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Analysis of Several Water Environment Parameters Affecting the Accumulation of Heavy Metal Lead in the Body of Blood Shells in the Coastal Waters of Muara Gembong Sub-District

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ABSTRACT

The research objectives are: 1) to analyze several parameters of the aquatic environment that affect the lead accumulation in shellfish body (*Anadara granosa* (Linnaeus, 1758)) at eastern coastal waters of Muara Gembong sub-district by using multiple regression analysis, 2) to reduce the variables through principal component analysis to reduce the research cost for monitoring of lead pollution in the next time, and 3) to analyze the location which has similar characteristics of lead accumulation by using hierarchical cluster analysis. Based on the multiple regression analysis, the lead concentration in water, lead concentration in sediment, and sulfur concentration in sediment has a very significant correlation ($P < 0.01$) to the lead accumulation in shellfish body. In contrast, COD of waters has a significant correlation ($P < 0.05$), which correlation coefficient (R) is 0.97. Through the principal component analysis, the lead concentration in sediment, COD of waters, and sulfur concentration in sediment gives the most variance contribution to the total data variance. Therefore, those variables are sufficiently used to monitor lead pollution on shellfish at the Muara Gembong sub-district's coastal waters. Cluster analysis shows that the location is agglomerated to be 3 clusters, which coastal water of Southern Bahagia Beach and Western Mekar Beach has highly similar lead accumulation characteristics.

***Keywords*:** aquatic parameters, lead accumulation, shellfish, coastal waters, Muara Gembong sub-district, *Anadara granosa*

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1. INTRODUCTION

The coastal waters of Muara Gembong Sub-district include waters heavily polluted by domestic waste, industrial waste, and agricultural waste, including pond waste [1]. However, these waters are still an intensive fishing area, both demersal and pelagic fish. According to [1], the waters of Pantura (West Java) are a water area that has experienced overfishing, especially pelagic fish. In this condition, local fishers are increasingly directing their efforts to find demersal fish with economic value. One type of demersal that attracts many traditional fisheries is sea shellfish fishing. This business is very stimulating because, in addition to market demand, which tends to increase, it also has competitive prices [1-5].

However, behind all these interesting factors, one thing that has received less public attention is the shells' heavy metal content. One of the heavy metal elements harmful to human health is the heavy metal lead (Pb). [5-7] stated that shellfish are marine animals that most efficiently accumulate heavy metals. This is because shellfish live in the bottom of the water's sediment layer, move very slowly, and their food is detritus at the bottom of the water, so the chance of heavy metals entering the body is substantial. In the condition of heavily polluted coastal waters of Muara Gembong Sub-district, the heavy metal content in consumption shells may have exceeded the permitted threshold. Minamata Disease (Minamata Disease) in Japan in the 1950s, which brought many victims, is an example of heavy metal poisoning through the consumption of fish from the sea and is categorized as a world tragedy.

The heavy metal lead is very toxic, has bio accumulative properties in the body of organisms, and will continue to accumulate until the organism is no longer able to tolerate the heavy metal content of lead in its body [8-12]. Due to the bio accumulative nature of lead-heavy metal, can occur that the concentration of this heavy metal in dissolved form in water is relatively low, in sediment it increases due to physical, chemical, and biological processes in aquatic animals and the body of aquatic animals increases several times (biomagnification).

Due to the very high toxicity of lead-heavy metal, the waste containing heavy metal is classified into Hazardous and Toxic Waste, whose control is regulated explicitly in government regulations with tighter Quality Standards. The permissible levels of lead-heavy metal in water for aquatic life are a maximum of 0.03 ppm, a maximum of 0.01 ppm in drinking water, and a maximum of 0.02 ppm in fish bodies [10-14]. Therefore, the measurement of the heavy metal lead in shellfish is critical because shellfish are an essential food material for the community and can be a link in the chain for the transfer of heavy metal lead into the human body.

Accumulation of heavy metals in the bodies of aquatic animals according to [12-13] is influenced by many factors, including: (1) levels of heavy metals in water, (2) levels of heavy metals in sediment, (3) pH of water and pH of bottom sediments of waters, (4) water pollution level in the form of COD (Chemical Oxygen Demand), (5) sulfur content in water and sediment, (6) types of aquatic animals, (7) age and body weight, and 8) life phase (eggs, larvae). Furthermore, [14-17] explain, if the concentration of heavy metals is high in water, there is a tendency for the heavy metal concentration to be high in the sediment, and the accumulation of heavy metals in demersal animals becomes higher than as it was. If COD in waters is relatively high, there is a tendency for heavy metal content in water and sediment to be high because COD indicates non-biodegradable organic matter levels, which generally come from industrial waste. Likewise, sulfur (S) levels in sediments also affect the content of heavy metals in sediments because the element sulfur is elementary to bind with heavy metals to form metal-sulfides, which settle on the bottom of the waters [13-14].

Besides, water pH and sediment pH also affect the accumulation of heavy metals in the bodies of aquatic animals because the lower the pH of the water and the pH of the sediments; the heavier metals dissolve in water (ionic form) so that, the easier it is to enter the bodies of aquatic animals, either through gills, food material or by diffusion. Thus, analyzing several factors that influence the accumulation of heavy metals in aquatic animals' bodies is essential so that measures can be taken to minimize these factors' influence to prevent possible poisoning in humans due to consuming food sourced from marine waters.

When the heavy metal lead enters the human body, the heavy metal will be accumulated in the body's tissues and cannot be excreted any longer outside the body. At levels that are already high in the human body, it will cause severe harmful impacts, namely: (1) inhibiting enzyme activity so that metabolic processes are disrupted, (2) causing chromosomal abnormalities (genes), (3) inhibiting fetal development, (4) reducing female fertility, (5) inhibits spermatogenesis, (6) reduces peripheral nerve conduction, (7) inhibits hemoglobin formation, (8) causes kidney damage, (9) causes blood deficiency or (anemia), (10) swelling of the head (encephalopathy), and (11) causing emotional and behavioral disorders [12-14].

The objectives of the study were: (1) to find out some of the factors that influence the accumulation of heavy metal lead in blood clams (*Anadara granosa*) in coastal waters of Muara Gembong sub-district through multiple linear regression, (2) reduce data for cost and time efficiency. Future research in monitoring lead heavy metal pollution in the coastal waters of Muara Gembong Sub-district through principal component analysis and (3) knowing the locations of waters in the coastal area of Muara Gembong Sub-district have similar characteristics the accumulation of heavy metals through fingerprints cluster (cluster analysis).

The uses of this research are: (1) as a contribution of information to local governments and the community in efforts to control lead heavy metal pollution in coastal waters of Muara Gembong Sub-district, and (2) it can be used as input in determining the main variables to be measured for monitoring lead heavy metal pollution. In the coastal waters of Muara Gembong Sub-district in the future as an effort to reduce monitoring costs.

2. RESEARCH METHOD

This research was conducted in the coastal waters of Muara Gembong Sub-district, which has an area of 122.90 Km^2, consisting of 6 (six) coastal areas, namely Bahagia Beach, Bakti Beach, Sederhana Beach, Mekar Beach, Jaya Sakti Beach, and Harapan Jaya Beach. The selection of research locations is based on the following considerations: (a) these coastal waters have a large population of blood clams, and (b) the coastal waters of Muara Gembong Sub-district have been contaminated with various types of industrial, domestic, and agricultural waste. These locations include the waters of (1) Eastern Bakti Beach, (2) Western Bakti Beach, (3) Northern Bahagia Beach, (4) Southern Bahagia Beach, (5) Northern Sederhana Beach Beach, (6) Southern Sederhana Beach, (7) Eastern Mekar Beach, (8) Southern Harapan Jaya Beach, (9) Northern Harapan Jaya Beach, and (10) Western Mekar Beach. This research took place from March to June 2020.

2. 1. Data Collection Method

The method used in this research is the field survey method. Primary data were obtained from the results of parameter measurements in the sample from the study location. A sampling of shells was carried out randomly (random sampling), which was obtained from 3 points of the bottom water location (replication), and at the same time taking samples of the bottom water mud in each coastal area. Meanwhile, water samples were taken from the upper water layer with the same repetition. They took water samples only from the surface because the depth of the water is relatively shallow (2 - 3 m). The lead in the sample's heavy metal content was analyzed using AAS (Atomic Absorption Spectronic) and other parameters using standard procedures from APHA (1992).

The parameters measured in this study were 7 (seven), namely: (1) heavy metal content of lead in blood shellfish (ppm), (2) heavy metal content of lead in water (ppm), (3) heavy metal content of lead in water. Bottom sediment waters (ppm), (4) water pH, (5) bottom sediment pH, (6) water COD content (ppm), and (7) sulfur content in sediment (ppm).

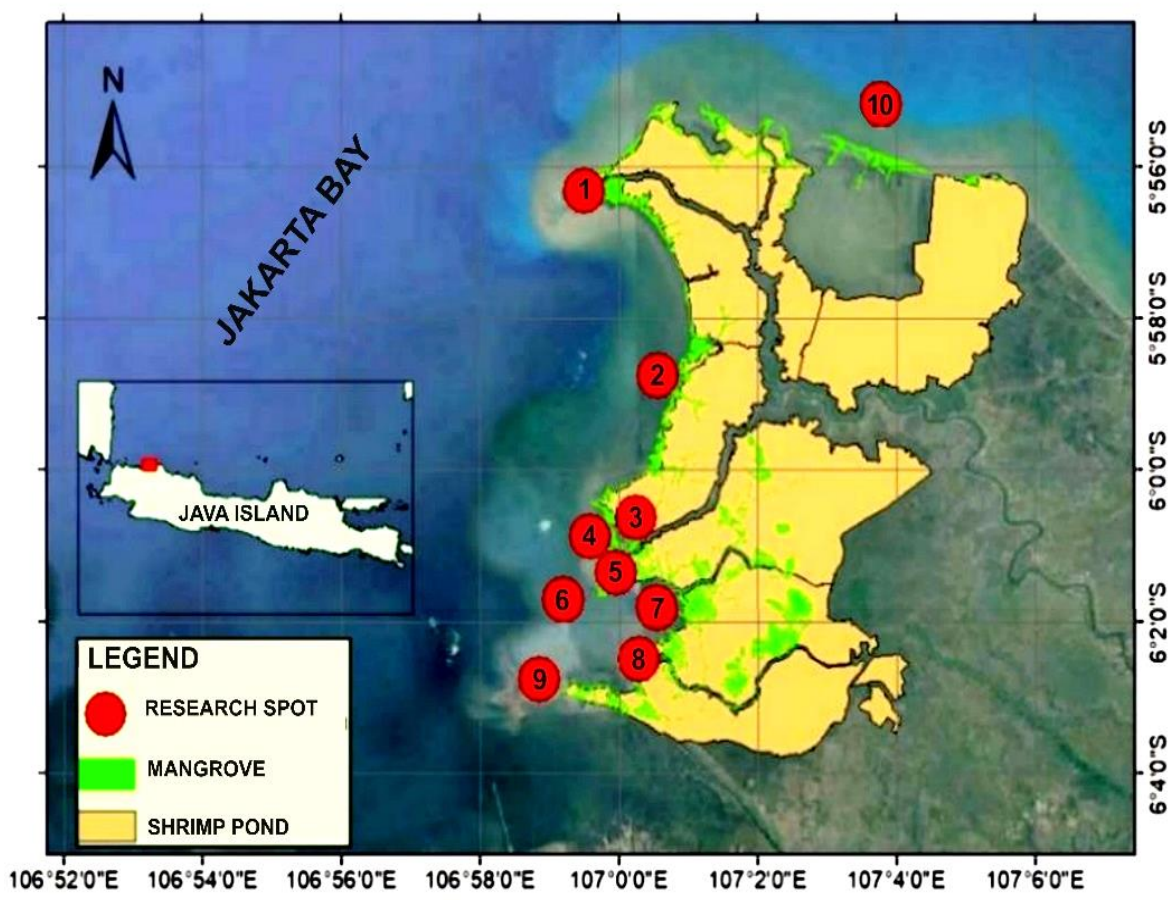

Figure 1. The research location of the coast of Muara Gembong Sub-District

2. 2. Data Analysis

2. 2. 1. Multiple Regression

To see the relationship of several factors that are strongly suspected to influence the accumulation of heavy metal lead in blood shellfish, multiple regression is used with the model:

$$Y_j = \beta o + \beta_1 X_{1j} + \beta_2 X_{2j} + \beta_3 X_{3j} + \beta_4 X_{4j} + \beta_5 X_5 j + \beta_6 X_{6j} + \varepsilon_j$$

where Yj is the content of heavy metal Pb in the shells body at location j (ppm), X1 is the content of heavy metal Pb in water (ppm), X2 is the content of heavy metal Pb in the bottom sediment of waters (ppm), X3 is the pH of the water, X4 is the pH of the bottom sediment, X5 is COD (ppm), and X6 is sediment sulfur content (ppm).

In this regression fingerprint, it can be seen that the partial correlation coefficient (r) of the relationship of each independent variable (X1 - X6) with the dependent variable (Y) and the actual level. Besides, to see whether the multiple linear regression model used is good enough as an estimator model, the coefficient of determination (R^2) of the regression equation generated in the investigation will be seen.

2. 2. 2. Principal Component Analysis

In terms of cost efficiency and time of researching the same topic in the future (monitoring heavy metal pollution), it would be nice if it could be determined which variables (2 or 3 variables) predominantly explain the variety structure of the observational data, so that measuring these variables is good enough to explain the problem being studied. This needs to be done considering the cost of analyzing heavy metal content in the sample is quite expensive because it uses Specthronic Atomic Absorption (AAS) equipment.

According to [17-18], the principal component analysis is one of the data reduction methods so that most of the variety of observational data (about 70%) can be explained by new components without any significant loss of information. The new component is a linear combination of variables that provides the widest variety and is not correlated, which is indicated by the enormous value of the feature's root or the vector of the variable's feature. By knowing the factors that significantly influence the accumulation of lead-heavy metal in blood clams, it is sufficient for future research (monitoring) to measure these parameters without any significant loss of information, so that it is very helpful in cost efficiency and time for conducting pollution research heavy metal in coastal waters of Muara Gembong Sub-District.

2. 2. 3. Cluster analysis

To find out the locations of the coastal waters of Muara Gembong Sub-district, which have almost the same characteristics, both in the accumulation of heavy metal lead in the shells and the aquatic environmental factors that influence it, a cluster analysis was carried out on the research data using the Euclidean Vector Distance. According to [18-19], vectors that are the same distance show the degree of similarity of the measured variables' characteristics. This analysis is quite useful to explain the location of waters that have the same characteristics as the problem being studied so that the location of the waters in the coastal area of Muara Gembong Sub-district should be given priority in handling lead heavy metal pollution, the handling method to be used and the budget.

3. RESULTS AND DISCUSSION

3. 1. The Influence of Aquatic Environmental Factors

Based on the results of measurements of the heavy metal content of lead in the body of blood clams in 10 research locations, it turns out that the heavy metal content of lead in blood clam samples originating from the coastal waters of Southern Bahagia Beach and Western Mekar Beach has exceeded the threshold allowed by the Ministry of Health, which has exceeded 0.02 ppm. The average heavy metal lead content in blood clams in the coastal waters of Southern Bahagia Beach reached 0.042 ppm, and Western Mekar Beach reached 0.03 ppm (Table 1).

The high levels of heavy metal lead in the two research locations are thought to be caused by industrial waste and other wastes containing heavy metal lead, which enter coastal waters through river flows. The Southern Bahagia Beach area is the center of industry, trade, and the port of Bekasi District so that the coastal waters of Southern Bahagia Beach become a storage place for various types of waste carried through the Bekasi River. Likewise, the Western Mekar Beach has the same characteristics as Southern Bahagia Beach, which is characterized by a dense population, heavy traffic, industrial, trade, and port centers, so that the waters of Western Mekar Beach have a great chance of being contaminated with waste containing heavy metals lead. Seeing that the content of lead metal has exceeded the permitted threshold, the Bekasi District government and Western Mekar Beach must take serious action in controlling the heavy metal pollution of lead through the implementation of Law no. 23/1997 on Environmental Management in Indonesia, and the implementation of a more stringent waste quality standard (emission standard). The heavy metal lead can enter the human body through the food chain sourced from the sea, such as shellfish, and can have harmful effects on human health.

Table 1. Heavy Metal Content of Lead in Blood Shell Body, and Several Environmental Factors that Affect It in Coastal Waters of Muara Gembong Sub-district.

Water spot	**Y**	**X_1**	**X_2**	**X_3**	**X_4**	**X_5**	**X_6**
Eastern Bakti Beach	0.008	0.0002	0.0005	6.8	6.3	135.42	0.23
Western Bakti Beach	0.011	0.0008	0.0012	6.7	6.1	140.24	0.27
Northern Bahagia Beach	0.016	0.0010	0.0018	6.2	6.0	158.42	0.34
Southern Bahagia Beach	**0.042**	0.0013	0.0030	6.2	6.0	180.52	0.52
Northern Sederhana Beach	0.014	0.0010	0.0012	6.3	6.2	160.23	0.32
Southern Sederhana Beach	0.005	0.0001	0.0008	6.9	6.5	124.60	0.16
Eastern Mekar Beach	0.012	0.0008	0.0010	6.6	6.2	145.83	0.26
Western Mekar Beach	**0.033**	0.0022	0.0028	6.4	6.1	172.24	0.46

Northern Harapan Jaya Beach	0.013	0.0008	0.0012	7.0	6.7	112.42	0.12
Southern Harapan Jaya Beach	0.018	0.0012	0.0014	6.8	6.5	124.25	0.18

Note: bold print shows the content of heavy metal lead exceeds environmental quality standards, Y = content of heavy metal lead in the body of blood shells (ppm), X1 = content of heavy metal lead in water (ppm), X2 = content of heavy metal lead in bottom sediments (ppm), X3 = ph of water (pH unit), X4 = pH of bottom sediment (pH unit), X5 = COD of waters (ppm), and X6 = sulfur content in sediment (ppm).

Based on the regression analysis results of the relationship between the independent variables (X1, X2, X3, X4, X5, and X6) and the dependent variable Y, the results show that the coefficient of determination (R^2) is 0.94 and the R-value is 0.97. By looking at this correlation value, it can be stated that about 97% of the Y variable (heavy metal accumulation of lead in the blood shellfish body) can be explained by the measured variables, and only about 3% is due to other factors. The estimation of the multiple linear regression equation is:

$$Y = - 0.006 + 0.070 X_1 + 3.694 X_2 – 0.012 X_3 – 0.024 X_4 + 0.00072 X_5 + 0.191 X_6$$

Based on the regression equation, it can be seen that the variable coefficients X1, X2, X5, and X6 are positive, while the variables X3 and X4 are negative. This implies an increase of 1-unit changes X1, X2, X5, and X6 causes an increase in the Y variable, respectively by 0.070; 3.694; 0.0007 and 0.191, while the reduction of 1-unit X3 and X4 causes the Y variable to decrease by 0.0123 and 0.0238 units. In other words, the increase in the levels of heavy metal lead in water and bottom sediments causes an increase (positive effect) of lead-heavy metal accumulation in the body of blood clams.

This situation is due to the heavy metal's relatively large opportunity to enter the shells because it lives in the bottom layer of waters (benthos). As stated by [19-22], an increase in heavy metal levels in the water will cause an increase in heavy metal levels in sediments due to physical, chemical, and biological processes in water, and the implication is that the accumulation of heavy metals in essential animal bodies such as shells will be higher because animals it moves very slowly and feeds on detritus in the bottom sediments of the waters. While the pH of the water and the pH of sediment reduce the accumulation of heavy metal lead in shellfish bodies. As explained by [23], the higher the acidity (pH), the lower the solubility of heavy metals in water and bottom sediments, thereby reducing heavy metals' chance to enter the shells.

The regression analysis also shows that the increase in the sediment's sulfur content causes the accumulation of heavy metal lead in the blood shellfish body. This stuff is because the element sulfur (S) easily binds to heavy metals to form metal-sulfides that settle on the bottom of the waters [23-26], so there is a big chance of being eaten shellfish that live on the bottom of the water. Likewise, with water COD levels, it turned out to positively affect the accumulation of heavy metal lead in shellfish bodies. This is in line with the explanation from [24-25] that COD levels indicate organic matter levels in water that are not biodegradable (non-biodegradable matter) and can only be broken down by potent oxidizing agents, which are generally sourced from industrial waste. And have the opportunity to contain heavy metals (dangerous waste).

To see the partial correlation between variables and the actual level, then, in summary, the correlation values are shown in Table 2. From this table, it can be seen that the relationship between variables is generally healthy and very real ($p < 0.01$). This means that the accumulation of the heavy metal lead in the coastal water environment components affects each other. In this case, the levels of heavy metal lead in water are influenced by the pH and COD of the waters, and the levels of heavy metal lead in water will affect the levels of heavy metal lead in sediments, and the levels of heavy metal lead in sediments will affect the sulfur content in the sediment, and vice versa. Sulfur in sediments also affects the levels of heavy metal lead in bottom sediments. The content of the heavy metal lead in the sediment will affect the heavy metal content of lead in the blood shellfish body. All of these conditions are consistent with the chemical characteristics of heavy metals in the aquatic environment.

Table 2. Coefficient of Partial Correlation Between Variables.

Variable	Y	X_1	X_2	X_3	X_4	X_5	X_6
Y	1	0.79**	0.96**	- 0.63	- 0.49	0.75*	0.85**
X_1	0.79**	1	0.84**	- 0.55	- 0.41	0.62	0.68*
X_2	0.96**	0.84**	1	- 0.67*	- 0.54	0.76*	0.85**
X_3	- 0.63	- 0.55	- 0.67*	1	0.87**	- 0.93**	- 0.87**
X_4	- 0.49	- 0.41	- 0.54	0.87**	1	- 0.89**	- 0.85**
X_5	0.75*	0.62*	0.76*	- 0.93**	- 0.89**	1	0.98**
X_6	0.85**	0.68*	0.85**	- 0.87**	- 0.85**	0.98**	1

Note: ** correlation is very real ($p < 0.01$) and * real ($p < 0.05$)

Besides, there is also a negative correlation between variables, which indicates an antagonistic relationship. Based on Table 2, it can be seen that two variables, namely X3 (pH of water) and X4 (pH of sediment), have a negative partial correlation coefficient to Y. This is in line with the discussion above, where these two variables are reducing the accumulation of heavy metal lead in shellfish bodies, blood. However, water pH and sediment pH have a weak relationship with Y. This is thought to be because the pH of the water and the pH of the bottom sediments of the waters in all research locations are relatively the same (small variations), as in coastal waters (sea) which have a relatively large buffer capacity, so that the pH is relatively stable in the range of neutral [26-30].

The pH value of water is below seven because the water sampling location is still influenced by the mass of river water flowing into coastal waters with salinity ranging from 20-25 ppt. This figure is relatively lower than the pH of the coastal waters of Muara Gembong Sub-district which is far from the influence of river water masses that generally have a pH ranging between 7.4 - 7.8 with a salinity of 30-33 ppt. Based on the description, it can be stated that the parameters of water pH and sediment pH are not suitable to be used as parameters for monitoring the levels of heavy metal lead in coastal waters of Muara Gembong Sub-district in the future.

3. 2. Data Reduction through Principal component analysis

As previously explained, Principal component analysis aims to reduce data by finding 2 or 3 main components (new factors) of the original variable based on the data obtained. Based on the Principal component analysis of the data in Table 1 with seven variables (Y to X6), it was found that with three new factors, 97% of the variety of measurement data could be explained by new factors. The total accumulation of this variety, amounting to 79.12%, is explained by the first principal component (F1), 13.24% by the second principal component (F2), and 3.54% by the third principal component. The total variance explained for each component is shown in Table 3.

Table 3. Total Variety Described by Each Component.

Principal component	Initial Eigenvalues (Characteristics)		
	Total	% Variety	% Cumulative
1	5.54	79.12	79.12
2	1.00	14.34	93.47
3	0.25	3.54	97.04

To find out the original variable which greatly influenced the new factor or gave the most considerable variance contribution to the main component, an analysis of the contribution of the original variable variance was carried out based on the length of the feature vector to the main component, and the results are shown in Table 4.

Table 4. Characteristic Vector Analysis of Main Components.

Variable (Water Environment Parameters)	Component		
	1	**2**	**3**
X_2 (Pb levels in the sediment)	0.981	- 0.101	0.114
X_5 (COD of water)	0.958	- 0.244	0.025
X_6 (sulfur content in the sediment)	0.905	0.376	0.112

Based on Table 4, it can be seen that the variables X2, X5, and X6 have the most considerable vector length relative to the first principal component. It means that in the first main component, these three variables contribute the most considerable variance to the observed data. Thus, the levels of lead in sediments, COD, and sulfur levels in sediments are sufficient to be used as variables in studying the heavy metal content of lead in blood clams in coastal waters of Muara Gembong Sub-district in the future. By only measuring 3 (three) parameters, it is beneficial to reduce the cost and time of researching the future for monitoring activities of heavy metal pollution in the coastal waters of Muara Gembong Sub-district.

If these three original variables (X3, X5 and X6) are regressed against Y, then an estimate of the new regression equation is obtained, namely: Y = 0.033 + 9,530 X2 - 0.00038 X5 + 0.089 X6 with R^2 = 0.94. The coefficient of determination that remains high proves that these three variables are valid enough to estimate the levels of lead-heavy metal accumulation in blood clams in coastal waters of Muara Gembong Sub-District.

3. 3. Grouping of Locations through cluster analysis

Cluster analysis of the research data was carried out based on the dissimilarity of parameter characteristics measured at each water location using the Euclidean distance. The inequality matrix by water location is presented in Table 5.

Table 5. Inequality Matrix Based on Water Location.

Coastal Water Spot	Eastern Bakti Beach	Western Bakti Beach	Northern Bahagia Beach	Southern Bahagia Beach	Southern Bahagia Beach	Southern Sederhana Beach	Eastern Mekar Beach	Western Mekar Beach	Northern Harapan Jaya Beach	Southern Harapan Jaya Beach
Eastern Bakti Beach	0.000	4.825	23.010	45.106	24.815	10.823	10.412	36.783	23.005	11.172
Western Bakti Beach	4.825	0.000	18.187	40.284	19.994	15.647	5.592	31.962	27.828	15.996
Northern Bahagia Beach	23.010	18.187	0.000	22.101	1.824	33.831	12.598	13.782	46.013	34.179
Southern Bahagia Beach	45.106	40.284	22.101	0.000	20.292	55.928	34.694	8.323	68.110	56.276

Northern Sederhana Beach	24.815	19.994	1.824	20.292	0.000	35.637	14.403	11.972	47.818	35.985
Southern Sederhana Beach	10.823	15.647	33.831	55.928	35.637	0.000	21.234	47.605	12.182	0.365
Eastern Mekar Beach	10.412	5.592	12.598	34.694	14.403	21.234	0.000	26.372	33.416	21.583
Western Mekar Beach	36.783	31.962	13.782	8.323	11.972	47.605	26.372	0.000	59.787	47.954
Northern Harapan Jaya Beach	23.005	27.828	46.013	68.110	47.818	12.182	33.416	59.787	0.000	11.834
Southern Harapan Jaya Beach	11.172	15.996	34.179	56.276	35.985	0.365	21.583	47.954	11.834	0.000

The results of clustering with the principle of agglomeration produce three groups (clusters), namely: (a) Group I consist of water locations: Eastern Pantai Bakti, Western Pantai Bakti, and Eastern Mekar Beach, (b) Group II consists of water locations: Northern Bahagia Beach, Southern Bahagia Beach, Northern Sederhana Beach, and Western Mekar Beach, and (c) Group III consisting of water locations: Southern Sederhana Beach, Northern Harapan Jaya Beach, and Southern Harapan Jaya Beach.

This implies that each cluster of water locations has the same characteristics of lead-heavy metal accumulation in the blood shellfish body and several other measured parameters. Knowing these similarities can determine the location of the waters that need to get priority in controlling lead heavy metal pollution.

From this analysis, it can also be stated that the coastal waters of Southern Bahagia Beach and Western Mekar Beach have a relatively high degree of similarity in the accumulation of heavy metal lead in blood clam bodies. This is supported by the fact that Southern Bahagia Beach and Western Mekar Beach have a densely populated area, centers of industry, trade, port activities, and locations for intensive shrimp ponds. T

herefore, it is very logical that the coastal waters in these two cities are polluted by various types of waste, including lead heavy metal pollutants, and in fact, the accumulation of heavy metals is relatively high in the body of blood clams exceeds the permitted threshold.

4. CONCLUSIONS

Heavy metal levels of lead in water (X1), in sediments (X2), and sulfur levels in sediments (X6) were highly correlated ($p < 0.01$) to the accumulation of heavy metal lead in blood shellfish (Y), while water COD (X5) significantly correlated ($p < 0.05$), and water pH (X3) and basic sediment pH (X4) were not significantly correlated ($p > 0.05$). The correlation coefficient shows that 97% of the accumulation of heavy metal lead in the blood shellfish body can be explained by the six measured variables, with the regression equation: Y = - 0.006 + 0.070X1 + 3.694X2 - 0.012X3 - 0.024X4 + 0.0072X5 + 0.191X5

The principal component analysis produces three main variables, namely levels of heavy metal lead in sediments (X2), COD levels in waters (X5), and levels of sulfur in sediments (X6), which can be used in research or monitoring levels of heavy metal lead in the body of blood clams in the water coastal Muara Gembong Sub-district in the future.

The cluster analysis resulted in three groups of locations that have the same characteristics of the aquatic environment in the accumulation of heavy metals, namely the first group is the coastal waters of Eastern Bakti Beach, Western Bakti Beach, and Eastern Mekar Beach, the second group, is Northern Bahagia Beach, Southern Bahagia Beach, northern Sederhana Beach, and western Mekar Beach, and the third group is southern Sederhana Beach, northern Harapan Jaya Beach and southern Harapan Jaya Beach.

The coastal waters of Southern Bahagia Beach and Western Mekar Beach have a relatively high degree of similarity in the accumulation of heavy metal lead in blood shellfish bodies and other measured parameters. The levels of heavy metal lead in the blood shellfish bodies in these two locations have exceeded the permitted threshold (> 0.02 ppm), so that it needs serious attention from the local government for its control.

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