Analysis of Groundwater Quality Using Water Quality Index (WQI) and Geographic Information System (GIS) Techniques: A Case Study of Boarding Area Near Hasanuddin University, Makassar (Workshop and Sahabat)

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Abstract. The importance and high demand of groundwater, in this case, the well water in the boarding area near Hasanuddin University is not supported by the data to ensure that the water quality in the area is sufficient and suitable for use. Several parameters are needed to determine the quality of groundwater in the area, such as pH, Turbidity, Lead (Pb), Antimony (Sb), Molybdenum (Mo), and Uranium (U). The methods used in this study are Water Quality Index (WQI) and Geographic Information System (GIS), combined with literature review results and field data. This study shows that the WQI index value of the second sample point (Workshop) is 51.76666667, which is classified as a C rating (poor water quality), and the seventh sample point (Sahabat) is the worst with an index value of 76.35185185, which is classified as a D rating (very poor water quality). These results indicate that land use and population will affect the water quality in the study area.

Keywords: boarding area; GIS techniques; groundwater; water quality index;

1. Introduction

Water below the ground surface consists of surface water and groundwater, where both types of water come from infiltration of hydrological processes, seeping through the pores of rocks from high pressure to low pressure (Wijaya & Kusmiran, 2021). Groundwater (well) is water located above the first impermeable layer, usually located not too deep below the surface (Tague & Grant, 2009). The existence of groundwater (wells) does not necessarily have good enough quality for use, because well water is water that is easily contaminated by leakage. Usually, leakage comes from landfills and human and animal waste disposal sites (Abiriga et al., 2020). Water quality degradation is usually caused by industrial waste and household waste (liquid and solid waste). The water quality has declined in several areas in Indonesia, including the Makassar City. As a metropolis in Indonesia, with a population of more than 1.6 million, industrial activities have grown rapidly with population growth. Due to increased pollution of industrial waste and household waste, has led to a decline in water quality (Suharto et al., 2018).

The boarding area around Unhas, namely Workshop, and Sahabat, is one of the areas in Makassar City that has experienced a decline in water quality due to this. Changes in land use are also the cause of the decline in water quality in the workshop area and friends, that's why this is an exclusive concern in this study.

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## 2. Methods

The study location is in the city of Makassar, precisely in the boarding area near Unhas. In this study location, there are many cottages and housing. The study location is divided into two places, namely Workshop, and Friends.

Land use in this area is dominated by housing and swamps. Determination of well water quality is carried out by taking well water samples at several points scattered in the two study areas (see Fig. 1 and Fig. 2).

The sampling locations were spread over the study area as many as 10 samples for each area (10 in Workshop and 10 in Sahabat) with a total of 20 samples.

There are two methods that are used, Water Quality Index (WQI) and Geographic Information System (GIS).

### 2.1. Water Quality Index (WQI)

Water Quality Index (WQI) is used to determine the value of water quality based on several parameters (Alobaidy et al., 2010). The parameters used in this study were pH, Turbidity, Lead (Pb), Antimony (Sb), Molybdenum (Mo), and Uranium (U).
In the WQI formula, the number of parameters is determined based on the intended use of water, here, water quality parameters are studied because of human consumption. The standard used for these parameters is the standard set by the WHO (Alobaidy et al., 2010) (Table 1).

Table 1. Water Quality Standard.

| Parameters          | WHO Water Quality Standard |
|---------------------|-----------------------------|
| pH                  | 6.5-8.5                     |
| Turbidity           | 5                           |
| Lead (Pb)           | 0.01                        |
| Antimony (Sb)       | 0.02                        |
| Molybdenum (Mo)     | 0.07                        |
| Uranium (U)         | 0.03                        |

(Source: WHO, 2017)

The calculation of the WQI formula is carried out in several steps. The first step is to determine the relative weight (Wi), with the following equation:

\[ Wi = \sum_{i=1}^{n} \frac{A_{wi}}{\sum_{i=1}^{n} A_{wi}} \]  

(1)

with,
Wi = Relative weight of each parameter
Awi = Assigned weight of each parameter
n = Number of assigned weight

The assigned weight (Awi) value of each parameter can be seen in Table 2.

Table 2. Assigned weight for each parameter

| Parameters          | Assigned Weight (Awi) |
|---------------------|------------------------|
| pH                  | 4                      |
| Turbidity           | 3                      |
| Lead (Pb)           | 5                      |
| Antimony (Sb)       | 5                      |
| Molybdenum (Mo)     | 5                      |
| Uranium (U)         | 5                      |

(Source: Kareem et al., 2017)  
(Source: Sener et al., 2017)

For each parameter, the quality rating (Qi) is obtained by dividing the concentration of the parameter in the sample with WHO quality standards and then multiplying the result by 100 with the following equation:

\[ qi = \left( \frac{C_i}{S_i} \right) \times 100 \]  

(2)

with,
qi = The quality rating
Ci = Concentration of each parameter
Si = WHO quality standard

The last step of calculating the WQI formula is to calculate the value of sub-indices (Sli) based on the calculation of relative weight (Wi) and quality rating (qi), with the following equation:

\[ Sli = Wi \times qi \]  

(3)

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

(4)

with,
Sli = Sub-indices
WQI = Water quality Index
The water quality rating is classified into 5 categories which are shown in Table 3.

| 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       |
| > 100     | Unsuitable for drinking purposes | E       |

(Source: Tyagi et al., 2013)

2.2 Geographic Information System (GIS)

Geographic Information System (GIS) is a method used to map an area (Dulin, 2010). This method is the last step to get the mapping results from the results of the previous Water Quality Index. The technique used is the IDW or Inverse Distance Weighted by first adding an Excel data layer that has been processed previously, this Excel data contains longitude, latitude, WQI values, and classification based on WQI values. After adding excel data to the layer, then the masking process and area weighting are carried out based on the WQI value, which will then produce an output in the form of a water quality map.

3. Result and Discussion

The results of laboratory tests of 20 samples for each parameter, namely pH, turbidity, lead (Pb), antimony (Sb), molybdenum (Mo), and uranium (U) showed that the values of each parameter in the two study areas were different. This difference can be seen in the results of the analysis of physicochemical parameters and statistical analysis for each parameter (Table 4 and Table 5). Statistical analysis was conducted to determine the average, standard deviation, and variance of each parameter.

| Sample | Latitude | Longitude | pH  | Turbidity (NTU) | Lead (Pb) (mg/L) | Antimony (Sb) (mg/L) | Molybdenum (Mo) (mg/L) | Uranium (U) (mg/L) |
|--------|----------|-----------|-----|-----------------|------------------|----------------------|-----------------------|---------------------|
| T1     | 775451   | 9431800   | 6.9 | 0               | 0                | 0.00933              | 0.00902               | 0                   |
| T2     | 775329   | 9431830   | 7.0 | 0.02            | 0.01538          | 0                    | 0                     | 0.01525             |
| T3     | 775317   | 9431640   | 7.0 | 0               | 0.01907          | 0.00603              | 0.00717               | 0.01496             |
| T4     | 775213   | 9431822   | 7.2 | 6.22            | 0                | 0.01069              | 0.01205               | 0                   |
| T5     | 775307   | 9432057   | 7.7 | 0               | 0.01499          | 0                    | 0                     | 0.01229             |
| T6     | 775322   | 9431881   | 7.1 | 0               | 0                | 0                    | 0                     | 0                   |
| T7     | 775472   | 9431649   | 7.6 | 0.46            | 0                | 0                    | 0                     | 0                   |
| T8     | 775365   | 9431573   | 7.5 | 0               | 0.00744          | 0.01240              | 0                     | 0                   |
| T9     | 775423   | 9431890   | 6.9 | 0               | 0                | 0                    | 0                     | 0                   |
| T10    | 775243   | 9431928   | 7.1 | 0.73            | 0.01926          | 0.00699              | 0.00972               | 0                   |
| Total  |          |           | 72  | 6.7             | 0.04944          | 0.03349              | 0.04064               | 0.04250             |
| Average |         |           | 7.2 | 0.743           | 0.00687          | 0.00405              | 0.00504               | 0.00472             |
| Standard Deviation | | | 0.29 | 0.941 | 0.00897 | 0.00445 | 0.00550 | 0.00713 |
| Variance |          |           | 0.08 | 3.391 | 0.00007 | 0.00002 | 0.00003 | 0.00004 |
| WHO Standard | | | 6.5-8.5 | 5 | 0.01 | 0.02 | 0.07 | 0.03 |

In the first parameter analysis (pH), the pH value of 10 samples in the Workshop area has a value that is in accordance with WHO standards with an average of 7.2. For the Sahabat area, 10 samples also have an average pH value of 7.11 which is in accordance with WHO standards.

For the second parameter (turbidity), among the 10 samples in the Workshop area, 1 sample in T4 did not accord the WHO turbidity standard, which was 6.22 NTU. As for the Sahabat area, out of 10 samples, 1 sample in T7 did not accord with the WHO standard, which has a turbidity value of 8.85 NTU.
The third parameter (Lead (Pb)), for the Workshop area, from 10 samples there are 4 samples, namely T2, T3, T5, and T10 which has values above the WHO standard with respective values of 0.01538 mg/L, 0.01907 mg/L, 0.01499 mg/L, and 0.01926 mg/L. In the Sahabat area, there were 2 samples from 10 samples, namely T6 and T7 with Pb values of 0.01577 mg/L and 0.01988 mg/L, both of these values were not in accordance with WHO standards.

Furthermore, the fourth parameter (Antimony (Sb)), from 10 samples in the workshop area, all had values that were in accordance with WHO standards with an average value of 0.00405 mg/L. For the Sahabat area, 10 samples also have a value according to WHO standards, the average value is 0.000637 mg/L.

Then, the fifth parameter (Molybdenum (Mo)), for the Workshop area, none of the 10 samples did not accord with WHO standards which have an average value of 0.00504 mg/L. In the Sahabat area, the value of each sample is also in accordance with WHO standards with an average value of 0.00551.

The last parameter (Uranium (U)), the values of 10 samples in the Workshop area were all in accordance with WHO standards with an average value of 0.00472 mg/L. The value of 10 samples of the Sahabat area also has a value that is in accordance with WHO standards, the average value of the 10 samples is 0.00265 mg/L.

After obtaining the results of the analysis of each parameter, then the WQI formula is calculated to determine the classification of water quality in the study area. WQI formula calculations can be seen in Table 6, Table 7, Table 8, and Table 9.

Based on the results of the WQI calculation, from 10 samples in the Workshop area, there are 4 samples, namely T2, T3, T5, and T10 which has a WQI value range of 50-75, this indicates that the four samples are rated C or poor water quality. The values for the four samples are 51.76, 66.66, 66.67, 65.85, 67.01, 50.55, 55.55, and 60.35. Furthermore, T1, T6, T7, T8, and T9 have a value range of 0-25, this range is classified as an A rating or excellent water quality, with the respective values 24.65, 24.98, 24.98, 24.98, and 24.98. Then, for T4 it has a value of 41.13 and is classified as A rating or excellent water quality.

As for the 10 samples in the Sahabat area, there is 1 sample namely T7 which is classified as a D rating or very poor water quality with a WQI value of 76.35. The other 7 samples, namely T1, T3, T5, T6, T8, T9, and T10 are classified as B rating or good water quality with WQI values of 29.73, 36.62, 35.18, 35.18, 36.62, 48.63, 50.54, 30.04, and 39.24. Meanwhile, the other 2 samples, T2 and T4 have values of 22.92 and 14.04, respectively. These values are classified as A rating or excellent water quality.
Table 6. WQI Calculation for T1 Workshop

| Parameter       | Concentration (Ci) | WHO standard (Si) | Weight (wi) | Relative weight (Wi) | qi ((Ci/Si)*100) | Sli (Wi*qi) |
|-----------------|--------------------|-------------------|-------------|----------------------|-----------------|-------------|
| pH              | 6.9                | 6.5-8.5           | 4           | 0.148148148          | 92              | 13.62962963 |
| Turbidity       | 0                  | 5                 | 3           | 0.111111111111      | 0               | 0           |
| Timbal (Pb)     | 0                  | 0.01              | 5           | 0.185185185          | 0               | 0           |
| Antimon (Sb)    | 0.009333           | 0.02              | 5           | 0.185185185          | 46.65           | 8.638888889 |
| Molibdenum (Mo)| 0.009023           | 0.07              | 5           | 0.185185185          | 12.88571429     | 2.386243386 |
| Uranium (U)     | 0                  | 0.03              | 5           | 0.185185185          | 0               | 0           |
| Sum             | 27                 |                   |             |                      |                 |             |
| WQI             |                    |                   |             |                      |                 | 24.6547619  |

Table 7. WQI Calculation for T1 Sahabat

| Parameter       | Concentration (Ci) | WHO standard (Si) | Weight (wi) | Relative weight (Wi) | qi ((Ci/Si)*100) | Sli (Wi*qi) |
|-----------------|--------------------|-------------------|-------------|----------------------|-----------------|-------------|
| pH              | 7.5                | 6.5-8.5           | 4           | 0.148148148          | 100             | 14.81481    |
| Turbidity       | 0.99               | 5                 | 3           | 0.111111111111      | 19.8            | 2.2         |
| Timbal (Pb)     | 0                  | 0.01              | 5           | 0.185185185          | 0               | 0           |
| Antimon (Sb)    | 0.010463           | 0.02              | 5           | 0.185185185          | 52.3            | 9.685185185 |
| Molibdenum (Mo)| 0.011473           | 0.07              | 5           | 0.185185185          | 16.38571429     | 3.034391534 |
| Uranium (U)     | 0                  | 0.03              | 5           | 0.185185185          | 0               | 0           |
| Sum             | 27                 |                   |             |                      |                 |             |
| WQI             |                    |                   |             |                      |                 | 29.73439153 |

Table 8. WQI Value for all samples in Workshop

| Sample Location | Result WQI   | Classification          |
|-----------------|--------------|-------------------------|
| T1              | 24.6547619   | Excellent water quality |
| T2              | 51.76666667  | Poor water quality      |
| T3              | 65.85670194  | Poor water quality      |
| T4              | 41.13042328  | Good water quality      |
| T5              | 50.55555556  | Poor water quality      |
| T6              | 14.02469136  | Excellent water quality |
| T7              | 16.0345679   | Excellent water quality |
| T8              | 24.98412698  | Excellent water quality |
| T9              | 13.62962963  | Excellent water quality |
| T10             | 60.35723104  | Poor water quality      |

Based on the results of mapping the value of WQI (see fig. 3) in the Workshop area, it was found that the locations of points classified as C rating, namely T2, T3, T5, and T10 were in environmental conditions near swamps. These swamps are a place for household waste disposal by the people near the location sample. Meanwhile, the points classified as A and B ratings, namely T1, T4, T6, T7, T8, T9 are in environmental conditions which are quite far from the swamps.

For the results of mapping the WQI value in the Sahabat area (see Fig. 4), the point classified as a D rating is T7, this point is in environmental conditions near the landfill and household waste of the people near the sample location. Then, points classified as A and B ratings, namely T1, T2, T3, T4, T5, T6, T8, T9, and T10 are in environmental conditions that are quite far from landfills and swamps.
### Table 9. WQI Value for all samples in Sahabat

| Sample Location | Result WQI      | Classification          |
|-----------------|-----------------|-------------------------|
| T1              | 29.73439153     | Good water quality      |
| T2              | 22.92098765     | Excellent water quality |
| T3              | 36.6287478      | Good water quality      |
| T4              | 14.02469136     | Excellent water quality |
| T5              | 35.18280423     | Good water quality      |
| T6              | 48.63148148     | Good water quality      |
| T7              | 76.35185185     | Very poor water quality |
| T8              | 25.38853616     | Good water quality      |
| T9              | 30.04673721     | Good water quality      |
| T10             | 39.24850088     | Good water quality      |

**4. Conclusion**

From the results of the analysis of each parameter at 20 sample points in the Workshop and Sahabat, it was found that the WQI values obtained varied. The classifications obtained from 20
samples are A (excellent water quality), B (good water quality), C (poor water quality), and D (very poor water quality). In the Workshop area, the A rating is at the T1, T6, T7, T8, and T9 points, the B rating is at the T4 point, and the C rating is at the T2, T3, T5, and T10 points. For the Sahabat area, the A rating is at the T2 and T4 points, the B rating is at the T1, T3, T5, T6, T8, T9, and T10 points, and the D rating is at the T7 point. The mapping results obtained indicate that the sample points with environmental conditions that are close to swamps and landfills actually affect the level of water quality in the two study locations, namely Workshop and Sahabat.

Reference
Abiriga, D., Vestgarden, L. S., & Klempe, H., 2020, *Groundwater Contamination from a Municipal Landfill: Effect of Age, Landfill Closure, and Season on Groundwater Chemistry*, Science of The Total Environment, 737, pp 1-11. doi: 10.1016/j.scitotenv.2020.140307.

Alobaidy, A. H., Abid, H. S., & Maulood, B. K., 2010, *Application of Water Quality Index for Assessment of Dokan Lake Ecosystem, Kurdistan Region, Iraq*, Journal of Water Resource and Protection, 2(9), pp 792-798. doi: 10.4236/jwarp.2010.29093.

Dulin, M. F., Ludden, T. M., Tapp, H., Blackwell, J., Hernandez, B. U. D., Smith, H. A., & Furuseth, O. J., 2010, *Using Geographic Information Systems (GIS) to Understand a Community’s Primary Care Needs*, The Journal of the American Board of Family Medicine, 23(1), pp 13-21. doi: 10.3122/jabfm.2010.01.090135.

Kareem, S. M. R., Ganjo, D. G. A., & Toma, J. J., 2017, *Physical and Chemical Properties of Rainwater and Its Suitability for Drinking and Irrigating in Erbil city*, ZANCO Journal of Pure and Applied Sciences, 29(5), pp 39-50. doi: 10.21271/ZIPAS.29.5.5.

Sener, S., Sener, E., & Davraz, A., 2017, *Evaluation of Water Quality Using Water Quality Index (WQI) Method and GIS in Aksu River (SW-Turkey)*, Science of the Total Environment, 584-584, pp 131-144. doi: 10.1016/j.scitotenv.2017.01.102.

Suharto, Septiyawati, F., & Yanuarita, D., 2018, *Kajian Kualitas Air dan Indeks Pencemaran Wilayah Pesisir Kota Makassar*, Jurnal Pengelolaan Perairan, 1(2), pp 41-55. E-ISSN: 2620-6552.

Tague, C. & Grant, G.E., 2009, *Groundwater Dynamics Mediate Low-flow Response to Global Warming in Snow-dominated Alpine Regions*, Water Resource Research, 45(7), pp. 1-12. doi: 10.1029/2008WR007179.

Tyagi, S., Sharma, B., Singh, P., & Dobhal, R., 2013, *Water Quality Assessment in Terms of Water Quality Index*, American Journal of Water Resources, 1(3), pp 34-38. doi: 10.12691/ajwr-1-3-3.

WHO, 2017, *Guidelines for Drinking-water Quality, 4th ed.*, World Health Organization, 541.

Wijaya, A., & Kusmiran, A., 2021, *Identifikasi Jenis Akuifer Airtanah Menggunakan Vertical Electrical Sounding Konfigurasi Schlumberger*, Jurnal Fisika dan Terapannya, 8(1), pp 10-18. doi: 10.24252/jft.v8i1.21210