K-Means Algorithm Grouping for Visualizing Potential of Hydrogen (pH) Data in Kali Lamong River

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Abstract: Water quality monitoring becomes vital in water management, such as in the Lamong River. Changes in the values of water pH will affect the water quality. For this reason, it is necessary to classify water quality to find information on water quality zones with good and poor conditions. This study employed the K-Means algorithm method for grouping water quality, and the final results of grouping were visualized on a website-based application. The test was carried out three times with the numbers of clusters 2, 3, and 4, then cluster analysis was carried out using the Davies-Bouldin Index to determine the best number of clusters. The research results indicated that the best number of clusters produced using the K-Means algorithm were two clusters (k = 3), with the smallest validity value of the Davies-Bouldin Index by 0.36. Three clusters were formed, with 43 stations from Cluster 1, 45 stations from Cluster 2 and 29 stations from Cluster 3. It yielded four iterations, with information C1 for poor conditions, C2 for good conditions, and C3 for medium conditions.

1 INTRODUCTION

Kali Lamong River is a river located on the border between Surabaya City and Gresik Regency. The upstream part of Kali Lamong river is between Mojokerto district and Lamongan district while the downstream part is between Mojokerto district and Surabaya city. Around the banks of Lamong River is often used for residents to do their daily activities (Luki Nasiti, Rahayu, & Indah, 2017). Kali Lamong River also functions as a water supplier for the people of Lamongan Regency and Gresik Regency, and is used in daily activities such as agricultural waters, industry and household activities. Water quality monitoring is an important instrument in water management, one of which is in Lamong River, because it can find out important information about the physical, chemical and biological state of water resources, determine a pattern and identify the emergence of water quality problems during certain situations (Ni'Am, Prasetya, & Utami, 2021). (Ni'am, Aulady, Hamidah, & Prasetya, 2022)

One of the parameters that can be used to measure water quality is the potential of hydrogen (pH). The pH value of water can affect the distribution of chemical factors of waters, and the distribution of microoganisms whose metabolism is influenced by the distribution of these chemical factors (Supriatna, 2020). Grouping data for water quality determination needs to be completed to obtain information on water quality at each location point in Lamong River. From a programming point of view, artificial intelligence includes the study of symbolic programming, problem solving, and search processes (Hani Subakti et al., 2022). This study will construct a system for classifying the water quality value of Lamong River using the K-Means algorithm. This research aims to help researchers in the field of AMDAL (Environmental Impact Analysis) in analyzing water quality based on which points the pH value of the water is included in good, medium, and poor quality. Then further analysis can be completed about the impact that will occur after clustering. In this study also proposed the use of the Davies-Bouldin Index (DBI) method to determine the best number of

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clusters, the smallest DBI value is used as the number of clusters selected. Finally, the final results of clustering using the K-Means algortima will be displayed in the form of visual analysis using website program applications, Orange data mining, and Surfer.

2 THEORY

2.1 Kali Lamong Gresik

Kali Lamong is a river that has a length of ± 89 km and has 7 tributaries, Lamong River is located in Kedung Kumpul, Lamongan Regency to Madura Strait, Segoromadu, Gresik Regency. Kali Lamong River is used as a water supplier by the people of Lamongan and Gresik Regencies and also used in daily activities such as agricultural waters and fisheries.

2.2 pH

The degree of acidity or pH is a parameter that aims to determine or measure acid/base levels in water. pH is used in determining alkalinity, CO2, and in acid-base equilibrium. At a given temperature, the intensity of the acid or base character in a solution can be indicated by pH and hydrogen ion activity. Causes of changes in the pH of water will cause changes in odor, taste, and color. The pH value = 7 is declared a neutral state, 0 < pH < 7 is declared an acidic state, 7 < pH < 14 is declared an alkaline state (Aswant, 2016).

2.3 K-Means Algorithm

Clustering aims to group and understand the data structure. Clustering is only the initial stage and then continues with core processing and class labeling for each group. K-Means is one of the non-hierarchical data clustering methods that seek to partition existing data into one or more clusters or groups so that similar data and data with different characteristics are grouped into other groups (Wahyudi, 2020). The stages of the K-means algorithm used are as follows (Ainun Novia, 2020) :

- Determine k as the number of clusters to be formed.
- Determine k initial centroids randomly.
- Calculate the distance of each object to each centroid of each Cluster using the Euclidian Distance method as in equation 1.

$$d(x,y) = \sqrt{\sum_{i=1}^{n}(xi - yi)^2} \quad (1)$$

Where:
$d(x,y)$ measure of dissimilarity
$xi = (x_1, x_2, \dots, x_i)$ which is the data variable
$yi = (y_1, y_2, \dots, y_i)$ i.e. the variable at the center point

- Allocate each object to the closest centroid.
- Perform iteration, then determine the new centroid position using the equation

$$C = \frac{\sum m}{n} \quad (2)$$

Description:
C: Centroid data
m: Data members that belong to the closest Cluster distance
n: The amount of data that is a member of a particular Cluster.

2.4 Davies-Bouldin Index (DBI)

DBI is a cluster validation found by Davidi L. Davies and Donaldi W, DBI is used to determine the best number of clusters that can be assessed using DBI. The grouping with the best number of clusters is a grouping that has a minimum value of Davies Bouldin Index (DBI) (Badruttamam, Sudarno, & Maruddani, 2020). The following stages of using DBI are formulated as follows:

1. Sum of square within cluster (SSW) which is an equation used to determine the cohesion matrix in an i-th cluster which is formulated as follows:

$$SSW_i = \frac{1}{m_i}\sum_{j=1}^{m_i} d(x_j, c_i) \quad (3)$$

Description:
m_i is the number of data in the i-th cluster
c_i is the i-th centroid
$d(x_j, c_i)$is the distance from the i-th data to the i-th cluster point.
The smaller the SSW value, the better the clustering results.

2. Sum of square between clusters (SSB) is an equation used to determine the separation between clusters, which is calculated using the following equation:

$$SSB_{i.j} = d(c_i, c_j) \quad (4)$$

3. After the cohesion and separation values are obtained, then the ratio measurement (Rij) is carried out to determine the comparison value between the i-th cluster and the j-th cluster using the following equation:

$$R_{ij} = \frac{SSW_i + SSW_j}{SSB_{ij}} \quad (5)$$

Notes: A good cluster is one that has the smallest possible cohesion value and the largest possible separation.

4. The ratio value obtained is used to find the Davies-Bouldin index (DBI) value from the following equation :

$$DBI = \frac{1}{k}\sum_{i=1}^{K} \max_{i \neq j}\left(R_{i,j}\right) \qquad (6)$$

k is the number of clusters used.
The smaller the DBI value (non-negative >= 0), the better the cluster obtained from the k-means clustering.

3 METHOD RESEARCH

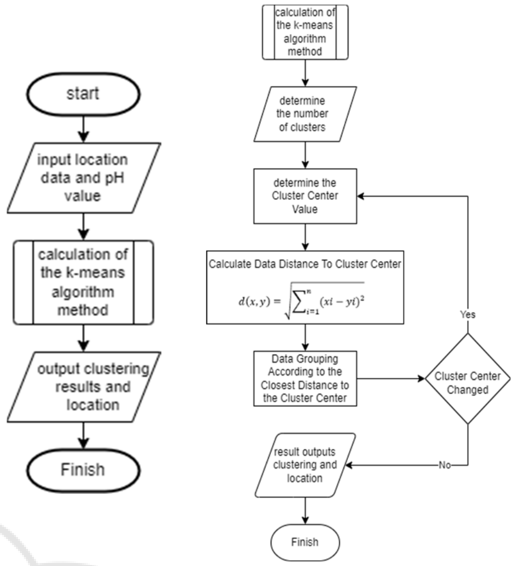
3.1 Water Quality Clustering

Research that performs water quality clustering is used to analyze data with high complexity, especially those caused by environmental changes around the Haihe river water in China. To determine the water quality value, several studies were conducted using a fast clustering algorithm to identify and analyze the quality of Haihe river water samples in China. The results of the simulation-based research can perform discriminative analysis and determine the most significant indexes that can affect water quality (Zou, Zou, & Wang, 2015).

Research on water quality grouping using the K-Means method was conducted to evaluate the quality of groundwater samples. The data was taken in the hydrographic basin region: the northern part of the Santo Domingo basin, the Baja California Peninsula state in Mexico. Groundwater samples are used as a dataset, which has several hydrogeochemical variables used in this study. The K-Means method and the spatial evaluation technique of the Geographic Information System (GIS) were used to identify the hydrogeochemical classes. The classes are illustrated into clusters. The first cluster is shallow wells and deep wells which are located close to the beach area and the city. The second cluster is medium and deep wells which are located adjacent to industrial areas in the city and residential areas. The third cluster is deeper wells which are located mainly close to agricultural areas and cities(Celestino, Cruz, Sánchez, Reyes, & Soto, 2018).

3.2 Flowchart System

Firstly, the system receives input of location point Latitude and Longtitude values along with water pH value data. Furthermore, the system performs calculations using the K-Means algorithm, and the final result is the result of water quality grouping based on pH value. Flowchart of the water quality grouping system is shown in Figure 1 (a).



(a) (b)

Figure 1: (a) Flowchart of water quality group of mapping system, (b) K-Means Sub Process Flowchart.

3.3 Calculation of K-Means Algorithm

To calculate the Clustering method using the K-Means flowchart algorithm can be seen in Figure 1 (b). K-Means algorithm calculation data uses Latitude and Longtitude values along with water pH values. These data can be seen in table 1.

Table 1: Latitude and Longitude

Station	Latitude	Longitude	pH
1	-7.19844335	112.6650415899	6.8
2	-7.1983343	112.6651770014	7.8
3	-7.19818011	112.6653213017	7.0
4	-7.19803752	112.6647503840	6.8
5	-7.19797383	112.6648587989	7.8
6	-7.19789205	112.6649671478	7.0
7	-7.19764996	112.6644049217	6.8
8	-7.19757713	112.6645404651	7.7
9	-7.19751337	112.6646669875	7.2
10	-7.19714456	112.6641405158	6.8

They were determining the number of clusters and initial initialization where the cluster center is done randomly, in this calculation example using 3 clusters (k = 3). The cluster center points are shown in table 2.

Table 2: Initial Center Point of Each Cluster

Centroid	1	2	3
pH	6.7	7.0	7.8

The final results of the K-Means algorithm calculation using the data presented in table 1 and the cluster membership used in table 2, the calculation is done 4 times, so that the membership of each cluster does not change or converge. The final result can be seen in table 3.

Table 3: Calculation results on the 4th iteration

Station	C1	C2	C3	Cluster Nearest	Cluster
1	0.03	0.47	0.91	0.03	1
2	0.97	0.53	0.09	0.09	3
3	0.17	0.27	0.71	0.17	1
4	0.03	0.47	0.91	0.03	1
5	0.97	0.53	0.09	0.09	3
6	0.17	0.27	0.71	0.17	1
7	0.03	0.47	0.91	0.03	1
8	0.87	0.43	0.01	0.01	3
9	0.37	0.07	0.51	0.07	2
10	0.03	0.47	0.91	0.03	1

Based on the results obtained in table 3, the membership of each cluster can be seen in table 4.

Table 4: Calculation result

Station	pH	Cluster
1	6.8	1
2	7.8	3
3	7.0	1
4	6.8	1
5	7.8	3
6	7.0	1
7	6.8	1
8	7.7	3
9	7.2	2
10	6.8	1

4 RESULT AND DISCUSSION

In this chapter, the accuracy of the Kali Lamong water quality grouping system is tested based on the pH value. The data used is the pH value of water with 117 station points scattered around the Lamong River estuary. The location of the data collection is shown in Figure 2.

Figure 2: Location of data collection in Kali Lamong Gresik

4.1 System Testing

System testing needs to determine the accuracy of the results of the K-Means calculation. System testing is k-means based on the number of clusters (k = 2,3,4). Table 5: Results of Total Membership of Clusters 2, 3 and 4 Using K-Means Calculation.

Table 5: Results of Total Membership of Clusters 2, 3 and 4 Using K-Means Calculation

	Cluster Total								
	2		3			4			
C	1	2	1	2	3	1	2	3	4
Total member	49	68	43	45	29	39	22	27	29

The results of the K-Means algorithm calculation in table 5 above show that each cluster number 2, 3 and 4 has a different number of members. In this case, in the K-Means calculation, K = 2, that cluster 1 members are 49 data and cluster 2 members are 68 data. In the K-Means calculation, K = 3, cluster 1 members are 43 data, cluster 2 members are 45 data, and cluster 3 members are 29 data. In the calculation of K-Means K = 4, cluster 1 members are 39 data, cluster 2 members are 22 data, cluster 3 members are 27 data, and cluster 4 members are 29 data.

4.2 Cluster Analysis Using Davies Bouldin Index (DBI)

The DBI calculation stage aims to determine the number of clusters that produce the best K value. An example of calculation with 2 clusters (K = 2), first calculating the Sum of square within cluster (SSW) using equation (3) produces the following values: SSW1=0.10 and SSW2=0.20. Furthermore, calculating the Sum of square between clusters (SSB) using equation (4) produces the following values: SSB1,2=0.61. Furthermore, calculating the R ratio measurement of cluster 2 using equation (5) results in R_1,2=0.49. Finally, calculating the DBI value using equation (6) results in: DBI=0.49. The results of the DBI calculation for clusters 2, 3 and 4 (K = 2, 3, or 4) can be seen in table 6, respectively.

Table 6. DBI value K = 2,3,4

K	2	3	4
DBI	0.49	0.36	0.47

Based on table 6, the smallest Davies-Bouldin Index value is 0.36 at K = 3, so the best number of clusters in this experiment is three.

4.3 Visualization of Cluster Results Using Orange Data Mining

To make it easier to analyze the results of the K-Means algorithm calculation, the Orange Data Mining application is used. This application will display visualizations in the form of scatter plots for the number of K = 2, 3, and also 4.

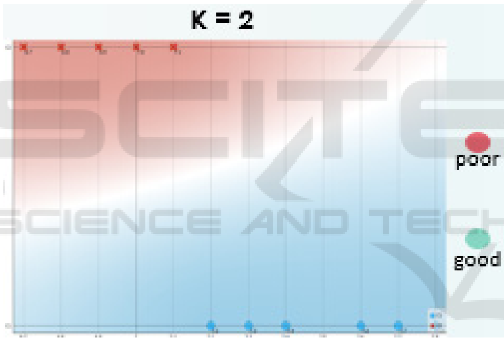


Figure 3: Cluster implementation results to the orange data mining application with K = 2.

Figure 3 shows the number of clusters K = 2, where the first cluster has 49 stations (red color) and the second cluster has 49 stations (blue color).

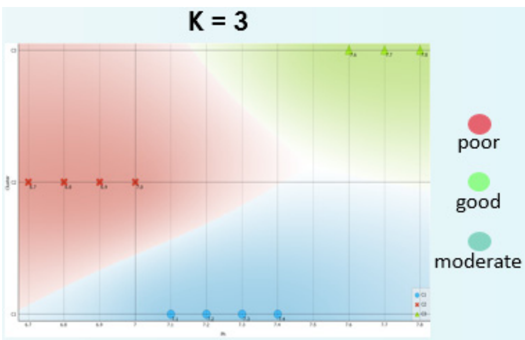


Figure 4: Cluster implementation results to the orange data mining application with K = 3.

Figure 4 displays the number of Cluster K = 3, where the first cluster is 45 stations (red color), the second cluster is 43 stations (blue color), and the third cluster is 29 stations (green color).

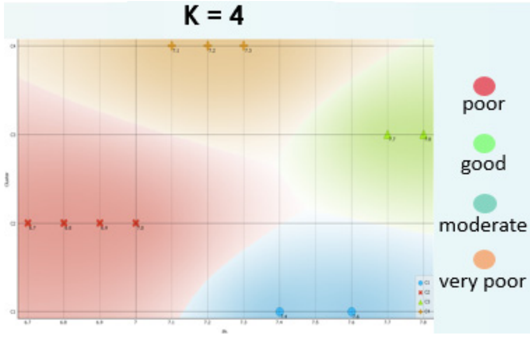


Figure 5: Cluster implementation results to the orange data mining application with K = 3.

Figure 5 displays the number of Cluster K = 4, where the first cluster is 19 stations (green color), the second cluster is 21 stations (blue color), and the third cluster is 34 stations (brown color), and the fourth cluster is 43 stations (red color).

4.4 Web-Based Implementation

The quality classification system of Kali Lamong is website-based (Khadafi, Salim, Prabowo, & Choirul, 2019). This website application was developed using the PHP programming language, JavaScript was created using the CodeIgniter framework, for marking location points it was created using the Google Maps API which is a library developed using the JavaScript programming language, while google maps is a popular digital map which is often developed for applications based on website to display information on a location (Khadafi, 2016).

Figure 6: Implementation Results to website-based applications

In Figure 6, the cluster result grouping system is a display after processing the K-Means method and has obtained a group on each water quality data respectively, in the image below there are three icons with different colors and each color difference has a different meaning where the red icon is intended for group 1 with poor conditions totaling 43 stations, green for group 2 with good conditions totaling 45 stations and blue for group 3 with moderate conditions totaling 29 stations, on the icon if clicked will display information in the form of station number, lat long, pH value and also group number.

4.5 Implementation Using Surfer Application

To find out the distribution of water pH values using the Surfer application program can be seen in Figure 7 below.

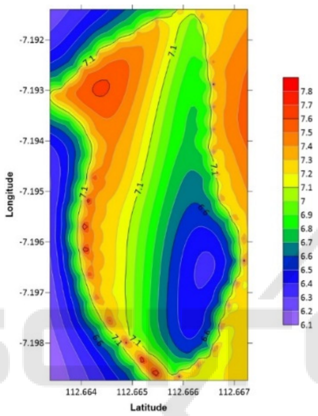


Figure 7: Results Implementation to the Surfer application

The display of the implementation results in the Surfer application can be explained by the distribution of pH values where variable X is Longitude, variable Y is Latitude and variable Z is the pH value of water. Red color information indicates that the pH value is high or the pH is alkaline, the lower the light green pH is neutral and the lower or blue to purple the pH value is low or the pH is acidic. From the description of Figure 5, it can also be seen that the highest pH value is 7.8 and the lowest is 6.1.

5 CONCLUSION

1. By using the K-Means algorithm, it can categorize water quality with good and bad conditions.
2. Based on the results, it can be concluded that the best number of clusters produced using the k-means algorithm method is three clusters (k = 3) with the smallest Davies-Bouldin Index validity value of 0.36. Where the three clusters are each membership, namely, the first cluster of 43 stations, the second cluster of 45 stations and the third cluster of 29 stations. In addition, it produces 4 iterations, with a description of C1 with poor conditions, C2 with good conditions and C3 with moderate conditions.
3. The use of Google Maps API and Code Igniter Framework can display visualization of clustering results well in accordance with the dataset used, namely the pH water quality values in Lamong River.

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