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GIS Mapping of Water Index Quality for Sungai Benut, Simpang Renggam

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Abstract: This study aimed to characterize the river pollution at Sungai Benut, Simpang Renggam by calculating the Water Quality Index (WQI) and use Geographic Information System (GIS) to perform the detailed condition of the study area. 3 different WQI models were computed from 8 water samples that were collected for on-site testing and physiochemical analysis. 6 parameters were considered in calculating the WQI such as Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Acidic and Alkaline (pH), Dissolved Oxygen (DO), Total Suspended Solids (TSS) and Ammonia Nitrogen (NH_3). Then, the WQI's variability thematic maps produced using QGIS software based on spatial and non-spatial database. As a result, 1 station was categorized as slightly polluted, 4 stations were classified as polluted and 3 stations were poorly polluted. These analysis indicated that GIS has the potential to efficiently present an interactive visualizations over a large study area in order for the authorities to upgrade the water quality management system.

Keywords: Water Pollution, Water Quality Index, Geographical Information System

1. Introduction

Water is the most abundant substances on earth as all forms of life depends on it and fortunately the water is not going to run out on earth. This is because in continuous cycle, the water evaporated from the earth's surface to the atmosphere as vapor and restore back as liquid water. Next, despite the ocean covered almost two-thirds of the earth and yet short supply of water frequently happened due to rise in global population to produce goods and services necessary. This has result to an increase in water use and water contamination. Next, despite the ocean covered almost two-thirds of the earth and yet short supply of water frequently happened due to rise in global population to produce goods and services necessary. This has result to an increase in water use and water contamination.

To get uncontaminated water, sustainable groundwater is considered as one of the most vital and precious asset as it acting as an ecosystem's foundation in supplying the drinking for millions of

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people, sustaining the aquatic ecological functions and many more purposes, therefore monitoring the raw water supply to restore the water quality is very important. The reason of that is because water quality is one of the fundamental matters in groundwater as it measures and describe the condition of the water chemically, physically and biological characteristic whether it suit for both human consumption and ecosystem [1].

To ensure the safety for drinking water, a detailed studies for dissolved elements in groundwater used by humans are made by hydro geologist. Further, few studies were made to determine the quality of groundwater by analyzing the hydro chemical date derived in the water samples. Water quality index (WQI) method and Geographic Information System mapping (GIS) are used to picture the spatial pattern the condition of the study area [2].

However, groundwater is susceptible to pollution because it absorbs the man-made products such as chemicals, oil, gasoline, and many more causing the groundwater to be unsafe and dangerous for human use and ecosystem. In addition, untreated waste from leaky landfills and underground storage tanks also can contaminate the groundwater over [3].

WQI method is an important tool to access the water quality issues by integrating complex data into score to easily describe the water quality status meanwhile GIS is a computer system for capturing, storing, checking, and displaying data on earth's surface in many ways that show the patterns and trends in the form of maps, charts and reports. GIS is also used as database system to develop 2D, 3D or 4D water quality status maps according to the concentration values of chemical elements in the rivers [4]. The combination of WQI and GIS provides detailed, quick and genuine information for decision makers to implement solutions and strategies related to the water pollution

2. Materials and Methods

A total of 8 sampling stations were selected as the sampling points (Figure 1) with 3 times data taken within 3 months interval. The parameters investigated including Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Acidic and Alkaline (pH), Dissolved Oxygen (DO), Total Suspended Solids (TSS) and Ammonia Nitrogen (NH_3). The water quality was calculated by using 2 formulae for comparison developed by Department of Environment (DOE) and Malaysian Interim National Water Quality (INWQS) with Weighted Arithmetic Index (WAI) method. Table 1 showed the evaluation of water quality index (WQI) from DOE-INWQS (Eq 1) and Table 2 was used for WAI (Eq 2) method. Besides that, the WQI values using both methods were calculated for every station at every 3 takes for a clear comparison.

$$\text{WQI}=(0.22*\text{SIDO}) + (0.19*\text{SIBOD}) + (0.16*\text{SICOD}) + (0.15*\text{SIAN}) + (0.16*\text{SISS}) + (0.12*\text{SIpH}) \qquad Eq1$$

Where: SIDO is Sub index DO, SIBOD is Sub index BOD, SICOD is Sub index COD, SIAN is Sub index AN, SISS isSub index SS and SIpH is Sub index pH.

Table 1: Water Quality Index (WQI)

Sub index and water quality index	Index range		
	Clean	Slightly polluted	Polluted
Biochemical oxygen demand (BOD)	91-100	80-90	0-79
Ammoniacal nitrogen (AN)	92-100	71-91	0-79
Suspended solids (SS)	76-100	71-75	0-69
Water quality index	81-100	60-80	0-59

$$\text{WQI}=\Sigma\, Q_i W_i / \Sigma\, W_i \qquad Eq2$$

Where, Qi is Quality rating of nth parameter for total of n water quality parameters, Wi is Relative weight of nth parameter and Σ Wi is the Total relative weight of nth parameter

Table 2: Water Quality Index (WQI) and Its Status for Human Consumption using Weighted Arithmetic Index method

WQI	Water type
<50	Excellent
50.1-100	Good
100.1-200	Poor
200.1-300	Very poor

GIS Database

Two types of data included spatial and non-spatial data were stored using GIS. The spatial data was used to capture the spatial variability of water quality where 8 toposheets from 8 stations of Sungai Benut, Simpang Renggam was used while non-spatial data were of 2 main components: district boundary map and field data. In order to import the coordination into the QGIS, an excel that was saved as CSV file was used. Plus, the concentration of water quality parameters can also be added into the excel.

These steps were important to ensure that GIS software can process the information easily. The design of a database was classified into 3 categories: conceptual design, logical design and physical design. The objective of the database was to illustrate how GIS software functions. GIS was used to gather data from water quality tests, design and develop geographic databases, establish and manage GIS workspaces, update and compile data, design database and map water quality locations, query water quality data, and analyzed water quality data.

After the ground WQI value for each river were calculated by using the Weighted Arithmetic Index method, then the ground water quality is obtained creating the attribute database for the study. Figure 1 showed the map of Sungai Benut, Simpang Renggam as a result from spatial data. For the generation of spatial distribution maps of all the water quality parameters, all 3 including the WQI map, the spatial and non-spatial (attributes) data bases are combined. The first step was right click on the sampling stations layer > open properties and choose diagrams > right click on every parameter > apply. Figure 2 showed the selection of water parameters.

Next, Figure 3 displayed the frequency distribution of water quality parameters of Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO), Total Suspended Solids (TSS), Ammonia Nitrogen (NH_3) and Acidic and Alkaline(pH), and for the 3rd observation because it had the highest concentrations of COD among the 1st and 2nd take while Figure 4 was the attribute data of water quality for the 3rd observation. To display the attribute data, right click > open attribute table and check the entered data was correct.

Figure 1: Map of Sungai Benut, Simpang Renggam

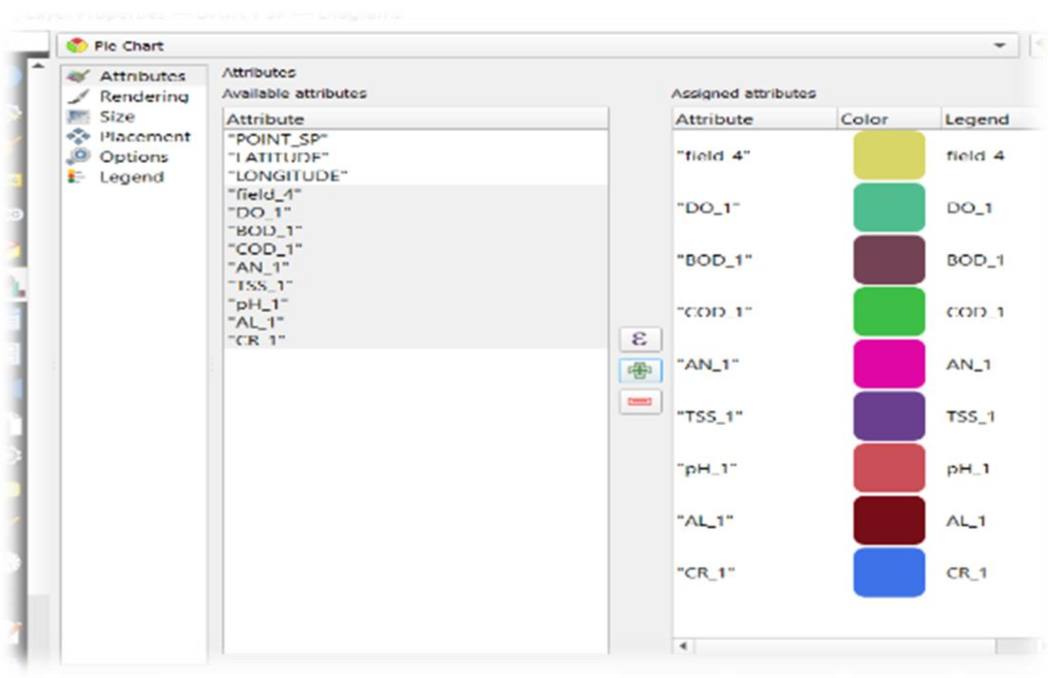

Figure 2: Selection of Water Quality Parameters

Next, Figure 3 displayed the frequency distribution of water quality parameters of Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO), Total Suspended Solids (TSS), Ammonia Nitrogen (NH_3) and Acidic and Alkaline(pH), and for the 3rd observation because it had the highest concentrations of COD among the 1st and 2nd take while Figure 4 was the attribute data of water quality for the 3rd observation. To display the attribute data, right click > open attribute table and check the entered data was correct.

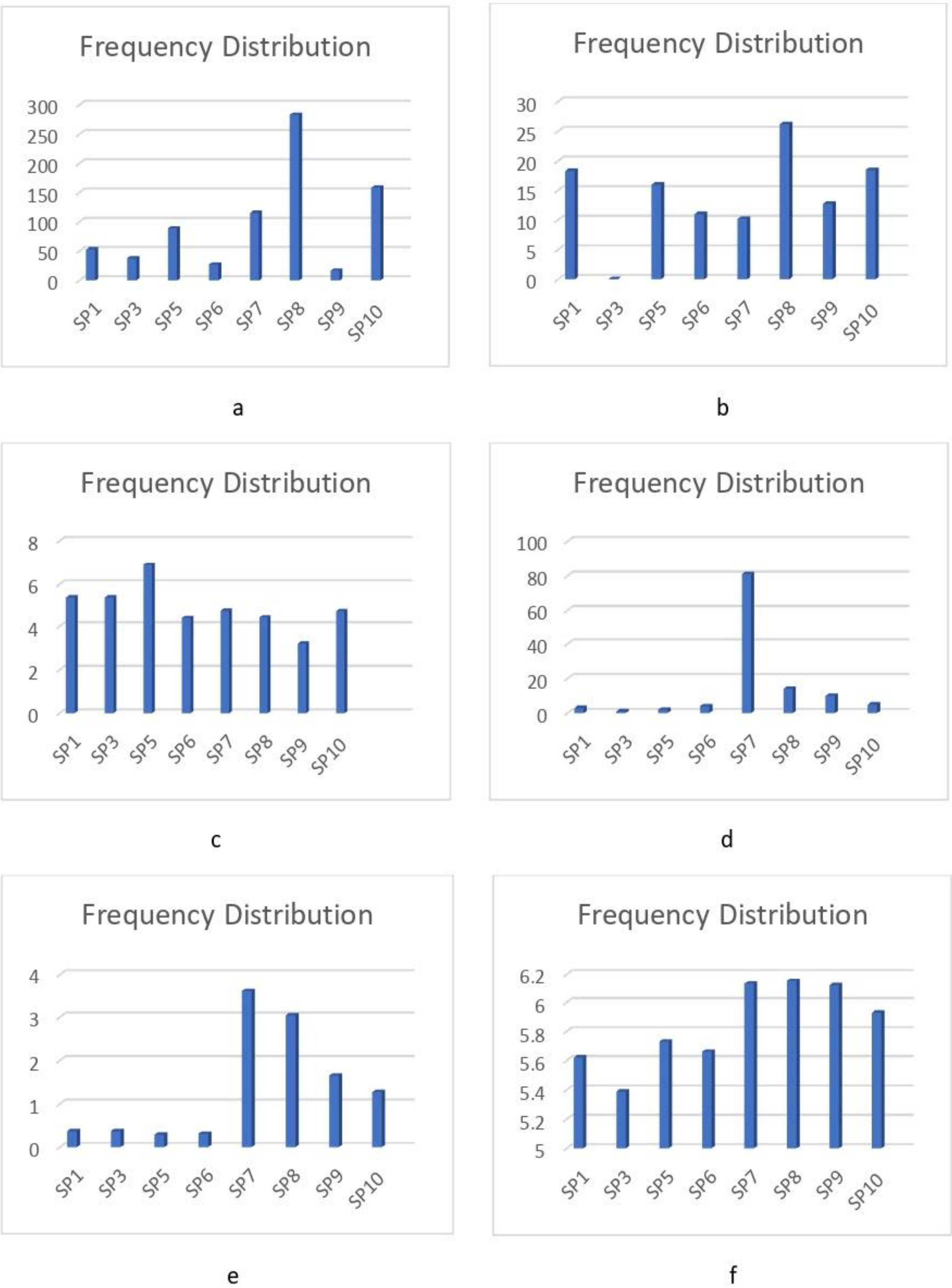

Figure 3: Frequency Distribution of Parameters; a) COD; b) BOD; c) DO; d) TSS; e) AN; f) pH on 3rd Observation

DATA 3 SP (1.10.19) — Features Total: 8, Filtered: 8, Selected: 0

	POINT_SP	LATITUDE	LONGITUDE	field_4	DO_3	BOD_3	COD_3	AN_3	TSS_3	pH_3	WQI_3	WAI_3
1	SP10	1.82618	103.29612	NULL	4.75	18.5	158.7	1.27	5	5.93	40.69	60.37
2	SP9	1.83316	103.30208	NULL	3.2	12.7	16.7	1.65	10	6.12	53.52	54.44
3	SP6	1.83028	103.29746	NULL	4.39	11	27.3	0.31	4	5.66	57.49	38.13
4	SP5	1.85837	103.29419	NULL	6.9	16	89.3	0.29	2	5.73	48.1	48.36
5	SP8	1.8437	103.34343	NULL	4.41	26.2	283.3	3.04	14	6.15	28.51	94.77
6	SP7	1.89295	103.36515	NULL	4.77	10.2	115.3	3.6	81	6.13	30.05	89.74
7	SP3	1.87338	103.27816	NULL	5.39	0	37.7	0.37	1	5.39	63.12	35.14
8	SP1	1.8882	103.2766	NULL	5.39	18.3	52.7	0.37	3	5.62	49.6	48.5

Figure 4: Attribute Data of Water Quality for the 3rd Observation.

3. Results and Discussion

Using the Figure 3 and 4 as a guide, it was readily apparent that the highest concentration was COD ranged from 16.7 – 283.3 mg/L then come BOD, which varies greatly from 0.0 – 26.2 mg/L followed by TSS with a range of 1.0 – 81.0 mg/L. According to the third river assessment conducted in wet condition using the 3 top parameters of COD, BOD and TSS, station 8 was evaluated as the worst station in terms of water quality with 283.3 mg/L, 26.2 mg/L and 14.0 mg/L subsequently. By using the Table 1 and 2 as a point of reference, the station was graded as polluted (28.51) and poor (94.77) based on the WQI-WAI calculated where the concentration of COD affected the grading greatly.

Next, station 7 was evaluated as the second-worst station evaluated due to the value of WQI-WAI graded the river as polluted and good with 35.05mg/L and 89.74 mg/L accordingly. Thus, these parameters showed that the higher concentration of COD, the higher pollution in water because the similarity in both stations was from their high concentration of COD. In addition, the concentration from other parameters also affected the grading of stations since station 8 had high concentration of BOD but with low concentration of TSS and the vice versa for station 7.

Other water quality parameters such as DO and AN were in range as provided by the INWQS for drinking except than the concentration of AN for station 7 and 8 which exceed the limit of 2.7 mg/L with 3.60 mg/L and 3.04 mg/L correspondingly. In the final analysis, station 3 was evaluated as the most suitable for drinking purposes since the WQI-WAI graded the station as excellent and slightly polluted with 35.14 mg/L and 63.12 mg/L respectively. This is due to low concentration of COD, DO, AN and TSS while no reading recorded for BOD and in fact, pH (5.39) of the station was almost neutral therefore not much water quality treatment needed. As for the second least polluted station fall to the station 6 with graded of polluted and excellent by referring to the calculated WQI-WAI in Figure 4 because the concentration of COD affected the pollution greatly and in station 6 there was only 27.3 mg/L which is lower than station 1 but station 6 had BOD and other water quality were higher than station 1

After that, the average Water Quality Index (WQI) data was analyzed and then generated the mapping of pollution for station 1- 10. Based on the Figure 5, it was clear when comparing stations 8 and 7 which were both polluted with the other stations under slightly polluted category, the pollution level in station 8 and 7 were severed compared to the other stations. The pie chart stated that the yellow color indicated the station as slightlypolluted and the blue color as polluted, and the map presented the river along the station 8 and 7 were in blue color while the river along stations 1, 3, 5, 6, 9 and 10 were colored as yellow. Hence, the conclusion of station 8 and 7 as the polluted station between the others were accepted. Other than that, the other stations like stations 1, 3, 5, 6, 9 and 10 were slightly polluted with station3 as the least polluted with average WQI value of 62.39. Also from the Figure 5, it was clear to say that the station 3 was the first station in 'slightly polluted' class compared to the other stations that were in the same class.

In a nutshell, the analysis showed that the most polluted station has the value of WQI-WAI range of 26.36 – 129.79. Hence, the analysis showed that stations 3 as slightly polluted – excellent, next station 5 and station 6 as polluted – excellent, later station 9 and station 10 were polluted – good, and finally the grading of polluted- poor fall to station 1, station 7 and station 8.

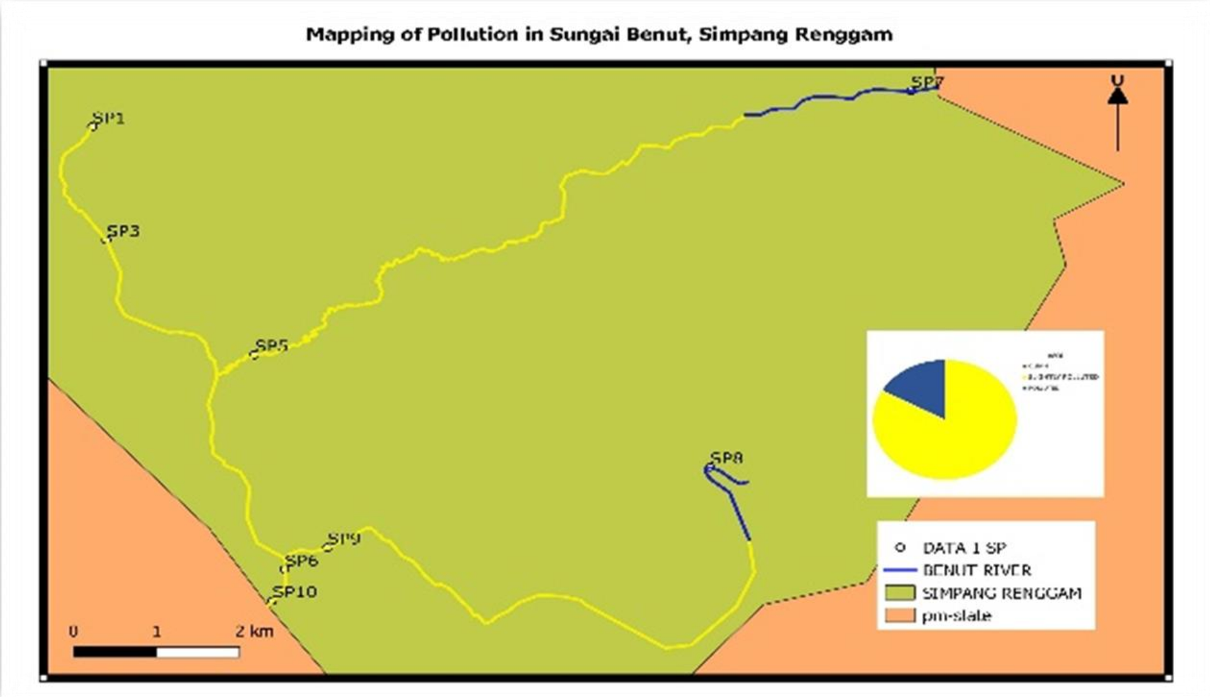

Figure 5: Mapping of Pollution in Sungai Benut, Simpang Renggam

4. Conclusion

The characterization and developing a database of Water Quality around Sungai Benut, Simpang Renggam were achieved where the level of pollution on 8 sampling stations stated that 1 station was categorized as slightly poor – excellent, 2 stations as polluted – excellent, 2 stations as polluted – good, 3 stations as polluted – poor based on the calculated WQI – WAI while no stations were categorized as unpolluted. All in all, can be concluded that Sungai Benut was severely polluted in few stations but still polluted at every stations. In closing, GIS is a suitable and excellent tool to help in determining the water quality of study area by generating the map and charts based on the parameter provided from the data collected either in-situ or laboratory test. In addition, GIS can also be used to monitor the natural environment and managing water resources on a large scale, as well as analysis the contamination risk of water. Basically, the objectives of this study were achieved but for better results, more attention should be given to all factors to improve this study as they may have a better possible outcome. Some of the recommendation that can be done based on the findings of this research:

i. Collect the data in wet condition because the pollutants will spread more throughout the water therefore accurate concentration of water quality parameters can be recorded.

ii. Collect the data every year to see the graph changing from year to year thus planning to manage and treat the water can be done effectively.

iii. Add few stations from the existing stations to collect the data in order to get even accurate conclusion on evaluating the study area

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