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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.

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)

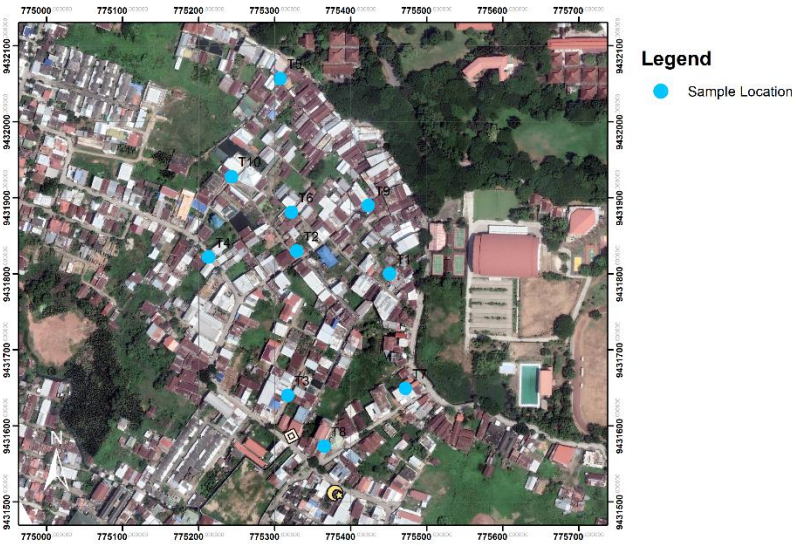

Fig. 1. *Sample location in Workshop*

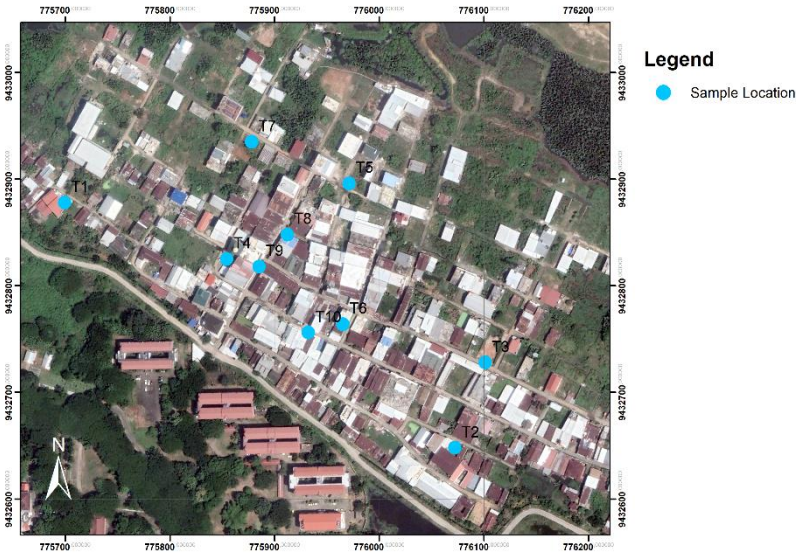

Fig. 2. *Sample location in Sahabat*

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:

$$Wi = \sum \frac{Awi}{\sum_{i=1}^{n} Awi} \quad (1)$$

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

a. (Source: Kareem *et al*, 2017)
b. (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:

$$qi = \left(\frac{Ci}{Si}\right) \times 100 \quad (2)$$

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:

$$Sli = Wi \times qi \quad (3)$$

then,

$$WQI = \sum_{i=1}^{n} Sli \quad (4)$$

with,

Sli = Sub-indices
WQI = Water quality Index

The water quality rating is classified into 5 categories which are shown in Table 3.

Table 3. *Classification of water quality rating*

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 Ms. 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 (Pb), 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.

Table 4. *Result of analysis physicochemical parameters and statistical analysis, Workshop.*

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	0.00744	0.01240	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.

Table 5. *Result of analysis physicochemical parameters and statistical analysis, Sahabat.*

Sample	Latitude	Longitude	pH	Turbidity (NTU)	Lead (Pb) (mg/L)	Antimony (Sb) (mg/L)	Molybdenum (Mo) (mg/L)	Uranium (U)(mg/L)
T1	775699	9432878	7.5	0.99	0	0.01046	0.01147	0
T2	776072	9432648	6.8	4.27	0	0	0	0
T3	776101	9432728	6.7	2.25	0	0.01692	0.01031	0
T4	775854	9432825	7.1	0	0	0	0	0
T5	775971	9432896	7.2	4.39	0	0.00949	0.00914	0
T6	775965	9432764	6.9	0.98	0.01577	0.00391	0	0
T7	775878	9432935	7.0	8.85	0.01988	0	0	0.00979
T8	775912	9432848	7.0	4.63	0	0	0.00481	0
T9	775885	9432818	7.6	0	0	0.01332	0.01021	0
T10	775932	9432756	7.3	1.44	0	0.00960	0.00919	0.01670
Total			71.1	27.8	0.03565	0.06370	0.05513	0.02649
Average			7.11	2.78	0.00356	0.00637	0.00551	0.00265
Standard Deviation			0.29	2.77	0.00758	0.00637	0.00505	0.00582
Variance			0.08	6.91	0.00005	0.00004	0.00002	0.00003
WHO Standard			6.5-8.5	5	0.01	0.02	0.07	0.03

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 51.76666667, 65.85670194, 50.55555556, and 60.35723104. 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 value 24.6547619, 14.02469136, 16.0345679, 24.98412698, and 13.62962963. Then, for T4 it has a value of 41.13042328 and is classified as a B rating or Good 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 76.35185185. 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 29.73439153, 36.6287478, 35.18280423, 48.63148148, 25.38853616, 30.04673721, and 39.24850088. Meanwhile, the other 2 samples, T2 and T4 have values of 22.92098765 and 14.02469136, respectively. These values are classified as A rating or excellent water quality.

Table 6. *WQI Calculation for T1 Workshop*

Result of WQI 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	0.111111111	0	0
Timbal (Pb)	0	0.01	5	0.185185185	0	0
Antimon (Sb)	0.00933	0.02	5	0.185185185	46.65	8.638888889
Molibdenum (Mo)	0.00902	0.07	5	0.185185185	12.88571429	2.386243386
Uranium (U)	0	0.03	5	0.185185185	0	0
		Sum =	27	1	WQI =	24.6547619

Table 7. *WQI Calculation for T1 Sahabat*

Result of WQI 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	0.111111111	19.8	2.2
Timbal (Pb)	0	0.01	5	0.185185185	0	0
Antimon (Sb)	0.01046	0.02	5	0.185185185	52.3	9.685185185
Molibdenum (Mo)	0.01147	0.07	5	0.185185185	16.38571429	3.034391534
Uranium (U)	0	0.03	5	0.185185185	0	0
		Sum =	27	1	WQI =	29.73439153

Table 8. *WQI Value for all samples in Workshop*

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*

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

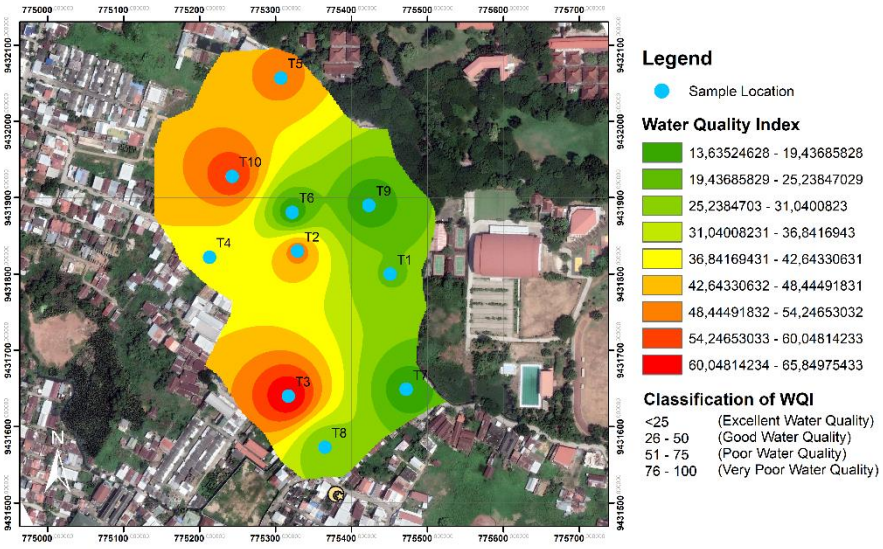

Fig. 3. *Water quality maps in Workshop*

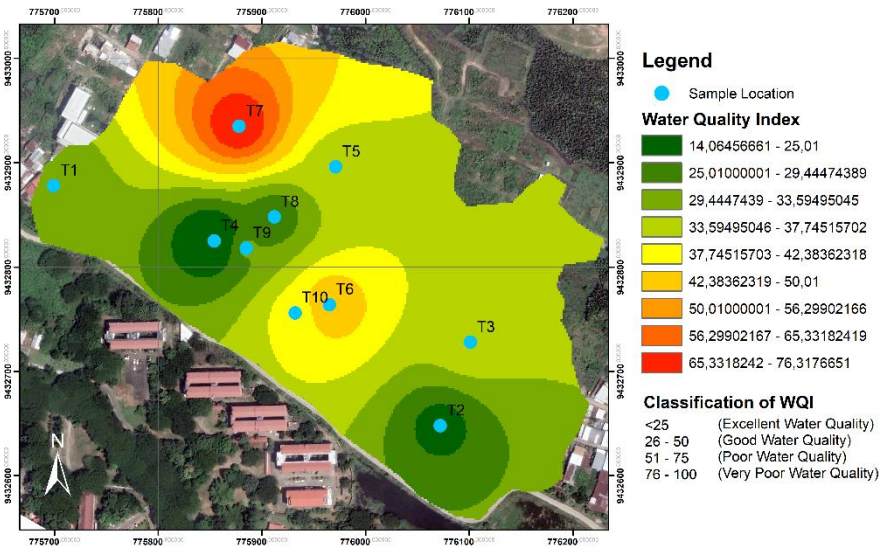

Fig. 4. *Water quality maps in Workshop*

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.

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