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Determination of Water Resources in Tube Well Using Hydrofacies for Riverbank Filtration

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Abstract: The reliability of water in riverbank filtration application is hard to be determined since the source of water and what happen at below ground cannot be see. These difficulties give effect for application of riverbank filtration since it is important in determination of its water quality and quantity. Due to that, this method was suggested to be used to determine the source of water in pumping well (PW) at Lubok Buntar, Kedah. The soil and water samples were taken from the PW and river water to determine the soil type and major ion (anion and cations). The results show that most of PW soil type is sandy loam (52%). Based on the piper diagram of the hydrofacies showed that the RW and PW were connected for a certain period of time. The most predominant cation in the PW was Na2+-CI-, consequently, the tube well water mostly came from groundwater rather than from river water. Therefore, this location is suitable for riverbank filtration applications as it has two reliable water sources. Due to that, for riverbank filtration water treatment, the river and groundwater water quality and quantity is important in order to make sure the system is reliable and sustainable.

Keywords: Riverbank filtration, hydrofacies, water resources, piper diagram, groundwater, geoenvironmental

1. Introduction

The riverbank filtration (RBF) system is a reliable water treatment which have large capacity of water and good water quality that can be abstracted in certain place. This is depending on four basic significant conditions that give affect the accomplishment of the RBF. They are mixing with natural underground water and source water quality, sediment permeability and spacing of wells and distance of the well from the riverbank as well as pumping rates [1]. The location of abstracted well need to be sited at suitable and strategic places. In order to decide the location of abstracted tube well for RBF, the first step to be taken is to determine the existence of connectivity between the river and aquifer [2]. There is a view method can be used such as pumping test method and resistivity. This method was required to pump the water from the abstracted well for only one to three days in order to measure the capacity of water and to determine the source of water either from groundwater or river. This method is quite expensive and seem it is not giving overall condition of water passage through year during rainy and drought season.

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In order to analyze the natural resources in RBF water that affect its quality it is significant to understand the hydrochemistry. Most of the countries that apply RBF show that the underground water course is connected to the alluvial soil aquifer. This would be the site of high-quality for drinking water production [3]. Usually, the water in the well close to the river is made up of river water and underground water. However, this condition those not follow all the time during pumping process. It is depending on type of soil aquifer in saturated zone either sand or clay which some circumstances there will most of the time groundwater is abstracted from the tube well rather than river water. when river water and groundwater flow past the saturated zone, this condition will dissolve the most important ions and total dissolved solids where it normally occurs here. The major ion variations in the following sequence results are shown in Eq. (1).

$$\begin{gathered} HCO_3^- \rightarrow HCO_3^- + SO_4^{2-} \rightarrow SO_4^{2-} + HCO_{3-} \rightarrow SO_4^{2-} + Cl^- \rightarrow Cl^- + SO_4^{2-} \rightarrow Cl^- \\ \text{Bicarbonate waters} \rightarrow \text{Sulphate waters} \rightarrow \text{Chloride waters} \end{gathered} \quad (1)$$

Close to the surface of the ground occurs bicarbonate water, while in the deeper geological layer occurs chloride water. Furthermore, at the lower strata occupy by water with high specific gravity have higher salinity. Hence, at shallow depth occur bicarbonate waters while transitional is of type sulphate waters [4]. To create a graphical image of groundwater hydrochemistry, there are actually a variety of techniques that can be used to depict water quality values. This study uses the piper diagram technique where it is currently widely used to show the main differences in hydrochemical elements between different water sources for groundwater and rivers [5]. In addition to being able to determine the relationship between other samples, the Piper diagram can also graphically show the properties of a given sample [6]. It can be used to understand various hydrochemical processes that affect the properties of these samples such as the occurrence of base cement contamination, salt water (end product water), blending of origin water, cation exchange, sulfate reduction, and various other important hydrochemical phenomena.

The Piper diagram consists of a diamond and two triangles which is anions (CO_3^{2-}, HCO_3^{2-}, Cl^- and SO_4^{2-}) are on the right while the cation (Na^+, K^+, Ca^{2+}, and Mg^{2+}) are plotted as a point on the left triangle as shown in Fig. 1. A point on the diamond is plotted where two lines intersect. The values are calculated as percentages of anions or cation in equivalent per litre [7]. These diamond diagrams show the different types of water. The top quadrant represents calcium sulphate water (gypsum groundwater and mine drainage), while the right quadrant shows sodium chloride water (marine and deep ancient groundwater). The left quadrant is calcium bicarbonate water (shallow fresh groundwater) and the bottom quadrant is sodium bicarbonate water (deep groundwater influenced by ion exchange).

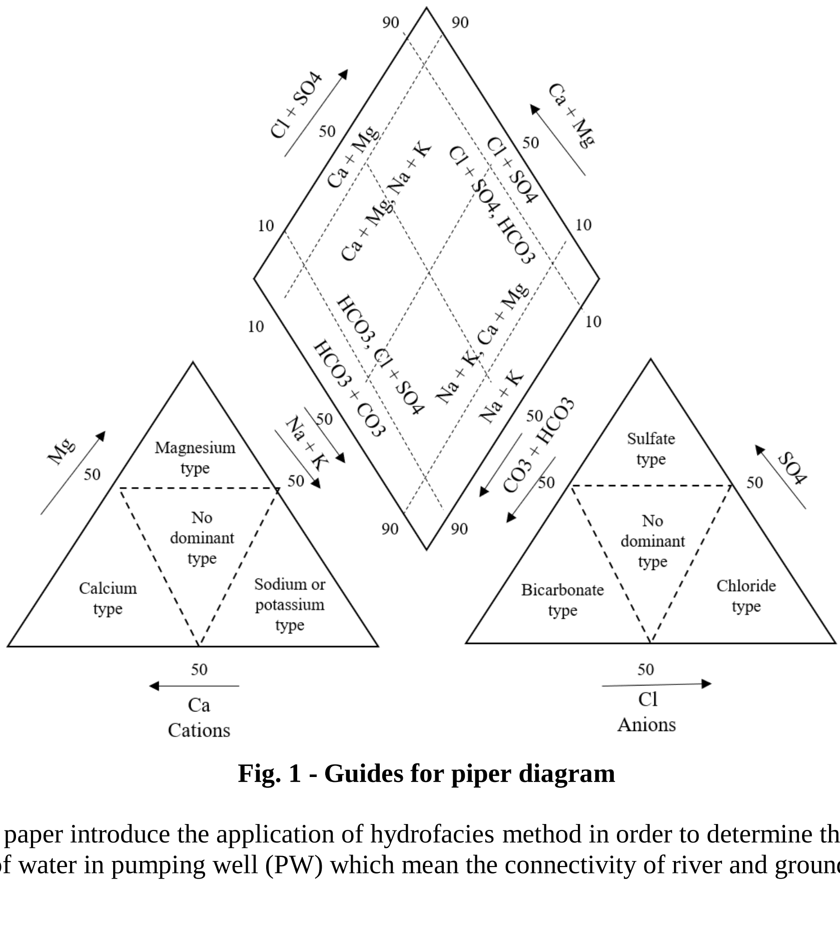

Fig. 1 - Guides for piper diagram

Due to that this paper introduce the application of hydrofacies method in order to determine the one year and half situation of source of water in pumping well (PW) which mean the connectivity of river and groundwater into the tube well for RBF application. The soil and water samples were taken from river and PW at Lubok Buntar, Kedah. By using the Aquachem 5.1 software, the main ion analyse data that has been obtained using the Ion Chromatography System (ICS) will be plotted as a piper diagram. Hydrofacies can help to give the overall water passage phenomena, which it can help to determine the reliable of water for riverbank filtration.

2. Methodology

2.1 Water Sampling

The PW and river water (RW) samples were collected from Sungai Kerian at Lubok Buntar, Kedah, Malaysia. It was obtained by using submersible pump (Model: OEM, serial no: 125QW1003596). In order to obtain a more representative sample of the actual condition of the aquifer, purging was carried out before sampling. The stagnant water residing in the tube well was removed using submersible pump and the amount being removed is three times the volume of the tube well column (6-10 m^3 due to fluctuate of water level), thus permitting the tube well to be fill up by water head-to-head formation and also riverbank filtrate. Due to several flooding incidents occurring at the study site, there were times when water samples could not be taken. This has extended the water intake period from April 2015 to September 2017 to meet 18 months of sampling. Fig. 2 shows the layout of the RBF area for RW sampling.

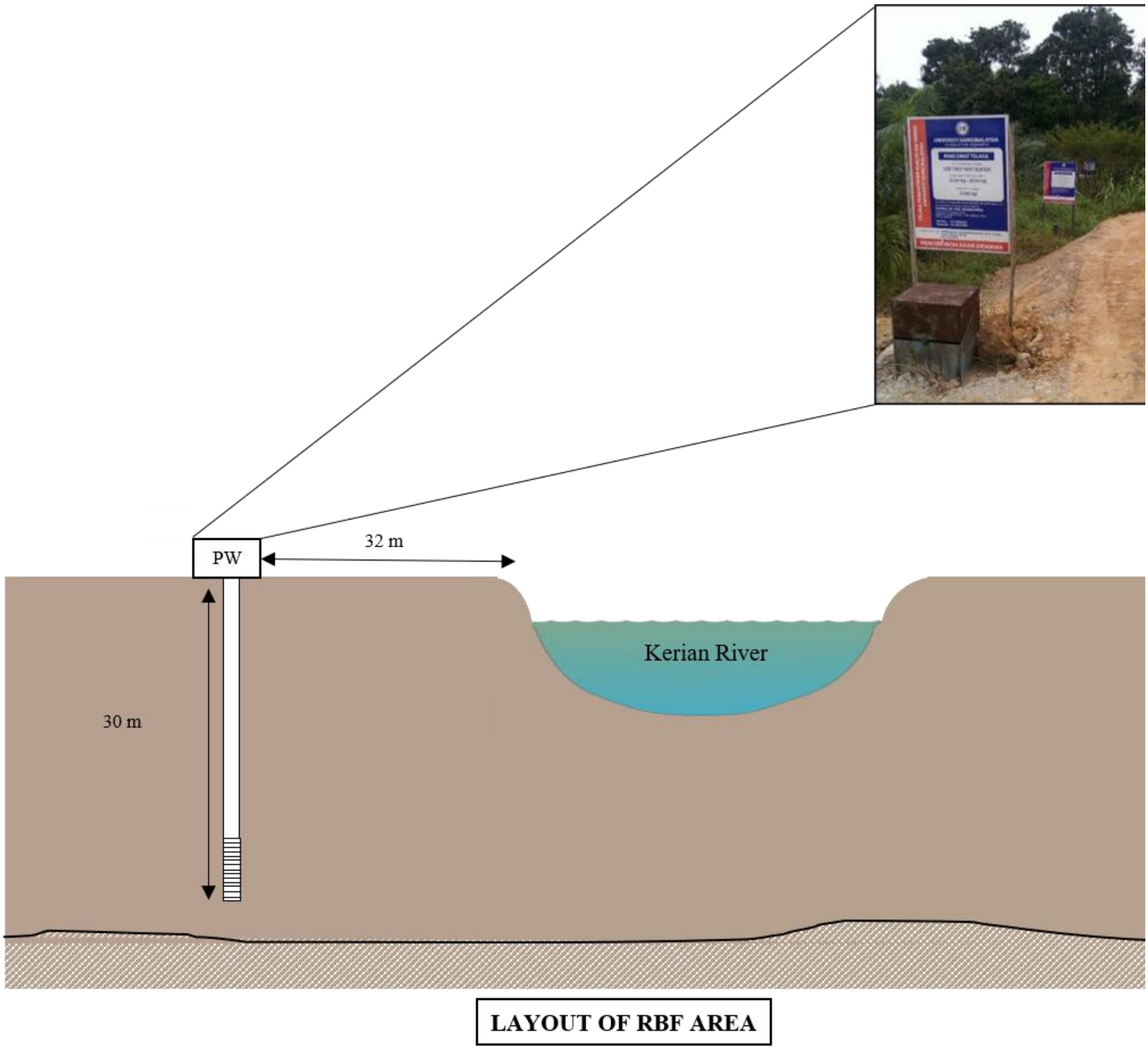

Fig. 2 - Tube well on the river band of Sungai Kerian at Lubok Buntar, Kedah

2.2 Soil Sampling

The soil samples were collected from borehole made for PW near the Sungai Kerian at Lubok Buntar, Kedah. The soil samples were collected using mould and borehole drilling machine as shown in Fig. 3(a) and Fig. 3(b). The depth of PW is 30 m with diameter 0.2m. The distance between PW and river is 32m. The soil sample was taken for each 1 m depth. The sample was taken to the Geotechnical Laboratory at Universiti Sains Malaysia to test soil particle size distribution (PSD) based ASTM D 2487-06 standard procedure. The result will be determined the soil type.

To ensure that the hydrogeological conditions at the study site can be studied accurately, laboratory tests for alluvial soil samples at the study site are very important. This is because with this the reaction of the removal of pollutants during the passage of underground water can be understood in a more accurate way. In fact, with this test we can determine the important properties of the soil in RBF, namely the permeability structure of the soil and the particle size distribution.

(a)

(b)

Fig. 3 - The; (a) borehole mould; (b) borehole drilling machine used for soil sampling

2.3 Measurement of Anions and Cations

In hydrochemistry methods, major ion (anion and cations) was measured by ICS as in Fig. 4. ICS integrated system basic IC 1100 was used to analyze the groundwater for the major ions value. The columns and Self Regenerating Suppressor columns were used in this equipment to detect cations Potassium (K^+), Magnesium (Mg^{2+}), Calcium (Ca^{2+}), Lithium (Li^+), Sodium (Na^+) and Ammonium (NH_4^+) and anions Nitric (NO^{3-}), Bromide (Br^-), Phosphate (PO^{4-}), Sulphate (SO_4^{-2}), Fluoride (F^-), Chloride (Cl^-) and Nitrate (NO^{2-}). This equipment consists of a high-pressure pump, a sample injector, a guard and separator column, a chemical suppressor, a liquid eluent, a conductivity cell and a data collection system. A standard solution was used to calibrate the ICS before running the samples. By comparing the figures gained from a sample found from a known standard, sample ions can be quantified and identified. Data collection systems, classically chromatographic run computer software which lead to in chromatograms (a plot of detector output vs time). Chromatography software convert each peak in the sample into result.

The AquaChem 5.1 software was used to analyze and interpret the hydrochemical results which is in a form of piper diagram. The two triangles consist in Piper diagram showed anions (CO_3^{2-}, HCO_3^{2-}, Cl^- and SO_4^{2-}) and cations (Na^+, K^+, Ca^{2+} and Mg^{2+}) values. As the result, the two lines which intersected will point on the diamond and shows the different water types.

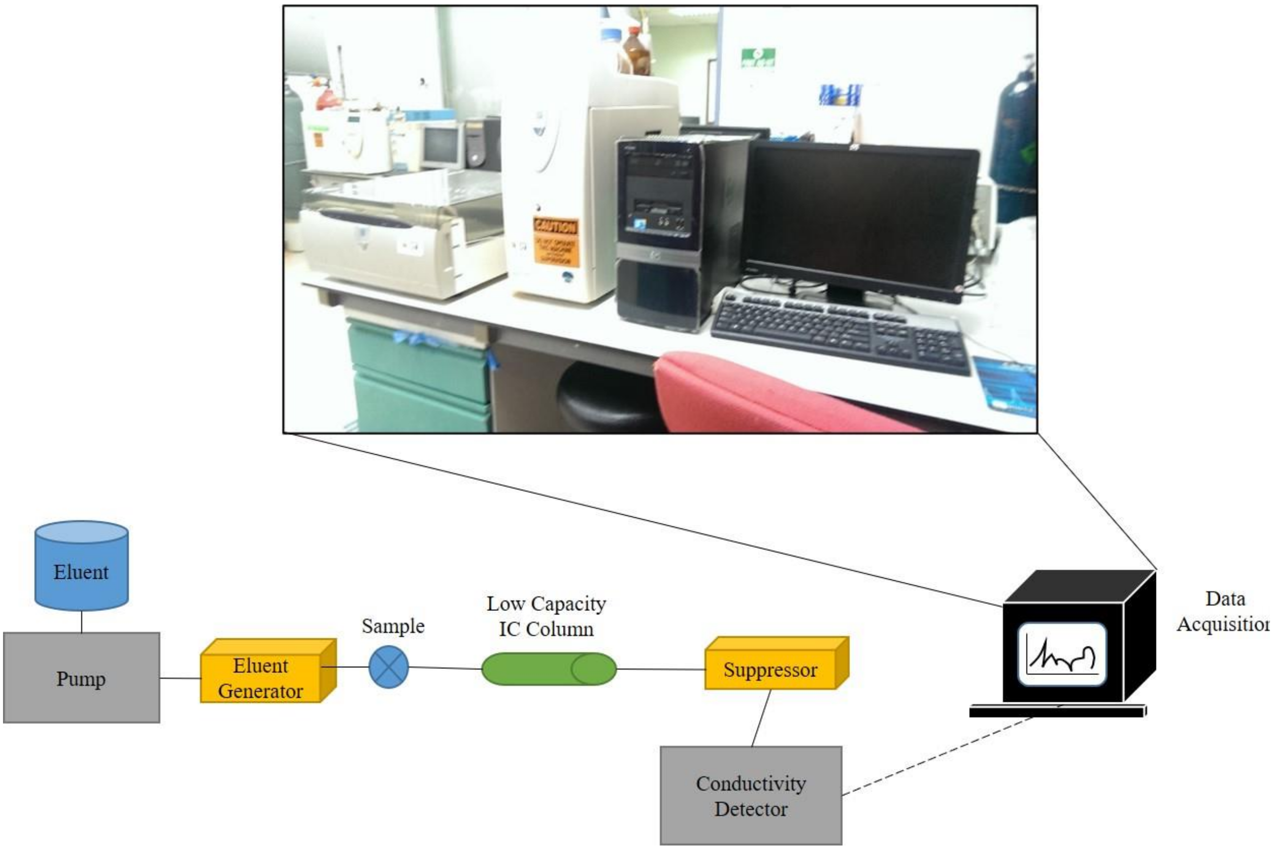

Fig. 4 - Ion Chromatography System (ICS) integrated system basic IC 1100

3. Results and Discussion

3.1 Soil Analysis

The particle size distribution result for all soil samples each meters shows that the soil type of that level and summarize in Table 1. Most of the soil sample in the tube well is sandy loam (52%) which is similar with result found by Ghazali et al. [8]. Based on Rashid et al. [9] stated that to support dynamic performance of the RBF system the sites selected for RBF abstraction will need to show well graded of sand. So that it can provide consistently high removal of pollutants over a long period. The permeability is classified as low according to the most soil type sample [10].

Table 1 - Summary of soil type for each meter from PSD curve

Soil layer at Meter	Type of soil (Result from PSD curve)	Percentage (%)
1-3 m	Sandy clay loam	9
4-5 m	Clay	6
6- 16 m	Sandy clay loam	33
17 - 33 m	Sandy loam	52

3.2 Hydrofacies of Well Water Samples

The ion analysis was displayed via a Piper diagram. Fig. 5 shows the Piper diagram for the 18 sampling points of the Lubok Buntar PW and RW. Two lines crossed was plotted from a point on the diamond. These points were projected on the diamond along outlines which were parallel to the sloping lines. The diagram was classified into 6 hydrochemical facies for RW and 7 hydrochemical facies types of PW based on the dominance of different anions and cations. Total of 11 hydrochemical facies were recognized as (i) Calcium-Magnesium facies, (ii) Calcium-Magnesium-Potassium-Sulfate-Bicarbonate facies, (iii) Sodium-Magnesium-Sulfate-Chloride facies, (iv) Sodium-Magnesium-Chloride facies, (v) Magnesium-Sulfate-Chloride facies, (vi) Sodium-Magnesium-Sulfate facies, (vii) Magnesium-Sodium-Bicarbonate-Chloride facies, (viii) Sodium-Magnesium-Sulfate-Bicarbonate facies, (ix) Potassium-Magnesium-Sodium-Chloride facies, (x) Sodium-Magnesium-Sulfate-Bicarbonate-Chloride facies, and (xi) Sodium-Magnesium-Potassium-Bicarbonate-Chloride facies water types. The visual images of the water classification showed that the PW and RW were linked for certain time period. The most predominant cation in the river was Ca^{2+}-SO_4^{2-}, typical of gypsum groundwater and mine drainage. In contrast, The Na^{2+}-Cl^- was dominant in PW, typical of deep ancient and marine groundwater. The tube well water mostly came from groundwater rather than from river water because of the depth of the tube well was 30 m. Based on the Chebotarev sequence assumption the results also concluded that the groundwater was very slow. This is in line with the results from the soil analysis in section 3.1 above. Chebotarev concluded that in intermediate geologic strata (slow flow) occurred the sulfate water, while in the deeper geologic layer (very slow flow) occurred chloride water. Meanwhile, bicarbonate water occurred close to the surface of the ground (rapid flow).

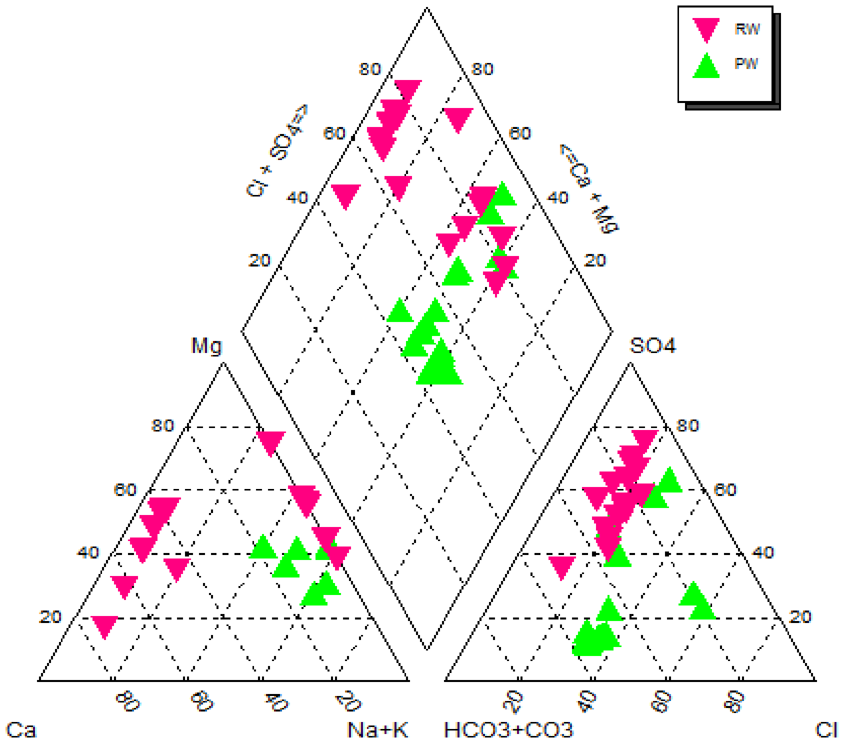

Fig. 5 - Piper diagram for RW and PW at Lubok Buntar, Kedah

The result shows similar research made by Mohamad et al. [11]. The research was made at RBF at Kuala Kangsar, Perak using Time - lapse Electrical Resistivity Imaging. It shows that there are no significant changes of hydraulic head can be seen after a few hours of pumping. In contrast, the major fluctuations of hydraulic head occur near the river towards the PW during the early pumping process. This shows that as the aquifer became steady, most of water in the PW originated from the groundwater. However, until the end of the pumping shows that this discharging and recharging is a nonstop progression and it continued. The results show the recharge zone became more intense, which the river water started to drift into the groundwater rapidly to re-establish the subsurface aquifer after end of the pumping test.

However, riverbank filtration sites in Europe showed that the water abstracted from tube well most of the time come from the river [12]. This is because the soil type at the Lubok Buntar and Kuala Kangsar are sandy loam and sandy silt. Due to that the permeability of soil is low compared to RBF in Europe. This condition promotes the groundwater to be filtrated more rather than river water which more far. This shows that the source of water in PW cannot be sustained either from river or groundwater, it depends on the situation. Due to that, in order to make sure the water quality for riverbank filtration water treatment, it is important to analysis both water quality river and groundwater so that the technology will be sustained and more reliable. Moreover, the application of artificial barrier can be the solution [13].

However, the knowledge contributing to water availability during drought-prone regions, excess nutrients, hypoxia, and extreme events is quite complex and challenging which requires community-wide efforts to address such challenges for water security [14].

4. Conclusion

The result shows that the RW and PW were connected for a certain period of time. However, most of the time the predominant cation in the PW was Na^{2+}-CI^{-}, consequently the abstracted water from PW most come from groundwater during one year and half at Lubok Buntar, Kedah. The result similar with other method used at particular place. However, this method simpler which we only need to take the water sample from the PW compared to Time - lapse Electrical Resistivity Imaging method. Most of soil sample in tube well was sandy loam (52%) and from that the permeability classified as low. The result in line with result using the Chebotarev sequence assumption. Hydrofacies can be used as one of method to determine the invisible of water flow in underground. This seems beneficial compared to old method which can be used as screening step in determination of suitable location of abstracted tube well for RBF or as monitoring step for RBF system for security and maintenance. This location is suitable for riverbank filtration applications as it has two reliable water sources. Due to that, for riverbank filtration water treatment, the river and groundwater water quality and quantity is important in order to make sure the system is reliable and sustainable.

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