Water quality index analysis of lake Rawa Besar, Depok, West Java, and its relationship with land use

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Abstract. The lake's catchment area is one of the objects of land use conversion as a space for community needs. The boundary of the Lake Rawa Besar has been widely used by the surrounding community to carry out activities. Human activity and land use around lake shorelines can affect water quality. This study aims to investigate the pattern of spatial distribution of Lake Rawa Besar water quality and its relationship with land use within the lake shoreline. Water quality was tested based on the insitu sampling method in 30 samples evenly distributed in the water body and laboratory testing based on 6 water quality parameters such as turbidity, BOD, total phosphate, total solid, pH, and nitrate. Water quality is measured based on the water quality index level of WQI (Water Quality Index) and interpolated using the IDW method. Large-scale land use is used from digitizing large resolution images and potential sources of pollutants obtained from field observations. The results showed that the water quality in water bodies was almost evenly distributed with mild polluted criteria. Land use in the form of domestic activities affecting the quality of water in the Lake Rawa Besar is characterized by high turbidity and BOD values, while the total phosphate, total solid, nitrate, and pH value is low. The high correlation between turbidity and BOD which is impacted from land use concluded that the poor quality of the lake's water was caused more by organic waste.

1. Introduction

The lake's catchment area is also one of the objects of land use conversion as a space for community needs. Various activities that make people live around the lake's catchment area to make use of land [1]. Water bodies located in urban areas serve as reservoirs for surface runoff and are sensitive to activities around them, especially settlement activities [2].

Dense population settlements are a sign of the many human activities in the area around Lake Rawa Besar. Lake Rawa Besar also has varied land uses, namely settlements, trade, gardens, neighborhood roads, and public facilities. The effect of land use resulted in an increase in the amount of pollutants and domestic wastewater which were disposed of in Lake Rawa Besar [3].

Domestic wastes are at risk of disrupting the quality of water in a body of water and affecting several types of parameters, namely BOD, nitrate, and total phosphate [4,5]. Water runoff containing waste such as industrial products and waste trees and chemicals will affect the parameters of water quality such as turbidity, total solid, and pH [6,7,8].

For this reason, this study is important. The reason for the importance of the study is that the quality of water in a water body requires serious attention and management, especially from surrounding...
communities and governments that have authority [9]. In addition, water sources and water buildings, including those there, must be protected, secured, maintained and preserved [10].

2. Data and Methods

2.1. Study Area
This research was conducted in Lake Rawa Besar and its surrounding area. Lake Rawa Besar is located in Pancoran Mas District, Depok City, West Java Province. The Lake is located between two villages, namely Depok and Depok Jaya Villages. The absolute location of the Lake Rawa Besar is $6^\circ23'27" - 6^\circ23'53"$S and $106^\circ48'54" - 106^\circ49'2"$W. Lake Rawa Besar has an area of about 12.92 hectares.

2.2. Water Quality
Water samples tested based on water quality parameters have 30 locations spread in Lake Rawa Besar. The location of the water sample has its own characteristics. The distribution map of the location of the water sample and the imagery of the area is shown in figure 1.

Water quality data used are turbidity, BOD, total phosphate, total solid, pH, and nitrate parameters. Water quality data with the 6 parameters are produced from the results of testing 30 water samples in the AAS Cilodong laboratory. The data will then be compared with the quality standards that have been previously set as a comparison between the water quality standard value.

![Figure 1. Water Samples in study area.](image-url)

Water quality data processing is the first step that needs to be done in this study, because spatial pattern data is obtained from the processing of water sample data that has been tested. The water quality index is first calculated using WQI. Each sample point location was calculated to determine the water quality
The formula used to calculate WQI is in Eq. (1) [11]. The standard value used in the WQI calculation are shown in Table 1.

\[
WQI = \frac{\sum \left[ \frac{C_i}{P_{li}} \right]}{n}
\]

Where:
- \(WQI\) = Water Quality Index
- \(C_i\) = Concentration of i variable
- \(P_{li}\) = Standard value allowed for i variable
- \(n\) = number of variable

| Parameters          | Standard value |
|---------------------|----------------|
| Turbidity           | 25 NTU         |
| BOD                 | 2 mg/L         |
| Total Phosphate     | 0.2 mg/L       |
| Total Solid         | 1,050 mg/L     |
| pH                  | 6.5 – 8.5      |
| Nitrate             | 10 mg/L        |

Water quality data is prepared to be interpolated. Interpolation methods can be used to estimate objectively the spatial distribution of data [12]. IDW and kriging interpolation performed better than spline on quantitative assessment, but kriging is interpolating at inexact location, so the interpolation will be used is Inverse Distance Weighted (IDW) interpolation [13]. Interpolation was carried out to determine the spatial distribution of WQI calculation results in the waters of Lake Rawa Besar. Data to be generated from interpolation is the distribution of WQI for each parameter and total distribution of WQI.

After that, categorization of the water quality level was carried out to map the spatial distribution of the water quality index of each parameter and the total water quality index in the Lake Rawa Besar area. The level of water quality used is the water quality classification criteria [14]. The criteria classification for WQI can be seen in Table 2.

| WQI value          | Criteria           |
|--------------------|--------------------|
| \(WQI \leq 0.30\)   | Excellent          |
| \(0.31 \leq WQI \leq 0.89\) | Clean            |
| \(0.90 \leq WQI \leq 2.49\) | Mild Polluted    |
| \(2.50 \leq WQI \leq 3.99\) | Moderately Polluted |
| \(4.00 \leq WQI \leq 5.99\) | Heavily Polluted |
| \(WQI \geq 6.00\)   | Dirty              |

2.3. Land Use
Secondary data used in this study is Digital Globe imagery data. The imagery is then digitized to obtain several land use variables. The variables used in digitizing land use are buildings, gardens, and...
environmental roads. Land use is digitized at a scale of 1:5000. Pollutant sources within land use also identified by field observing the land study area.

3. Result and Discussion

3.1. Turbidity
The results of WQI calculation of water turbidity parameters indicate an index based on a review of water quality turbidity standards. The WQI level based on turbidity parameters produces 5 criterias for water quality level, which are clean, mildly polluted, moderately polluted, and heavily polluted. Two samples counted as water with clean water quality, 3 samples were mildly polluted water, 9 samples were moderately polluted water, 12 samples were heavily polluted water, and there were 3 samples which were dirty water based on turbidity parameters. Spatially, the turbidity in Lake Rawa Besar has a high value in areas close to the land. Turbidity with high numbers also exists in the northern part of the lake. The center part of the lake is showing smaller turbidity value. This is shown in samples 17 and 20 in the middle of the lake. In the north, water samples show small values in samples 4, 8, and 9. The closer to the shoreline, the higher turbidity value will be. Turbidity WQI spatial pattern in Lake Rawa Besar is shown in figure 2.

3.2. BOD
The BOD in Lake Rawa Besar shows a number that is quite varied. Samples 1 to 30 have a variety of values. Spatially, the BOD in Lake Rawa Besar has higher value at several sample points, such as in the north of the lake and in the middle of the lake near the edge of the lake. The BOD in Lake Rawa Besar is quite uniform with mildly polluted criteria scattered throughout the lake. BOD with a high value is on the edge of the lake with a presence that is not too dominant towards the overall value of BOD. BOD WQI spatial pattern in Lake Rawa Besar is shown in figure 3.

3.3. Total Phosphate
The total phosphate present in Lake Rawa Besar shows almost uniform values. Spatially, the total phosphate present in Lake Rawa Besar has a higher value at several sample points, such as in the western part of the lake, precisely in the middle and at the southern edge of the lake. Total phosphate in Lake Rawa Besar is quite uniform with excellent criteria spread throughout the lake. Total phosphate with clean criteria is at the edge of the lake with a less dominant presence in the total value of total phosphate. Total phosphate WQI spatial pattern in Lake Rawa Besar is shown in figure 4.

3.4. Total Solid
The total solids value shows that 30 water samples have total solids that do not exceed the quality standard which is valued 1050 mg / L. Spatially, the total solids present in Lake Rawa Besar have uniform WQI values. There is only one water quality criteria based on the total solids parameter, which is water that is considered excellent. Total solid WQI spatial pattern in Lake Rawa Besar is shown in figure 5.

3.5. pH
WQI level based on pH parameters produces 1 type of water quality criteria, which is lightly polluted. All water samples have a pH value that is included in the criteria for mild contamination. Spatially, the existing pH in Lake Rawa Besar has a uniform WQI value. There is only one water quality criteria based on pH parameters, which is critically polluted. pH WQI spatial pattern in Lake Rawa Besar is shown in figure 6.

3.6. Nitrate
The nitrate value also shows that 30 water samples have nitrates that do not exceed the water quality standard which is worth 10 mg/L. Spatially, nitrates in Lake Rawa Besar have uniform WQI values. There is only one water quality criteria based on the nitrate parameter, water that is critically clean. Nitrate WQI spatial pattern in Lake Rawa Besar is shown in figure 7.
3.7. Total WQI
The calculation of the total WQI in Situ Rawa Besar shows quite varied figures. The lowest WQI score is 0.48 in sample 4, while the highest WQI value is in sample 2 with a value of 2.10. Spatially, the total WQI in Situ Rawa Besar has low values at several sample points, mainly at the center of the lake. The dominant scattered value around Situ Rawa Besar are values in the mildly polluted criteria. Water quality with clean criteria is only found in the middle of the lake and at some points in the northern part of the lake. Total WQI spatial pattern in Lake Rawa Besar is shown in figure 8.

3.8. Landuse
The lake’s catchment area has different uses around it, such as settlement, market, public buildings, and vegetation cover. The details of the building classification such as permanent and semi-permanent house, permanent and semi-permanent commercial building, house with garden cover, and also public building differentiate by the difference of the uses. The landuse around Lake Rawa Besar with Total WQI value can be seen on figure 9. The west side of Lake Rawa Besar has permanent houses area which are built organizedly. In addition, there are also school areas consisting of several elementary, middle, high school, vocational schools, and foundations that have buildings and also garden. Toward to the west of house and school area around the collector road, there are also many buildings used for food stalls and commercial activities. There is a utilization as garden house in the eastern part of Lake Rawa Besar. In the garden house, there grows wild trees and there are only unpaved roads to get through to the house. Around the garden house there is a garbage dump and a chicken coop. There are some places for daily activities such as poultry cages, fish cages, iron workshops, wood sawmills, tofu factories, garbage dumps, and food stalls that have the potential to become pollutant sources for Lake Rawa Besar. Some chicken coops are in slums in the west of Lake Rawa Besar, but there are also several locations in the north and east of Lake Rawa Besar. The type of land use in the north tends to be dominated by permanent houses. The northern part of Lake Rawa Besar on the shoreline of Lake Rawa Besar also has a lot of semi-permanent commercial building. Public buildings in the form of schools are mostly located in the west of Lake Rawa Besar. In the southwest there are semi-permanent houses because of the existence of slum settlement located on the banks of Lake Rawa Besar. There are uses of many garden lands in the edge around the lake. Permanent commercial buildings on the shoreline near the local streets are found in the western part of public buildings. There are also several garden houses around slums and gardens. The area of land use types is shown in Table 3.

| Land use type                    | Area (m²) |
|---------------------------------|-----------|
| Public building                 | 18,653.71 |
| Street and road                 | 160,258.63|
| Garden                          | 57,600.66 |
| Permanent Commercial Buildings  | 17,003.60 |
| Semi-Permanent Commercial Buildings | 1,928.16 |
| House with Garden               | 759.05    |
| Permanent House                 | 114,050.82|
| Semi-Permanent House            | 5,325.80  |
Figure 2. Turbidity WQI spatial pattern within Lake Rawa Besar.

Figure 3. BOD WQI spatial pattern within Lake Rawa Besar.

Figure 4. Total Phosphate WQI spatial pattern within Lake Rawa Besar.

Figure 5. Total Solid WQI spatial pattern within Lake Rawa Besar.

Figure 6. pH WQI spatial pattern within Lake Rawa Besar.

Figure 7. Nitrate WQI spatial pattern within Lake Rawa Besar.

Figure 8. Total WQI spatial pattern within Lake Rawa Besar.
Figure 9. Total WQI value with landuse around Lake Rawa Besar.

There are some pollutant sources such as chicken coops in slums behind the school area and in the north and east of Lake Rawa Besar. Fish cages located on the edge of the Lake Rawa Besar are spread almost evenly in water bodies near permanent settlements in the eastern part of the lake and slums. The boundary of the Lake Rawa Besar also has an inlet flow in the form of sewers and culverts flowing into the lake body. The use of land and sources of pollutants that exist in the boundary of the Lake Rawa Besar has the potential to affect the lake and flow through the inlet to the water body.

3.9. The Effect of Landuse to The Water Quality
This study found that turbidity and BOD parameters is more variative scattered in the water body than total phosphate, total solid, pH, and nitrate. These may indicate that the water turbidity and BOD level in the waters of Lake Rawa Besar can be affected by the land use surrounding the lake. The lake's catchment area mostly in the form of built-up land, such as settlements, commercial areas, and school zones are heavily filled with pollution source caused by human activities. The existence of settlements producing household waste can be a major cause of high BOD values so that water becomes turbid [15]. The dominance of permanent home land use and environmental roads does not affect water quality, but the use of trade land in the north with the type of trade land use and source of pollutant landfills affects several water quality parameters, such as turbidity entering the dirty criteria and BOD entering the moderately polluted criteria. Uneven turbidity in Lake Rawa Besar has varying characteristics of land use, such as extensive garden areas in the south, as well as several landfills in parts of the slum area around semi-permanent houses area. Turbidity with dirty levels is also found in the north of Lake Rawa Besar with the type of land use dominated by gardens and the use of semi-permanent commercials, but there are several landfill locations on the edge of Lake Rawa Besar. Some locations for food stalls and
chicken coops do not affect the total phosphate value, but some locations of chicken coops and landfills are related to the location of BOD values that are included in the medium polluted criteria. The total phosphate parameters are related to agricultural and plantation activities that produce chemical waste and runoff of large and small materials. The total phosphate value is only slightly higher in the western part of the back of the school area and gardens near the southern part of the housing complex. It is possible that more disposal of chemicals and wastes is found in the vicinity of slums, especially there are also poultry cages in that location.

4. Conclusions
The pattern of spatial distribution of Lake Rawa Besar water quality based on the total value of the WQI produces a relatively clean and increasingly dirty central part of the lake towards the edge of the lake. The spatial distribution of water quality turbidity and BOD parameters has a similar pattern, which is high on the edge and lower in the middle. The water quality of the total phosphate, total solid, and nitrate parameters has an almost uniform pattern, such as the excellent criteria that is evenly distributed in the Lake Rawa Besar water body. The water quality of the pH parameter has a uniform mildly polluted pattern. The pattern of spatial distribution of water quality is closely related to land use and the existence of potential sources of pollutants. The high BOD and turbidity values are caused by domestic waste.

5. References
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