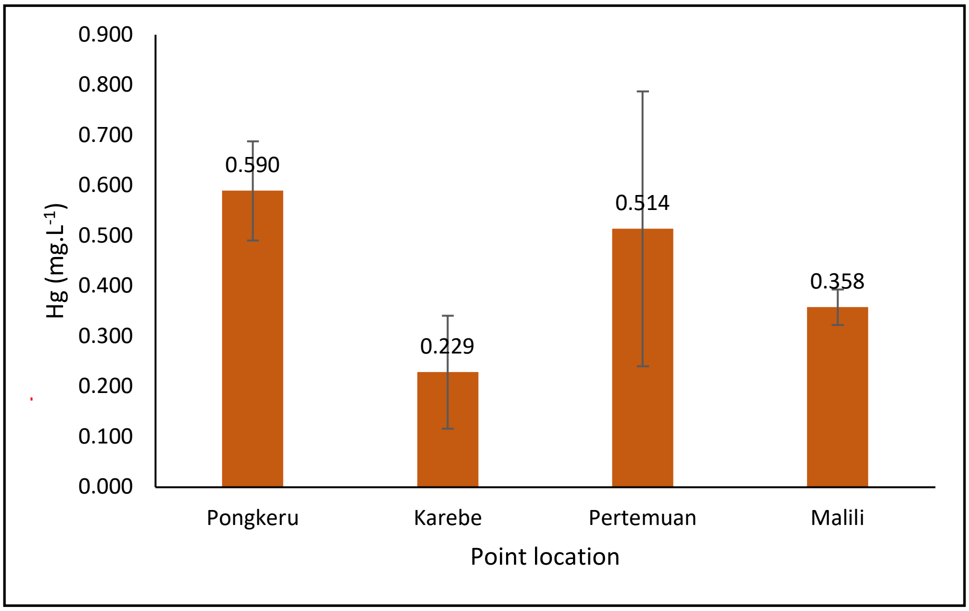

Fig. 4: Diagram of heavy metal Hg at each point.
Source: Primary Data, 2023

(Table 3). It can be said that each point is polluted by heavy metal Hg which exceeds the quality standard threshold limit of 0.15 μg.g^{-1}. The difference in each location point of heavy metal Hg can be seen in Fig. 4.

Based on Fig. 4, the results of the Hg metal content at each point location exceed the quality standard limit. In the upper reaches of the Pongkeru sub-dash, the highest Hg metal content among each point is 0.590 μg.g^{-1}. In Pongkeru, it can be seen on Map 1 that it is a stream from a large mine engaged in nickel, and along this stream, there is also dry land agriculture, namely the conversion of forest land into pepper plantations. This is in line with the statement of Alwan (2021), which states that sampling points closer to the mine have the potential to have a relatively large accumulation of Hg metal compared to sampling points far from the source of mining activities. Supported by Yudo's (2006) opinion, heavy metal pollution can be caused by industrial activities around the river, including the transportation industry, oil industry, mining, agriculture, and service industries that can produce waste and will increase pollution in the river. The high mercury content is also due to the sampling time during the dry season. In the dry season, mercury concentration will be greater than in the rainy season (Widodo 2008).

The results of the diagram at Kawasule, the meeting point between the upstream of the Larona sub-dash and the upstream of the Pongkeru sub-dash, also exceeded the quality standard limit of 0.514 μg.g^{-1}. The high content of Hg metal at point 1 Pongkeru is thought to flow into Kawasule, causing the high content of Hg metal. Activities around Kawasule waters are also illegal sand miners, agriculture, and plantations are the cause of high Hg metal. According to the opinion of Yulianti et al. (2016), mercury concentrations have increased after mining; environmental quality has decreased due to pollution due to mining and processing methods that do not follow the rules of "good mining practice." The beginning of contamination of aquatic organisms is the entry of industrial waste into water bodies (Yudo 2006).

The lowest result of Hg metal content is found in Karebbe, which is 0.229 μg.g^{-1}. At point 2, Karebbe is the upstream river of the Larona sub-dash which is a mining stream from a large company engaged in nickel. However, these Karebbe waters already have a dam as a prevention of mine waste disposal so as not to enter the waters compared to the high Hg metal results in Pongkeru waters which also have nickel mining activities, but at this point Pongkeru there is no dam around the waters. According to Syarifuddin (2022), the solution to reduce mining waste is to make tailings dams, make a waste paste, or process waste to be returned to the ground. Tailings containing mercury directly discharged into the river can pollute aquatic biota such as fish and other aquatic plants and further damage the aquatic environment's food chain (Boky et al. 2015).

At Malili Point downstream to the sea, the Hg metal content of 0.358 μg.g^{-1} exceeds the NOAA quality standard. Residential activities around the river, sales, and platforms that become community tourism in Malili are some of the factors causing Hg content in the waters. The impact of domestic waste disposal in rivers can cause pollution and reduce water quality. According to Pratiwi (2020), mercury can enter the water due to mining activities, coal combustion residues, factory waste, fungicides, pesticides, household waste, and so on. Malili waters also have shipping and weathering activities that are thought to be a source of Hg. The results of Zulfikar's research (2016) suggest that the average Hg content of 1.00 $mg.kg^{-1}$ in Karebbe is thought to be caused by ship washing activities, refueling, which is thought to be accidentally discharged into water bodies and is a port area.

Malili's proximity to fishery ponds and the sea can toxic impact water organisms. Poisoning caused by mercury generally begins with the habit of eating food from the river, such as shrimp, fish, and shellfish that have been contaminated with mercury (Yudo 2006). The high content of Hg has a toxic impact on the aquatic environment and humans. Fish or any type of food with a content of > 0.5 ppm Hg should be banned from the market and include water with a content of < 1 mg $Hg.dm^{-3}$ (Herman 2006). This is in line with the opinion of Syaifullah et al. (2018), which states that the danger of Hg metal content in waters will have an impact on the life of aquatic biota, affect aquatic biota, and pose a risk to fish eaters, such as humans and animals.

Relation of Sediment Grain Size with Pb, Cd, and Hg

Based on the measurement results of sediment particles at each location point, namely point 1. Pongkeru, point 2. Karebbe, point 3. Kawasule, and point 4. Malili, sediment has been classified based on the grain size listed in Table 4.

The presence of heavy metals in sediments is closely related to the size of sediment grains. Generally, sediments with finer sediment sizes contain greater concentrations of heavy metals than sediments with large sediment grain size types (Maslukah 2013). However, the Malili River waters have a medium sand grain size classification. The analysis shows that grain size and total metal concentration in sediment have a weak correlation, with correlation coefficient values of 0.0322 (Pb), 0.0065 (Cd), and 0.0511 (Hg). The weak correlation coefficient value of grain size and metals is due to the texture of medium sand grains that bind little metals. This is in line with the opinion of Miranda et al. (2018) that the sandier the texture of organic matter is, the less and heavy metals are also less, so the correlation relation is weak.

Fine sediment particles have a large surface with a more stable ion density to bind metals than larger sediment particles. So the smaller the sediment particle size, the more

Table 4: Sediment classification based on grain size (mm).

Point location	Pb	Cd	Hg	Grain Size
Point 1.1	5.701	0.068	0.699	164.6
Point 1.2	1.195	0.021	0.507	163.2
Point 1.3	4.56	0.044	0.563	158
Point 2.1	2.567	0.038	0.213	464,1
Point 2.2	1.672	0.031	0.125	440.6
Point 2.3	2.847	0.044	0.348	865.6
Point 3.1	2.497	0.023	0.335	379.1
Point 3.2	2.639	0.019	0.829	379.3
Point 3.3	2.812	0.02	0.378	384
Point 4.1	4.612	0.036	0.364	334.2
Point 4.2	4.479	0.043	0.32	323.8
Point 4.3	4.419	0.04	0.39	331.3

Source: Primary Data, 2023

it will have a large surface area where the process of binding heavy metals by sediments will increase (Sahara 2009). However, the results of high Hg metal content at each point location do not affect the grain size or prove the phenomenon of adsorption with this model.

The difference in sediment grain size greatly affects the physical process, namely the process of stirring and deposition strongly influenced by environmental conditions such as currents. The current will affect the deposition or sedimentation rate and the size of sediment grains deposited. According to Maslukah (2013), shallower waters and higher current velocities will affect the grain size distribution in sediments. The sand fraction mostly influences the texture of sediments contained in the waters of the Malili River.

Relation of sediment grain size with Pb metal concentration: The analysis shows that The relation between Pb metal and the percentage of sediment grain size has a weak correlation, with a coefficient of determination of 0.0322 (Pb). The relation between sediment grain size and Pb metal can be seen in Fig. 5.

Based on the calculation of the correlation test, the coefficient of determination is 0.0322. The magnitude of the coefficient of determination (R^2) 0.0322 is equal to 3.22%. This figure means that the level of influence of sediment size on Pb metal in Malili river waters at 4 location points is 3.22%, while other factors influence the remaining 96.78%.

Relation of sediment grain size with Cd metal concentration: The analysis shows that The relation between Cd metal and sediment grain size percentage has a weak correlation, with a coefficient of determination of 0.0065 (Cd). The relation between sediment grain size and Cd metal can be seen in Fig. 6.

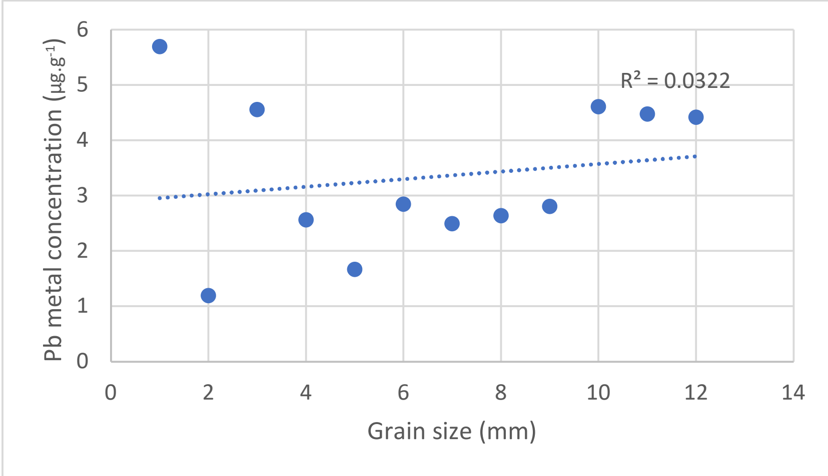

Fig. 5: The relation between sediment grain size and Pb metal concentration.
Source: Primary Data, 2023

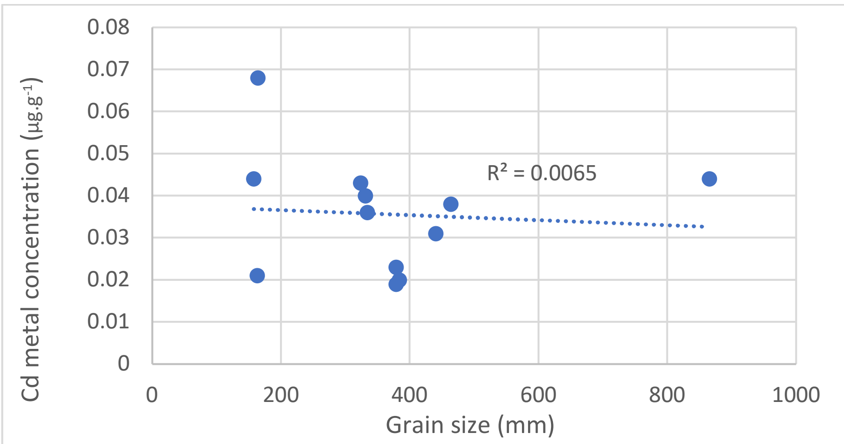

Fig. 6: The relation between sediment grain size and Cd metal concentration.
Source: Primary Data, 2023

Based on the calculation of the correlation test, it is known that the coefficient of determination is 0.0065. the magnitude of the coefficient of determination (R^2) 0.0065 is equal to 0.65%. This figure means that the level of influence of sediment size on Cd metal in Malili river waters at 4 location points is 0.65%, while the remaining 99.35% is influenced by other factors.

Relation of sediment grain size with Hg metal concentration: The analysis shows that the relation between Hg metal and sediment grain size percentage has a weak correlation, with a coefficient of determination of 0.0511 (Hg). The relation between sediment grain size and Hg metal can be seen in Fig. 7.

Based on the calculation of the correlation test, the coefficient of determination is 0.0511. The magnitude of the coefficient of determination (R^2) 0.0511 is equal to 5.11%. This figure means that the level of influence of sediment size on Hg metal in Malili river waters at 4 location points is 5.11%, while other factors influence the remaining 94.89%.

Relation of Sediment Organic Matter with Heavy Metal Concentrations of Pb, Cd, and Hg

Based on the results of measuring sediment particles at each location point, namely point 1. Pongkeru, point 2. Karebbe, point 3. Kawasule, and point 4. Malili, the sediment has been classified based on the organic matter listed in Table 5.

Organic matter has a relation to the concentration of metal content in sediments. According to Maslukah (2013), organic matter content generally tends to be high in sediments with

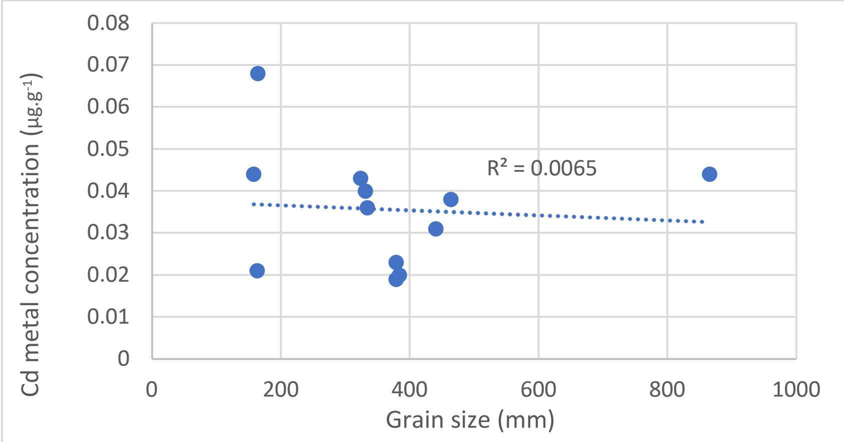

Fig. 7: The relation between sediment grain size and Hg metal concentration.
Source: Primary Data, 2023

fine grain size. Fine grain size will be followed by heavy metal concentrations that tend to be high. In Malili river waters at 4 point locations, the analysis results show that organic matter and total metal concentrations in sediments have a weak correlation The relation, with a correlation coefficient value of 0.3715 (Pb), 0.1451 (Cd), and 0.0208 (Hg). Based on the correlation test, organic matter shows a weak relation. The high Hg metal content at each point location does not affect organic matter. This is not in accordance with the opinion of Hoshika et al. (1991), which states that the content of heavy metals in sediments increases with the increase in the content of organic matter contained in water bodies and sediments. According to Thomas and Bendell (1998), organic matter is the most important geochemical component in controlling the binding of heavy metals from estuary sediments.

Table 5: Sediment classification based on organic matter (%).

Point location	Pb	Cd	Hg	Organic Material
Point 1.1	5.701	0.068	0.699	7.05
Point 1.2	1.195	0.021	0.507	6.92
Point 1.3	4.56	0.044	0.563	8.59
Point 2.1	2.567	0.038	0.213	5.05
Point 2.2	1.672	0.031	0.125	5.28
Point 2.3	2.847	0.044	0.348	5.79
Point 3.1	2.497	0.023	0.335	2.71
Point 3.2	2.639	0.019	0.829	6.82
Point 3.3	2.812	0.02	0.378	2.93
Point 4.1	4.612	0.036	0.364	11.47
Point 4.2	4.479	0.043	0.32	10.5
Point 4.3	4.419	0.04	0.39	11.74

Source: Primary Data, 2023

Other factors can also influence organic matter in water. According to Akbar et al. (2016), the amount of organic matter that will be deposited is also closely related to primary productivity, waves, currents, and the presence of predators and decomposers. Suspended solids are highly dependent on the physical and chemical characteristics of water. It is suspected that chemical factors other than total organic matter have a more prominent role, such as pH or sediment redox potential (Maslukah 2013). The high concentration of organic matter is influenced by the depth of the water, as well as the location of the measurement, which is close to human activities in the coastal area (Yudha et al. 2020). Given that the characteristics of the sediment itself are quite dynamic, the results obtained in this study are not necessarily the same as research conducted in different places and periods.

The relation between organic matter and Pb metal concentration: The analysis shows that the relation between Pb metal and the percentage of sediment organic matter has a weak correlation, with a coefficient of determination of 0.3715 (Pb). The relation between sediment organic matter and Pb metal can be seen in Fig. 8.

Based on the calculation of the correlation test, the coefficient of determination is 0.3715. The magnitude of the coefficient of determination (R^2) 0.3715 is equal to 37.15%. This figure means that the level of influence of sediment organic matter on Pb metal in Malili river waters at 4 location points is 37.15%, while other factors influence the remaining 62.85%.

The relation between organic matter and Cd metal concentration: The analysis shows that The relation between Cd metal and the percentage of sediment organic matter has a weak correlation, with a coefficient of determination of

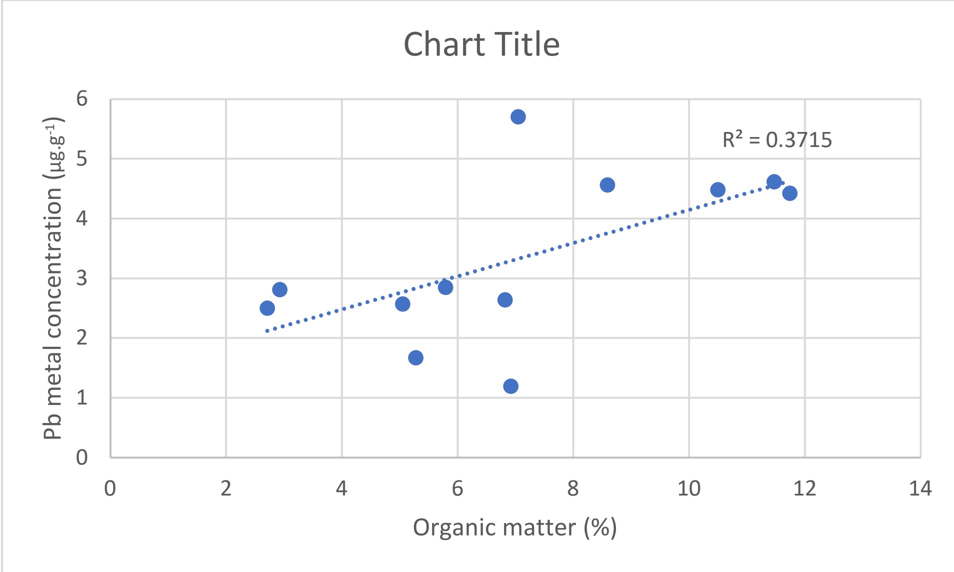

Fig. 8: The relation between sediment organic matter and Pb metal concentration.
Source: Primary Data, 2023

0.1451 (Cd). The relation between sediment organic matter and Cd metal can be seen in Fig. 9.

Based on the calculation of the correlation test, it is known that the coefficient of determination is 0.1451. the magnitude of the coefficient of determination (R^2) 0.1451 equals 14.51%. This Fig. 9 means that the level of influence of sediment organic matter on Cd metal in Malili river waters at 4 location points is 14.51%, while other factors influence the remaining 85.49%.

The relation between organic matter and Hg metal concentration: The analysis shows that The relation between Hg metal and the percentage of sediment organic matter has a weak correlation, with a coefficient of determination of 0.0208 (Hg). The relation between sediment organic matter and Hg metal can be seen in Fig. 10.

Based on the calculation of the correlation test, it is known that the coefficient of determination is 0.0208. the magnitude of the coefficient of determination (R^2) 0.0208

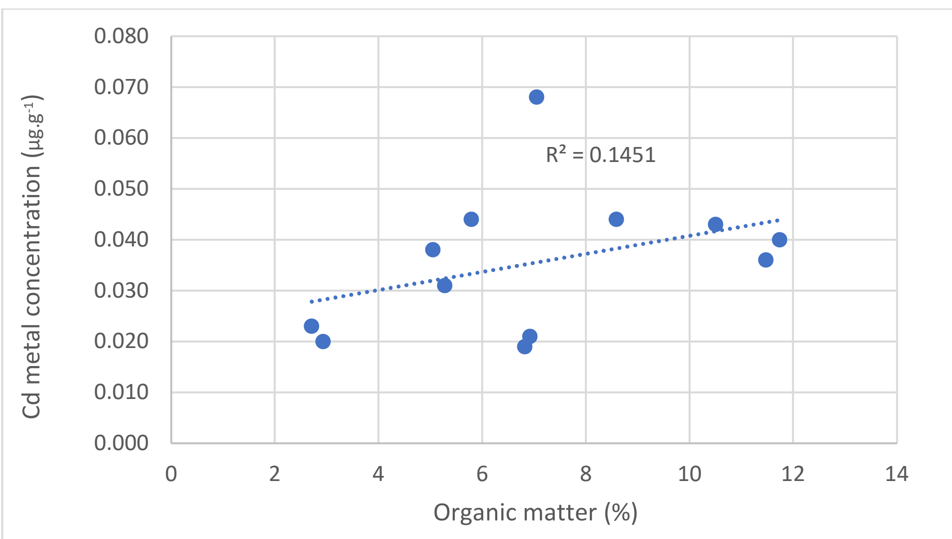

Fig. 9: The relation between sediment organic matter and Cd metal concentration.
Source: Primary Data, 2023

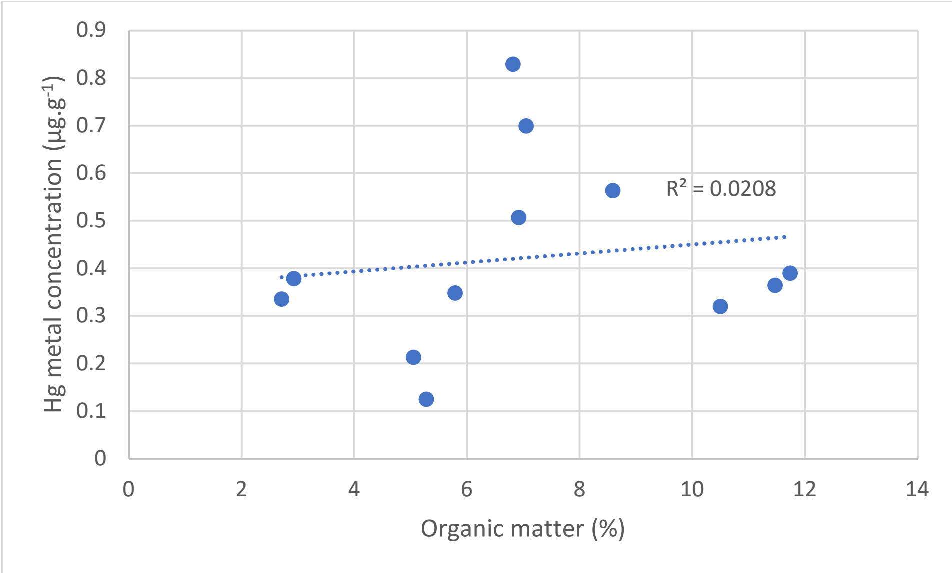

Fig. 10: The relation between sediment organic matter and Hg concentration.
Source: Primary Data, 2023

equals 2.08%. Fig. 10 shows that the level of influence of sediment organic matter on Hg metal in Malili river waters at 4 location points is 2.08%. In contrast, the remaining 97.92% is influenced by other factors.

CONCLUSIONS

Based on the results of research and discussion, it can be concluded that:

1. The sediment content of Pb and Cd metal concentrations at each location point does not exceed NOAA (1999) quality standards. In the sediment, the concentration of Hg metal exceeds the NOAA quality standard (1999) at each point, namely Pongkeru 0.590 $\mu g.g^{-1}$, Karebbe 0.229 $\mu g.g^{-1}$, Kawasule 0.514 $\mu g.g^{-1}$ and Malili 0.358 $\mu g.g^{-1}$.
2. The relation between sediment size and Pb, Cd, and Hg metal concentrations at each point has a weak correlation. The relation does not significantly affect the content of heavy metals in sediments because it may be due to other factors, such as the source of heavy metal pollutants at each different point location.
3. The relation between organic matter and Pb, Cd, and Hg metals concentration at each point has a weak correlation. The relation does not significantly affect the content of heavy metals in the sediment because it may be due to other factors, such as different sources of heavy metal contaminants at each point.

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