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DESCRIPTIVE AND CORRELATION ANALYSIS OF IRON AND MANGANESE IN THE RIVERBANK SYSTEM

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ABSTRACT
An increase in river water toxicity and frequent water cuts are major concerns in Malaysia. Riverbank Filtration system (RBF) is a good alternative technology to improve raw water quality. However, high concentration of metals such as Iron (Fe) and manganese (Mn) in RBF is one of the main problems. This study analyses and compares the concentration of Fe and Mn in RBF and the Kerian River water using descriptive statistical analysis and Pearson Correlation analysis. The results show that the mean concentration of Fe and Mn is higher at the RBF pumping well with a mean value of 4.823 mg/l which is 96 % compared to the concentration of Fe in Kerian River (0.1708 mg/l). Meanwhile, Mn concentration in RBF pumping well is 0.1854 mg/l compared to the Kerian River water with Mn concentration of 0.00056 mg/l. The difference in the concentration is approximately 100%. Typically, the concentration of metals or minerals in groundwater is closely related to the type of soil in the area and hydro-geochemical activities in the location. In this study, the results prove that the concentration of Fe and Mn in RBF is higher than surface water which is highly connected to the soil layer in the study location. At the same time, the concentration of these elements in water exceeded the MOH standard for permissible drinking water standard which are Fe = 0.3 mg/l and Mn = 0.1 mg/l. From the Pearson Correlation analysis, it was found that Fe and Mn in both RBF and Kerian River have a strong correlation of ($R > 9.0$) indicating that the existence of Fe and Mn is highly influencing each other. Parameters such as EC, Turbidity, TSS and TDS moderately correlate with Fe and Mn and are within the ranges of ($0.3 < R < 0.7$) demonstrating that there is a higher influence on the other ions, minerals, and organic matter. In this study, the concentration of Fe and Mn exceeded the standard allowed by the Ministry of Health for drinking water, therefore, an additional treatment for Fe and Mn removal should be applied if the water from RBF is going to be used as drinking water.

Keywords:
Groundwater, RBF, Iron, Manganese, River water

INTRODUCTION

One of the major issues in Malaysia is the degradation of river water quality. Therefore, finding an alternate drinking water supply is critical as water resources are becoming difficult to treat due to flooding, pollution, and illegal dumping. Water disruptions from several water treatment plants have been a result of river pollution and industrialization (Khalid, 2018). Furthermore, most of Malaysia's present water treatment system is not equipped with a treatment technology to effectively remove dissolved inorganic and organic substances such as heavy metals and pesticides. The authorities that are responsible for water management find it difficult to overcome the challenges of providing access to safe and clean water. For that reason, Malaysia needs to improve the water infrastructure and not rely 98% on river water as the major source to obtain high-quality drinking water.

River Bank Filtration (RBF) technology can be an alternate source to obtain high-quality drinking water on a larger scale. RBF system is a form of water treatment process that uses simple technology to operate by extracting water from rivers by pumping wells. This system significantly improves the quality of surface water through natural chemical, physical, and biological processes. It has been used in Europe for over a century and countries such as America, and Canada; even some South American countries have been using this technology (Ray, 2002). According to the experience of these countries, the RBF system is capable of producing a high-quality water intake from the polluted river by going through natural filtration processes. However, this technology is considered relatively new in Malaysia and further understanding is required since the groundwater quality is dependent on the local soils and tends to carry high mineral content. Hence, there is a need to establish monitoring programs to oversee the water quality from the RBF.

The analysis made by previous research found that the concentrations of Fe and Mn are the most common contaminants found in the RBF system (Rashid & Abustan, 2020). This is a result of the geochemical activities within the soil layer which influence the concentration of Fe and Mn fluctuations in the groundwater. Fe and Mn are redox-sensitive minerals; therefore, a redox reaction plays an important role in the fluctuation of Fe and Mn level in the RBF system. The reduction and oxidation states along the flow path will increase and reduce the concentration of Fe and Mn in the water.

According to the Ministry of Health (MOH) Malaysia guidelines for drinking water, the permissible values for Fe and Mn in drinking water are 0.3 mg/l and 0.1 mg/l respectively. Long term consumption of metal-contaminated water poses a significant threat to the human body because of its bio-accumulative nature, persistence in the environment and toxicity (Alidadi, et al., 2019).
WHO guidelines, however, do not have any health-based guidelines for Fe levels. This was based on the view of Fe as an essential element for the survival and growth of plants, animals, and human life. This issue is of great concern, as Fe has been detected to be heavily abundant in the environment (Agoro, Adeniji, Adefisoye, & Okoh, 2020).

For Mn, the toxicology review by WHO, (2006) states that there is an association between the progressive increase of Mn-level concentrations and the progressive increase in the prevalence of the neurological effects as signs of chronic manganese poisoning. Based on these toxicity findings, several studies have argued the importance of reexamination of Mn (Frisbie et al., 2012).
Hence, this study analyzes the Fe and Mn concentrations in the RBF pumping well and the Kerian River in Malaysia, and compares the findings. Since Malaysia has plenty of rivers, the RBF system can easily be installed given the hydrogeological conditions and the water obtained from the RBF pumping well can produce high-quality water. Additionally, innovation in water treatment technologies helps to minimize the use of land, improve manufacturing capacity, is more cost-effective and decreases labor costs. The advancement and improvement of water treatment technologies are undeniably dependent on the declining condition of the water supply and the current demand for water over time because of population and business expansion (Huang et al., 2015). This study analyzes and compares the concentration of Fe and Mn at the RBF pumping well to the Kerian River. This study however does not use primary data. Therefore, there are limitations to this study where the study uses a specific sample size and parameters which means its findings cannot be generalized to other situations.

MATERIALS AND METHODS

Site Description

The Kerian River is located along the northern part of Malaysia that runs along the states of Penang, Kedah and Perak and flows into the straits of Malacca on the West Coast. The Kerian River has a length of 90 km and an area of 1,418 km^2, flat land with an elevation of 50 m above sea level and a relative relief of 1,525m. (National Water Resources Study Perak State Report, 2000). Thereby, knowledge in such relationships at a catchment scale across seasons is still lacking due to the large area and monitoring difficulties. Identifying the spatial and seasonal variability of land use impacts on water quality represents a significant challenge for understanding the land use impacts on water quality (Rodrigues, et al., 2018).

The weather in Malaysia is between 20 - 30 degrees on average, throughout the year; however, mountainous terrains experience colder temperatures. Malaysia experiences two monsoons, depending on the area, the south-west (Malacca Straits) experiences the monsoon from May to September and the north-east experiences it from November to March. Depending on the location of the study, the dataset varies depending on weather and seasonality in that period.

Data Analysis

A total of 20 data sets obtained from the RBF pumping well and Kerian River water (Ibrahim, 2018) were used for the descriptive statistic and correlation analysis in this study. The data was collected over a duration of five months from April to August 2015. The water samples collected had been properly preserved and tested according to the APHA 2005, American Public Health Association Standard Method for the Examination of Water and Wastewater. This study uses MS Excel to determine the descriptive analysis which includes mean, standard deviation, skewness, and kurtosis. Another analysis that was also used in this study is the Pearson correlation of regression analysis.

RESULTS AND DISCUSSION

Table 1 presents the results of descriptive analysis for RBF pumping well. The results show that the standard deviation (SD) for temperature, pH, and Mn is less than 1 (<1) indicating that the values are close to each other. Whereas Turbidity, Color, TDS, TSS and Fe are larger than 1 and less than 10 (1<x= parameter SD<10) indicating that the data fluctuates. The remaining parameter, Conductivity, which demonstrated SD greater than 10 (>10), means that the data points are spread out and inconsistent. The skewness value between -0.5 to 0.5 indicates that the distribution is approximately symmetrical for the parameters such as conductivity, Fe and Mn.

Table 1: Descriptive Analysis of the RBF Pumping Well

SN	Parameters	Unit	Counts	Mean	SD	Min.	Max.	Sum	Skewness	Kurtosis
1	Temperature	C	5	28.56	0.33	28.32	29.1	142.8	1.61	2.53
2	pH	-	5	6.5	0.196	6.2	6.74	32.5	-0.77	2.1
3	Conductivity	uS/cm	5	91.05	11.15	76.41	101.6	455.2	-0.47	-2.15
4	Turbidity	NTU	5	1.59	1.67	0.18	4.205	7.93	1.13	0.71
5	Color	PtCo	5	3.2	3.89	1	10	16	1.99	3.95
6	TDS	ppm	5	58.72	8.1	47.15	293.6	293.6	-0.74	-1.16
7	TSS	ppm	5	4.7	4.82	1	23.5	23.5	1.85	3.6
8	Fe	ppm	5	4.82	3.88	0.062	8.8	24.11	0.043	-2.27
9	Mn	ppm	5	0.19	0.155	0.0036	0.927	0.927	0.29	-1.21

The skewness value between −1 to – 0.5 and 0.5 to 1 exhibits by pH and TDS indicates that their distribution is moderately skewed. Lastly, the skewness value of parameters greater than (> -1,1) such as temperature, turbidity, color and TSS is positively skewed.

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In term of Kurtois, color and TSS of RBF pumping well water has a value greater than 3 (> 3) which show that the distribution is leptokurtic. On the other hand, parameters such as temperature, pH, conductivity, turbidity, TDS, Fe and Mn have the value of kurtosis of lesser than 3 (< 3), indicating that the distribution is platykurtic.

The descriptive analysis of Kerian River water is shown in Table 2. The standard deviation (SD) for temperature, pH, Fe and Mn is less than 1 (<1), which is close to zero indicating that the values are close to each other, whereas conductivity, color, TDS are greater than 1 and less than 10 (1<x= parameter SD<10) indicating that the data fluctuates. The remaining parameters such as Turbidity and TSS exhibit SD of greater than 10 (>10), which is high and shows that the data are spread out. The skewness value between -0.5 to 0.5 indicates that the distribution is approximately symmetrical, which are the parameters such as temperature, turbidity, and color. The skewness value between (−1 to – 0.5, 0.5 to 1) indicates that the distribution is moderately skewed for parameters such as pH, conductivity, TDS and TSS. Lastly, the skewness value of parameters greater than (> -1,1) such as Fe and Mn are positively skewed. Kurtosis value of greater than 3 (> 3) indicates that the distribution is leptokurtic for parameters such as Mn. Kurtosis value of less than 3 (< 3) indicates that the distribution is platykurtic for parameters such as temperature, pH, conductivity, turbidity, color, TDS, TSS and Fe.

Table 2: Descriptive Analysis of the Kerian River

SN	Parameters	Month Unit	Counts	Mean	SD	Min.	Max.	Sum	Skewness	Kurtosis
1	Temperature	C	5	28.0	0.78	27.1	28.85	140.01	-0.043	-2.63
2	pH	-	5	5.57	0.46	4.89	6.13	27.83	-0.52	0.81
3	Conductivity	uS/cm	5	37	5.24	30.35	44.9	185.1	0.55	1.73
4	Turbidity	NTU	5	80.17	17.8	59.3	103.6	400.85	0.27	-1.47
5	Color	PtCo	5	27.3	4.84	21	33	136.5	-0.13	-1.47
6	TDS	ppm	5	24.1	3.46	19.7	29.3	120.5	0.56	1.72
7	TSS	ppm	5	106.4	12.22	88	119	532	-0.77	0.32
8	Fe	ppm	5	0.171	0.25	0	0.567	0.852	1.38	0.76
9	Mn	ppm	5	0.00056	0.001	0	0.0028	0.0028	2.2361	5

From the results in Tables 1 and 2, it is clearly seen that Fe and Mn are both positively skewed from both locations. However, the same could not be said for kurtosis as the value at the pumping well shows a negative kurtosis while the Kerian river shows positive kurtosis. In contrast, both Fe and Mn possess a linear relationship with similar representation.

Pearson Correlation for Kerian River and RBF pumping well

The results for Pearson correlation analysis for the Kerian River and RBF pumping well are presented in Table 3. In this analysis, the relationship between Fe and Mn with other water quality parameters such as temperature, pH, EC, turbidity, colour, TDS and TSS were determined.

Table 3: Correlation Analysis for Kerian River and RBF pumping well

Kerian River	*Temperature*	*pH*	*EC*	*Turbidity*	*Color*	*TDS*	*TSS*	*Fe*	*Mn*
Fe	*0.293*	*0.238*	*0.481*	*0.363*	*-0.660*	*0.484*	*0.410*	*1.000*	
Mn	*0.608*	*0.301*	*0.094*	*0.372*	*-0.323*	*0.097*	*0.439*	*0.889*	*1.000*
RBF well	*Temperature*	*pH*	*EC*	*Turbidity*	*Color*	*TDS*	*TSS*	*Fe*	*Mn*
Fe	*-0.310*	*-0.175*	*0.587*	*0.300*	*0.723*	*0.538*	*0.519*	*1.000*	
Mn	*-0.183*	*-0.423*	*0.532*	*0.311*	*0.850*	*0.478*	*0.310*	*0.963*	*1.000*

According to the linear regression analysis for the Kerian River water in Table 3, Fe and Mn showed the strongest correlation with r = 0.889. The strong correlation demonstrated the highest influence of the parameter on each other. In this case, when the concentration of Fe is high, the concentration of Mn will be high. It can be said that 89% of the variation in Mn was influenced by Fe or vice versa. The relationship between Fe and colour is also significant with r = -0.723 indicating 72% of variation in colour in Kerian River water was influenced by the presence of Fe. However, the negative sign in the value insinuated a contrasting relationship where an increase of Fe in water will reduce the amount of colour. This finding is interesting because the result is opposite to the common understanding where iron is known to contribute to brownish colour in water. At the same time, Fe is also moderately correlated with EC (r = 0.481), TDS (r = 0.484), and TSS (r = 0.410). However, Mn in the Kerian River water is only highly correlated to Fe (r = 0.889) and moderately correlated to temperature (r = 0.608) and TSS (r = 0.439). The results also show that Mn presence in the water is not significantly influenced by pH, EC, colour, turbidity and TDS.

Similar to Kerian River water, Fe in RBF pumping well shows a high correlation to Mn (r = 0.963) and colour (r = 0.723). Contrarily, the relationship between Fe and colour in RBF pumping well is positively correlated which means an increase of Fe will also increase the colour. Besides that, the Fe is also moderately correlated with pH (-0.423), EC (r = 0.587), TDS (r = 0.538), and TSS (r = 0.519) but with a slightly higher correlation than the Kerian River water sample. On the other hand, temperature (-0.310), pH (r = -0.175), and turbidity (r = 0.300) show an insignificant relationship with Fe. Mn relationship with Fe (r = 0.963) and colour (r = 0.850) is highly correlated followed by pH (r = 0.81), EC (r = 0.532) and TDS (r = 0.478) with moderate correlation.

It can be seen from the regression correlation, Fe is not the factor that influenced colour in the Kerian River water but had a large influence in well water. This finding shows that the concentration of iron is mainly contributed by the presence of mineral in the existing soil which is complimented by the concentration of Fe presented in Table 1 and Table 2 respectively. In this case, Fe is typically carried into the pumping well during the natural filtration process from the river to the pumping well. Other than that, it can be concluded that in both RBF pumping well and Kerian River, Fe and Mn concentration has a strong positive correlation (i.e., they influence each other's concentrations). Meanwhile, the medium correlation between Fe and Mn with TDS and EC in RBF pumping well water also indicated high concentrations of minerals and ions present in the water (Nasir et al., 2019).

CONCLUSION

Statistical analysis has shown to be an important tool that is used to analyze the data. Using this tool helps to obtain a significant relationship between the Fe and Mn concentration pairing with different physical and chemical parameters of the water sample. This method of analysis has proven to be a significant approach to understanding the relationship between the variable and visualize the quality of the Kerian River and the pumping well water samples. River water quality is easily influenced by external factors such as surrounding activities and land use. On the contrary, well water is mainly influenced by the soil layer and mineral present in the soil. In this study, the water quality of Kerian River water quality improved in term of colour, turbidity and TSS after RBF but the higher concentration of Fe and Mn detected makes it less suitable to be used as drinking water without further treatment to reduce the concentration of Fe and Mn in the water.

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