Analysis of temporal change in land use and impact of water resource in Delta’s Jeneberang Makassar, South Sulawesi

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Abstract. Twelve groundwater samples were collected in the delta Jeneberang River to study the possible impact of municipal solid waste (MSW) cause by land use cover change. The groundwater samples were collected for assessment in terms of physicochemical parameters such as pH and turbidity. A statistical analysis has been done with the calculation of the correlation coefficient and the water quality index (WQI) was used to analyze the groundwater quality of the study area. The study has revealed that the correlation between these parameters is about -0.476155325. Further, the WQI at the first location has a rating scale of C known as a poor water quality with an index value of 61.5 and the worst is at the 12th location has an index value of 90.58, or with a D rating as very poor water quality.

1. Introduction

Makassar is the 5th largest industrial and metropolitan city with a population of 1.6 million and the enhancement of industrial activity resulted in a sharp increase in urban land demand along with an increase in urban population. Therefore, the amount of municipal solid waste (MSW) generation has increased with the population. Municipal solid waste (MSW) disposal in the surrounding environment has increased a large amount due to rapid urbanization and industrialization. Disposal of solid waste and sewage, urban runoff, agricultural activities and polluted surface water are major contributors to deteriorate urban groundwater resources [1].

Since the era of industrialization and rapid population growth, land-use change phenomena have strongly accelerated in many regions which directly impacting the hydrology of the catchment area [2]. Groundwater supplies are replenished, or recharged, by rain and snowmelt that seeps down through the rocks from the land surface. The quality of groundwater is a result of all processes and reactions that have acted on the water from the moment it condensed in the atmosphere until it is discharged by a well [3]. Overpopulation has resulted in an increase in demand which eventually has lead to an accelerated rate of urbanization which results in a reduction in infiltration, and thus affecting the groundwater recharge and storage [4] as water resources.

The determination of physical and chemical parameters of water samples that also dictate various other life processes should be taken as an environmentally viable study. Statistical studies have been done on physicochemical parameters such as pH and turbidity to find out the correlation coefficient of samples. The aim of this study is to analyze land use cover change implicates the quantity and quality of groundwater as a water resource in the delta Jeneberang River.
2. Materials and Methods

2.1. Study Area

The delta Jeneberang River location was selected for this study. It is 3 km far from the downtown and directly adjacent to Gowa district. Groundwaters samples were collected from tube-wells from 12 locations around the delta (See Figure 1).

![Figure 1. Selected study area at Jeneberang Delta.](image)

2.2. Landsat Data Analysis

The addition of Landsat-8 data from the USGS website and processing the data in ArcGIS (Hasanuddin University licensed) for land use cover change analysis by comparing two or more imageries data in the same area but with different time taking [5].
2.3. Analytical Method

The collected groundwater samples then measured in a laboratory. In case of physicochemical parameters includes pH was measured by PHT-026 Multi-function water quality meter and the turbidity parameter was measured by Turbidity Meter Lutron TU-2016.

2.4. Statistical Analysis

The correlation between the calculated parameters is pH and turbidity water samples were analyzed statically through Microsoft Excel by equation (1).

\[ r = \frac{n(\Sigma xy) - \Sigma x \cdot \Sigma y}{\sqrt{[n \Sigma x^2 - (\Sigma x)^2][n \Sigma y^2 - (\Sigma y)^2]}} \tag{1} \]

with,

- \( r \) = Coefficient of correlation
- \( x \) = Individual reading of 1st parameter
- \( y \) = Individual reading of 2nd parameter
- \( n \) = Number of values of single parameter

The correlation among the different parameters will be true when the value of correlation coefficient \( r \) is high and approaching one [6].

2.5. Drinking Water Quality Index (DWQI)

Water quality assessment is carried out using WQI, which is widely used to evaluate the quality of drinking water. WQI was initially discovered by [7] and then modified by [8]. According to the report of the World Health Organization (WHO) in 2004, using WQI could help to clarify the combinatorial effects of each parameter and also the qualitative parameters of drinking water quality [9]. Each parameter has a relative role in determining the quality of drinking water. The relative weight was calculated using the following equation (2):

\[ Wi = \frac{\sum w_i}{\sum_{i=1}^{n} w_i} \tag{2} \]

with,

- \( Wi \) = Relative weight of each parameter
- \( w_i \) = Weight of each parameters
- \( n \) = Number of parameter

For each parameter, the quality rating scale was calculated by dividing its concentration in each water sample to its respective standards (released by World Health Organization 2011) and then multiplied the results by 100 through equation (3):

\[ qi = \left( \frac{Ci}{Si} \right) \times 100 \tag{3} \]

with,

- \( q_i \) = The quality rating
- \( Ci \) = Concentration of each parameter (mg/L)
- \( Si \) = Standard limit (mg/L) according to WHO released in 2011
Water quality is categorized into 5 types which are shown in Table 1. To calculate the sub-index of each parameter, the weight (Wi) of each parameter can be seen in Table 2.

**Table 1. Rating of water quality index [10].**

| WQI Value | Rating of water quality | Grading |
|-----------|-------------------------|---------|
| 0 – 25    | Excellent water quality | A       |
| 26 – 50   | Good water quality      | B       |
| 51 – 75   | Poor water quality      | C       |
| 76 – 100  | Very poor water quality | D       |
| Above 100 | Unsuitable for drinking purposes | E     |

**Table 2. The weight (wi) and WHO standard values for drinking water.**

| Parameters | Concentration (mg/L) (Ci) | WHO (mg/L) (Si) | Weight (wi) |
|------------|---------------------------|-----------------|-------------|
| pH         | 7.64                      | 6.5 – 8.5       | 4           |
| Turbidity  | 3.01                      | 4               | 3           |
|            |                           | Sum = 7         |             |

The final part of the WQI calculation is to computing the Sli for each parameter and the sum of Sli values is the final value of WQI, indicated by equations (4) and (5):

\[ Sli = Wi \times qi \]  

(4)

with, Sli is the sub-index of each parameter

\[ WQI = \sum_{i=1}^{n} Sli \]  

(5)

with, WQI is the water quality index.

3. Results and Discussion

Analysis results of the physicochemical parameters namely pH and turbidity of the groundwater samples are shown in Table 3. Further, some statistical analysis has done with the results shown in Table 4.

Results from the laboratory test, the values of pH and turbidity parameters in the 12 groundwater samples in the study area obtained several parameters for statistical analysis such as the average value, standard deviation, variance, n (total sample), and correlation. The average value of the pH parameter is 6.605 in accordance with WHO standard whereas for turbidity parameter obtained 2.094 NTU. For variance, the measurement differences are relatively the same in both parameters. However, the correlation between pH and turbidity parameters did not have a significant value obtained by -0.476.
Table 3. Values of Jeneberang Delta’s data sample with coordinate.

| Sample | Lat.    | Long.    | Turbidity Meter (NTU) | pH 1 | pH 2 | pH 3 | Average | Stdev |
|--------|---------|----------|-----------------------|------|------|------|---------|-------|
| 1      | -5.1941600 | 119.41188 | 2.31                  | 6.54 | 6.52 | 6.53 | 6.53    | 0.0100000 |
| 2      | -5.1891178  | 119.40258 | 1.02                  | 6.64 | 6.63 | 6.64 | 6.64    | 0.0057735  |
| 3      | -5.1874341  | 119.40724 | 2.08                  | 6.81 | 6.82 | 6.64 | 6.76    | 0.1011599  |
| 4      | -5.1871768  | 119.39834 | 2.19                  | 6.44 | 6.43 | 6.42 | 6.43    | 0.0100000  |
| 5      | -5.1807760  | 119.39376 | 2.31                  | 6.83 | 6.83 | 6.82 | 6.83    | 0.0057735  |
| 6      | -5.1913695  | 119.39091 | 1.89                  | 6.85 | 6.86 | 6.85 | 6.85    | 0.0057735  |
| 7      | -5.1833331  | 119.38896 | 1.79                  | 6.95 | 6.94 | 6.93 | 6.94    | 0.0100000  |
| 8      | -5.1833331  | 119.38896 | 1.73                  | 6.86 | 6.87 | 6.88 | 6.87    | 0.0100000  |
| 9      | -5.1833933  | 119.39265 | 1.77                  | 6.92 | 6.93 | 6.90 | 6.92    | 0.0152753  |
| 10     | -5.1805609  | 119.39053 | 1.94                  | 7.02 | 7.00 | 7.01 | 7.01    | 0.0100000  |
| 11     | -5.1902899  | 119.38834 | 1.82                  | 5.63 | 5.62 | 5.61 | 5.62    | 0.0100000  |
| 12     | -5.1903389  | 119.41013 | 4.82                  | 5.88 | 5.87 | 5.86 | 5.87    | 0.0100000  |

After the statistical analysis has done, the final stage of the computation is calculating the WQI (Water Quality Index) using equations (2), (3), (4), and (5). The result is shown in Table 5 and Table 6.

The value of WQI in the first location till location 11 was found variation values in the ranges of 51 to 75, so could be said that the water quality is poor and grading as C (Table 1). Except for the 5th location, reveals WQI value 76.76269841 and it indicates in that location had very poor water quality and grading as D. Lastly, for location 12 same as the 5th location the water quality in this location is very poor and not suitable for drinking purpose because the QWI value shown 90.58095238 which is between the range of 76 to 100 and grating as D (Table 1).

Table 4. Values of physicochemical parameters.

| Location | pH  | Turbidity |
|----------|-----|-----------|
| 1        | 6.53| 2.31      |
| 2        | 6.64| 1.02      |
| 3        | 6.76| 2.08      |
| 4        | 6.43| 2.19      |
| 5        | 6.83| 2.31      |
| 6        | 6.85| 1.89      |
| 7        | 6.94| 1.79      |
| 8        | 6.87| 1.73      |
| 9        | 6.92| 1.77      |
| 11       | 7.01| 1.94      |
| 10       | 5.62| 1.82      |
| 12       | 5.87| 4.82      |
| Sum      | 79.26| 25.13    |
| Average  | 6.605| 2.0941667    |
| Standard Deviation (STDEV) | 0.4395372| 0.7690071     |
| Variance | 0.1931929| 0.591372     |
| n        | 12 | 12        |
| Correlation | -0.476155325 |          |
| WHO Standard | 6.5 – 8.5 | 4          |
Table 5. Results of WQI for Location 1.

| Parameters  | Concentration (mg/L) (Ci) | WHO (mg/L) (Si) | Weight (wi) | Relative Weight (Wi) | qi (Ci/Si) * 100 | Sli (Wi * qi) |
|-------------|---------------------------|-----------------|-------------|----------------------|-----------------|-------------|
| pH          | 6.53                      | 6.5 – 8.5       | 4           | 0.57142857           | 87.0666667     | 49.75238    |
| Turbidity   | 2.31                      | 4               | 3           | 0.42857143           | 57.75           | 24.75       |
| Sum         |                           |                 | 7           |                      | WQI = 74.50238  |

Table 6. Results of WQI for all location sample.

| Sample Location | Result WQI  |
|-----------------|-------------|
| 1               | 74.50238095 |
| 2               | 61.49365079 |
| 3               | 73.76507937 |
| 4               | 72.45476190 |
| 5               | 76.76269841 |
| 6               | 72.46587302 |
| 7               | 72.05476190 |
| 8               | 70.87857143 |
| 9               | 71.66269841 |
| 10              | 74.19523810 |
| 11              | 62.31904762 |
| 12              | 90.58095238 |

Figure 2. Spatial digitations of land use Jeneberang Delta’s.
Figure 3. Spatial variation of Water Quality Index using IDW.

The varied results obtained are clearly caused by several factors like municipal solid waste generation increased since there is a land-use change from agricultural land purpose to urban land and impact the groundwater catchment area and also the study area directly adjacent to the Jeneberang river flow.

Digitization was carried out on ArcGIS which produced a map of land use cover change in the study area shown in Figure 2 and also has done an Inverse Distance Weighted (IDW) interpolation for all WQI values, the graph in Figure 3 represents the spatial variation of WQI around the delta Jeneberang River.

4. Conclusion

From the analysis of temporal change in land use and how it impacts water resources in the delta Jeneberang River, it is found that the correlation coefficient (a value between -1 and 1) could use to display how strongly two variables are related to each other. Statistical analysis used for indicates the value of physicochemical parameters is a good measure before detailed observation about groundwater pollution because its time saving also cost-effective. WQI was used to analyze the underground water quality of the study area. Hence we can conclude that an accelerated rate of urbanization could implicate the quantity and quality of groundwater as water resources. The result showed that overall the groundwater quality in the study area needs to be treated before use and for more detailed research, parameters of water quality should be a variation to find out how much environmental damage has occurred the same as the correlation results can vary between parameters.

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