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The Effect of Peat Soil on Shallow Groundwater Quality in Parit Nipah, Batu Pahat

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Abstract: Groundwater is potential for immense pollution from soil leachates of agricultures, thus drastically increase the ions and trace mineral concentrations of the water body. Many people have used groundwater as one of their main sources of water and using them directly without any thought of filtering and processing. As the concerned of pollutant from human activities around Parit Nipah, Batu Pahat to contaminate the shallow groundwater below the peatland has become an inspiration to this study. There are mainly 2 objectives that are to be achieve, which is to determine the classification of shallow groundwater quality in terms of Cation and Anion and classify the types of the groundwater by using Piper Diagram approach. In this study, a series of laboratory test such as Atomic Absorption Spectrometer (AAS), Ion Chromatography (IC) and Water Quality testing such as temperature, pH and Dissolved Oxygen (DO) are done throughout the study. Analysis of the laboratory data are then evaluated using classifications of water quality and types of groundwater based on Malaysia Ground Water Quality Standards (MGWQS), Interim National Water Quality Standards (INWQS) and plotting of Piper Diagram. From the data collected, the current state of the shallow well water was found strongly affected by the surrounding peat soil as results of the groundwater shows chemically and physically close to the characteristics of the soil itself. The plotting of Piper Diagram shows that the groundwater type of Parit Nipah area as mixed type water with bias to Sodium-Chloride type (Na-Cl waters). Meanwhile from water quality parameter obtained, the sampled groundwater is classified as Class III based on the INWQS and permissible or safe to use according to MGWQS, whereas the water is suitable for agricultural, and livestock use and considered safe for human skin contact

Keywords: Shallow Groundwater, Peatland, Piper Diagram, Water Quality

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1. Introduction

Water has many uses including agriculture, irrigation, drinking, generating energy, recreation, domestic uses and many more to come. As multipurpose it can be, water served as an important factor in human lives to survive. Clean and pure water are essential to promise a better future in various of aspect especially in health and wellbeing [1]. Groundwater is one of the water sources that is protected by nature and layers of strata from any harmful pollutants, thus, act as a pure and clean aquatic source for human's use. Before realizing groundwater is potential for immense pollution from soil leachates of agricultures, toxic from industrial waste, thus contributing to an increase in ion and trace mineral concentrations, many people have used groundwater as one of their main sources of water and using them directly without any thought of filtering and processing [2]. In the year of 1970 to 1990, massive development has existed in order to extract groundwater for human and industrialized purposes. Although the exploration of groundwater has been discovered as early as civilization starts, as social and economic demand increase, industrialization era has suddenly affected the quality of groundwater and degrading them [2].

In past studies related to investigation of groundwater quality, the utilization of Piper Diagram method is considered as one of the oldest techniques used to assess the preposition and characteristic of the investigated groundwater. The Piper Diagram approach has been carried out by Arthur M. Piper where this technique suggested an effective visual approach in 1944 in sorting key analytical data in order to identify the origins of dissolved elements in water. From Piper's research, this method was created with basis of cations and anions are in chemical equilibrium in most natural waters. the Piper Diagram approach that was invented, are capable of proving the attributes and types of the water source analyzed [3]. Piper Diagram approach in use to analyze types of groundwater has also been utilized by other past research such as in central and south-eastern parts of Romania for irrigation purposes where in this study proved that Piper Diagram is suitable to use as a standard benchmark in determining groundwater quality through dissolved chemical concentrations [4].

Parit Nipah, is one of the peatland areas in Batu Pahat that are frequently selected to conduct studies of the peat soil [5]. In Parit Nipah, the type of industry present is palm oil, pineapple plantation and small local farm. According to past researchers, the depth of peatlands at the area is only 4 meters deep until it reaches the clay layer [5]. This 4-meter depth also represent middle deep of the peatland. Through those layers of peat soils, the hydraulic conductivity is increasing proportional to the depth of the soil. This means, the deeper the soil, the easier the water can pass through the peat and further contribute to the groundwater [6]. The concerned of pollutant from human activities around Parit Nipah, Batu Pahat to contaminate the shallow groundwater below the peatland has become an inspiration to start this study. Vast palm oil and pineapple plantation existed in the area and have contributed heavy metal pollutants from fertilizers and pesticides that may give negative impact of the water table quality. Determination of water quality status and types of groundwater is important as local residents use well-water as their source of water for daily basis, particularly for agriculture. Contaminated water table below the peatlands will cause not only harm to human body and health, but also can affect aquatic ecosystem around the area.

2. Groundwater in Peat Soil Areas

Peat is the accumulation of undecomposed and decomposed organic soils that were developed through many years to achieve layers of plant deposits. In peat soils, the decomposition goes through a slow anaerobic process. This is possible due to constant submerge of the soil to the water table and consequently create an environment which contains lack of oxygen to supporting in the rapid decay activity [7], [8]. According to past researchers, the depth of peatlands at the area is only 4 meters deep until it reaches the clay layer [5]. This 4-meter depth also represent middle deep of the peatland. Through those layers of peat soils, the hydraulic conductivity is increasing proportional to the depth of the soil. This means, the deeper the soil, the easier the water can pass through the peat and further contribute to the groundwater. Generally, the moisture content of the peat soil in Johor is recognized between 150 to 700 % [6]. The peat soil pH is highly likely to be acidic (around pH 3 to 5) as proven by past studies [5], [9]. Other properties such as high compressibility, high organic contents, low shear strength, low permeability rate and high-water retention are also considered as a contributing factor in this research [10].

Point sources from urbanization and industrial wastewater that incorporates dangerous microbes, detergents and industrial chemicals to groundwater reservoirs, as well as non-point sources such as the use of fertilizers and pesticides in agricultural sector, are major risks to groundwater health [11]. Water supply stability is essential to meet the demands of an expanding population, manufacturing, and agriculture fields. As an alternative to water supply system in case of excessive pollution and shortage of surface water, groundwater would be the solution to cater every water needs in Malaysia. Groundwater is significant and could be a good and cost-effective alternative source of freshwater [12]. However, groundwater on the other hand, also faces a number of natural and anthropogenic concerns, as well as the implications of increase in sea levels and changes in hydrologic regime that are linked with global warming that would deteriorate the coastal groundwater's quality [13].

3. Materials and Methods

The aim of this research is involving the study of well water surrounded by peat soils located at Parit Nipah, Batu Pahat. In order to determine the current water quality status and types of groundwater below the peatlands, on-site field test will be conducted to obtain water quality parameter such as temperature, pH and Dissolved Oxygen (DO). Laboratory test that includes the Atomic Absorption Spectrometer (AAS) and Ion Chromatography (IC) testing will also be performed in this study to collect concentration of Calcium ion, Magnesium ion, Sodium ion, Potassium ion ($Ca^{+}, Mg^{2+}, Na^{+}, K^{+}$) and Sulphate ion, Chloride ion, Bicarbonate ion, Carbonate ion ($SO_4^{2-}, Cl^{-},\ HCO_3^{-} + CO_3^{-}$), which is the Cations and Anions, respectively. Then, technical methods such as water quality classification based on Interim National Water Quality Standards (INWQS) and plotting of Piper Diagram will be performed throughout this study.

Throughout this study, selected water quality parameters such as temperature, pH and Dissolved Oxygen (DO) are tested through parameter tool immediately in the laboratory. Next for the laboratory testing, well water that were collected and preserved, are evaluated through Atomic Absorption Spectrometer (AAS) and Ion Chromatography (IC) to measure the Cation and Anion of the groundwater. The well water sampling and preservation, as well as in-situ and laboratory testing are done according to APHA 2017 standards.

2.1 Tools and Equipment

In this study, the tools and equipment used are mainly the tools that are to prepare the samples before experimenting with AAS and IC equipment. Before proceeding to use AAS Perkin Elmer Model AA 800 and Dionex, Model ICS 2000, filtration and dilution process are needed to be done, in which several laboratory tools are necessary. The tools used in filtration process are:

- Grade 5 filter paper
- Funnel
- Conical flask
- Beaker
- HDPE bottles

Whereas, for dilution process the tools needed are:

- Ultra-Pure Water (UPW)
- Volumetric flask
- Beaker
- Pipette
- Dropper

During the water quality testing, the equipment used for the experiment are mainly parameter tools, which is the Eutech DO 450 Handheld and Eutech pH 2700 Benchtop Meters. There are no additional apparatus and tools needed as the equipment is readily set up in the laboratory to use.

2.2 Methods

In this study, throughout sampling and preservation activity, the method used is based on APHA [14]. During the sampling and preservation of the groundwater, the sampling container used is readily rinsed distilled water High-density polyethylene (HDPE) plastic bottles as recommended by the standards. The distilled water was rinsed at the inside and outside, as well as the mouth of the container and the lids.

Before taking the well water for sampling, each of the sampling container were rinsed thoroughly with the well water by bottling it for 2 – 3 minutes and poured out afterwards. To minimize any sediments or solids to mixed up freely, the well water from the bottle were dumped outside of the well while discarding. Then, after taking the water samples for storage and laboratory use, each of the water samples were taken by an interval 10 to 15 minutes.

As for the analyzation of cations and anions obtained by laboratory testing through IC and AAS, the Piper Diagram approach is utilized, where a group of cations and anions were calculated and plotted onto the Piper graph manually to determine types of groundwater present below the peatland [3].

3.3 Equations

In this section, all formulae used during the calculation for Piper Diagram plotting are listed here. In order to calculate the concentrations of cations and anions, the formula used are the same, meanwhile, to obtain concentration of Bicarbonate and Carbonate ions or alkalinity, different equations are applied.

Equations for obtaining concentration of cations and anions are:

$$Average\ Formula = \frac{Total\ Sum\ of\ All\ Numbers}{Number\ of\ Item\ in\ the\ Set}\ , where\ ;\ Average = \frac{(a_1+a_2+\cdots+a_n)}{n} \quad Eq. 1$$

$$Concentration\ of\ Ions\ = \frac{Avg.\ Conc\ of\ Ions\ (in\ ppm\ ormg/L)}{1000} \times \frac{Value\ of\ Oxidation\ States}{Atomic\ Mass\ of\ Element} \quad Eq. 2$$

$$Ions\ (\%) = \frac{Calculated\ Concentration\ of\ Ions\ (in\ Equivalent\ /\ Liter)}{Summation\ of\ all\ \ cations/anions\ (in\ \ Equivalent/Liter)} \times 100\% \quad Eq. 3$$

Equations for obtaining concentration of alkalinity are:

$$Sum\ of\ Cations\ [+ve\ charged\ ions] = Sum\ of\ Anions\ [-ve\ charged\ ions]$$
$$Na^{+} + Ca^{2+} + Mg^{2+} + K^{+} = Cl^{-} + NO_3^{-} + [HCO_3^{-} + CO_3^{-}]\ or\ [Alkalinity] \quad Eq. 4$$

Where the alkalinity can be obtained in ppm or mg/L after rearranging the equilibrium equation.

4. Results and Discussion

After all analysis and discussions are complete, it can overall be decided that the data represented has achieve its target objective. The objective of this study is to determine the chemical and physical properties of the water table below the peatsoil/mire conditions area by analyzing the major ions using piper diagram, as well as determining the water quality parameter. In this section, data presentation and outcome of Piper Diagram plotting are explained, as well as justified.

4.1 Results

From Table 1 shown, the value of Potassium is the highest of all the concentration of ions obtained. Of all the 3 readings, the Potassium ions was found the highest during the third sampling data, with the value of 19.61 mg/L and lowest during the first sampling data, which has the value of 16.97 mg/L. From observation on site, this has happened as chemical fertilizers are used around the time of third sampling data was taken. This justification is similar to past studies, where the concentration of Potassium fluctuates with the use of both organic and chemical fertilizer [15]. The data also represent the lowest ionic concentration, which is the Magnesium Ions, where the lowest ionic value falls under first sampling data as 2.56 mg/L and with the highest value for Magnesium concentrations as 3.25 mg/L during the third sampling data. The reason behind the low value of this ionic concentration is because Magnesium is commonly accumulated in proportion with depth of the soil. As the study are done within top-soil areas, the magnesium levels are found in little amount. The statement is parallel to the discovery in past study where source and conductivity of Magnesium within levels in soils are reviewed [16]. Of all the ionic value obtained and presented, based on MGWQS, it can be found that all of the ionic concentration passed the permissible level for agriculture use except for Potassium ions, which exceeds the permissible value of 12 mg/L [17].

From the water quality measured, all the collected pH value of the groundwater is acidic as the value befalls below the neutral indicator value ($pH < 7$). This data indicates that the groundwater is strongly affected by the peat soil of around the sampling area. The low pH value indicates that the groundwater is acidic as to the influence of the surrounding peat soil, which are naturally high in acidity due to the decomposition of organic matter. In past research, where the physical properties such as acidity, electrical conductivity, concentration of Calcium and total major nutrients (N, P and K) are influence by the habitat condition of mire [18]. As for DO value, based on Interim National Water Quality Standards (INWQS) table, the average class for DO value can be classified as Class III where the water conditions can be tolerably inhibited with organisms and be used as water sources to agriculture and livestock drinking although is needed several water treatments if the sources are used for human consumptions [19].

4.2 Tables

From both water quality parameter and geo-chemical parameter obtained, the values and end results are also partially influenced by the weather during at least 2 days before the sampling is taken according to the APHA [20]. As for the 3-sampling data collected, the groundwater samples were taken during early of November, end of November and early of December respectively, on site for laboratory testing.

The first sampling data were taken in hot and dry weather. Meanwhile, second sampling were taken in dry and cloudy weather and lastly the third sampling data was collected during damp and rainy weather. Hot and dry weather are potential in exacerbating saltwater intrusion activity, as well as increasing oxygen demand and increasing concentration of acidity in acidic water body. While, in damp and rainy season promote decrease in water temperature, increase in surface runoff that can lead to increase of chemical infiltration to the groundwater, thus justifying the increase value of magnesium and potassium ion in the third reading, where the condition was raining [21].

The data were obtained, analyzed and calculated can be referred in Table 1 below, where the cations, anions and selected water quality parameter are resulted from the laboratory experiments. From the analyzation, the water quality status of the groundwater was determined based on INWQS and MGWQS.

Table 1: Result Data of Groundwater Sampling

No.	Measurement (Units)	Sampling Data	Values	Water Quality Standard [19], [22]
1	Dissolved Oxygen (mg/L)	First	4.37	Class III
		Second	4.30	
		Third	4.22	
		Average	4.30	
2	pH	First	4.30	Below Permissible Level
		Second	4.15	
		Third	3.98	
		Average	4.14	
3	Temperature (°C)	First	29.50	Natural level
		Second	30.34	
		Third	29.64	
		Average	29.83	
4	Magnesium (mg/L)	First	2.56	Permissible
		Second	3.15	
		Third	3.25	
		Average	2.99	
5	Calcium (mg/L)	First	5.85	Permissible
		Second	6.52	
		Third	5.76	
		Average	6.04	
6	Sodium (mg/L)	First	5.59	Permissible
		Second	6.06	
		Third	6.61	
		Average	6.09	
7	Potassium (mg/L)	First	16.97	Exceeds Permissible Level
		Second	19.09	
		Third	19.61	
		Average	18.56	
8	Bicarbonate (mg/L)	First	12.42	Permissible
		Second	12.42	
		Third	13.87	
		Average	12.90	
9	Sulphate (mg/L)	First	14.02	Permissible
		Second	12.67	
		Third	14.08	
		Average	13.59	
10	Chloride	First	9.71	Permissible
		Second	9.27	
		Third	7.27	
		Average	8.75	

4.3 Figures

Using the concentration of ions data listed in Table 1, Piper Diagram of three sampling data was plotted as shown in Figure 1. The comparison of patterns and trends of the data can clearly be seen on the graph, thus presenting the type of groundwater for each sampling data that has been charted.

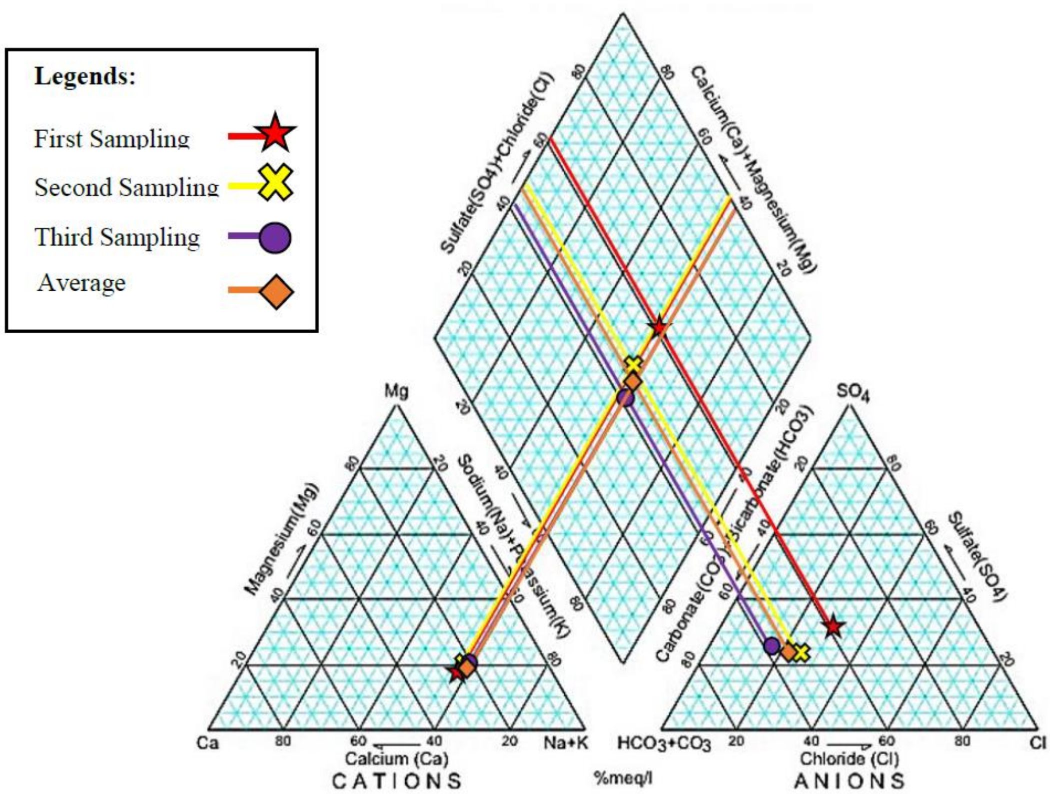

Figure 1: Sampling Data Analysis using Piper Diagram

From the data plotted in graph based on Figure 1, the average sampling data is taken as to compared from other data because of its accuracy of the value in representing the influence of peat soil to the water body within the area. In first sampling data, it is clearly shown that the major cations are Sodium and Potassium ($Na^{+} + K^{+}$). While, on the other hand, the major anions on the right-side of the graph are Carbonate and Bicarbonate ions ($HCO_3^{-} + CO_3^{-2}$). The ending result leads the plotting of the piper diagram to groundwater type of the first water sampling to be mixed type in meaning that the water body are characterized as typical shallow or fresh groundwater, with potential influence of ionic exchange as well as, it is also categorized as marine and deep ancient ground waters. However, by referring to the trend plotting in Figure 1, the water is also majorly dominant by marine water type as compared to others that has been mentioned before.

The answer that justifies that the groundwater shows a trend on Sodium-Chloride waters and Potassium as the major ions is due to the total contents of major nutrients of the peat soil are mainly from Nitrogen, Phosphorus and Potassium. According to past research, the chemical characteristics of the type of soil surrounding the water has influence that groundwater chemistry itself [18]. Another reason in justifying the contribution to groundwater types of well water in Parit Nipah is the probability of saltwater intrusion that has occur within the area. The distance between the sampling location and the nearest coastal area, is approximately 24 km away, whereas the saltwater penetration rate can reach up to around 160 km according to past research within Johor, which rationalize the possibility that the groundwater in Parit Nipah are influence by the saltwater along the coastlines [23].

As for the major ions in Anions, which is the Bicarbonate ions, the reaction that cause these ions to accumulate within the groundwater happened when the chemical interaction between calcium carbonates and mineral water occurs. These types of interaction come from the deposition of lime powder that was used in agriculture area within the sampling location [24].

Lime powder can also be added to water as a water treatment in adjusting pH levels for preparing optimum conditions in coagulating activity to take place. According to past research, it stated that lime powder are commonly utilized in water treatment process where lime can neutralize the acid water. Besides that, lime can also be used in aiding coagulating suspended solids, thus removing, or reducing turbidity from the raw water source [25].

3.5 Correlation Between Peat Soil and Groundwater

In past research, the peat soil in Parit Nipah is said to be 4 meters deep before reaching into clay layers. The 4 meters deep peat soil is categorized to be H3 in level of humidification and is fibric for the depth of 0-1.5 meters, whereas H4 and H5 level of humidification and hemic within depth 1.5-4.0 meters. During this discovery, it is also found that the shallow groundwater can be found during the 1.2 meter below the surface area, where the moisture content increases in proportion to depth. Meaning the deeper the peat soil, the higher the moisture content [5].

In correlation to the previous study on peat soil in Parit Nipah, the pH value of the Parit Nipah soil is ranged between 3.6 to 4.12, meanwhile the average pH value obtained from this study is 4.14, which is approximately the same levels as the previous peat soil research data [5]. The similarity of this value indicates that the peat soil are potential in influencing the shallow groundwater quality within the area [26], [27].

Next, the groundwater is also said to be closely affected by the peat soil condition as it is also high in water conductivity. As peat soil physical properties is high porosity and have good water absorption, this implies that the soil is also have high capability in holding much moisture and water. Peat soil, which are are high in porosity, increase the water conductivity, thus easily contributes any surface runoff to the shallow groundwater aquifers [5], [28], [29].

Lastly, in explanation of the outcome of Piper Diagram, where the average groundwater samples in Parit Nipah shows tendency in Sodium-Chloride (Na-Cl) water despite situated in within mixed type classification would be that the peatlands specifically in peninsular Malaysia are found within coastal areas in the East and West [5]. In justifying the contribution to groundwater types of well water in Parit Nipah is the probability of saltwater intrusion that has occur within the area, where the distance between the sampling location and the nearest coastal area, is approximately 24 km away, whereas the saltwater penetration rate can reach up to around 160 km [23].

5. Conclusion

In conclusion, the aim of this study has been accomplished as the result fulfil the objectives. Throughout this study, the laboratory testing and analysis has come out with the result that the groundwater type within the Parit Nipah location is mixed type, where the groundwater are also observed to be prone to Sodium-Chloride type. The investigated groundwater samples are presented Sodium and Potassium ($Na^+ + K^+$) as its major cation concentration and Bicarbonate and Carbonate ions ($HCO_3^- + CO_3^{-2}$) as its major anion concentration. The outcome of the studies shows strong relationship between the peat soil and the shallow groundwater in terms of geo-chemical analysis. Also in this study, the measured water quality parameter has summed up that the class of the groundwater quality is Class III according to INWQS, as well as permissible to use for agriculture according to MGWQS, where the water is suitable for agricultural and livestock use, as well as rated satisfactory in safety for direct human contact but still needs for intensive water treatment if intended for human consumption.

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