

Investigating Groundwater Quality in the Flood Prone Neighborhood Area in Malaysia

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Abstract The purpose of this study is to compare the quality of groundwater during wet and dry seasons in Malaysia especially in Kuala Krai District which frequently involved in annual monsoon floods and the question whether the wells can be used during floods as well as an alternative source when there are no floods. Six sampling stations were selected using six main parameters which included DO, pH, BOD, COD, TSS and NH₃N. The assessment was conducted based on the standards set by Malaysian INWQS and the classification of WQI. The results of the analysis showed that most of the water samples taken during the wet season had concentration values that did not meet the DOE standards such as the DO, BOD, and NH₃N parameters. Based on the WQI classification, majority stations during the wet season were in moderately contaminated except for station T6 which was clean. On the contrary, during a dry season were found to be clean except for station T1 which was moderately contaminated.

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1. Introduction

Flood is a common phenomenon in the area of tropic such as in Malaysia and Indonesia. Beside the fast flood, monsoon flood had occurred yearly and the impact to a people depend on the flood magnitude. The higher magnitude normally will be calculated based on the flood impacted area where the bigger area normally will get more people affected. Normally during the monsoon flood, people will be move out from their flooded house and will be placed in the temporary shelter known as temporary flood evacuation centre in the much higher ground. Normally the centre is the high rise building such as schools. Moreover during the flood, people will have difficulties to get the water supply for domestic use. For this reason, the research has been done and the result been presented in this article to investigate the probability to use groundwater reside in the well around the flood area for people to use it in daily chores. Groundwater is one of the main sources of freshwater stored in aquifers through penetration process or known as infiltration process (Nyanganji et al., 2011; Chin, 2006). This water source is widely consumed by people for domestic, industrial and agricultural purposes such as in the United States, Pakistan, Nigeria, Bangladesh, Africa and India, which approximately 40% of drinking water was from the groundwater, with 97% of villagers consumed it as drinking water and about 30-40% of it was used for agricultural purposes. Therefore, groundwater is a valuable water source and should be protected against any pollution. However, human activity factors had led to poor groundwater quality, such as excessive exploitation, agriculture, industry, and

farming. In addition, natural factors had also caused groundwater to be exposed to various concentrations of chemical compounds derived from the geological origin (Sanaullah et al., 2016). Therefore, water quality assessment plays an important role in ensuring that the groundwater is maintained and safe for use by the residents whether during the wet or dry seasons.

In Malaysia, Kelantan is a state that often experiences water supply disruption causing most residents to rely on groundwater for daily activities especially in the district of Kuala Krai. The situation gets worse when Kuala Krai is hit by floods during the monsoon season as residents who are affected by floods will have difficulties in obtaining clean water sources. This situation is caused by the damage factor in the water supply facilities submerged by floods or the water supply system is discontinued which resulted in the water supply cannot be channeled to the residents. The increase in flood water can cause damage to water supply infrastructures such as pumps and water treatment equipment (McCluskey, 2001). This damage further affects the health of the residents and increases the risk of spreading water borne diseases during floods due to the difficulty in obtaining clean drinking water (Bariweni et al., 2012; Shimi et al., 2010).

As a result, water quality assessment has become an important issue in groundwater survey where groundwater sources are potential to be used as domestic sources (Subramani et al., 2005; Nagaraju et al., 2014) whether during the wet or dry seasons. This is because the consumption of groundwater that is contaminated with impurities may contribute to an

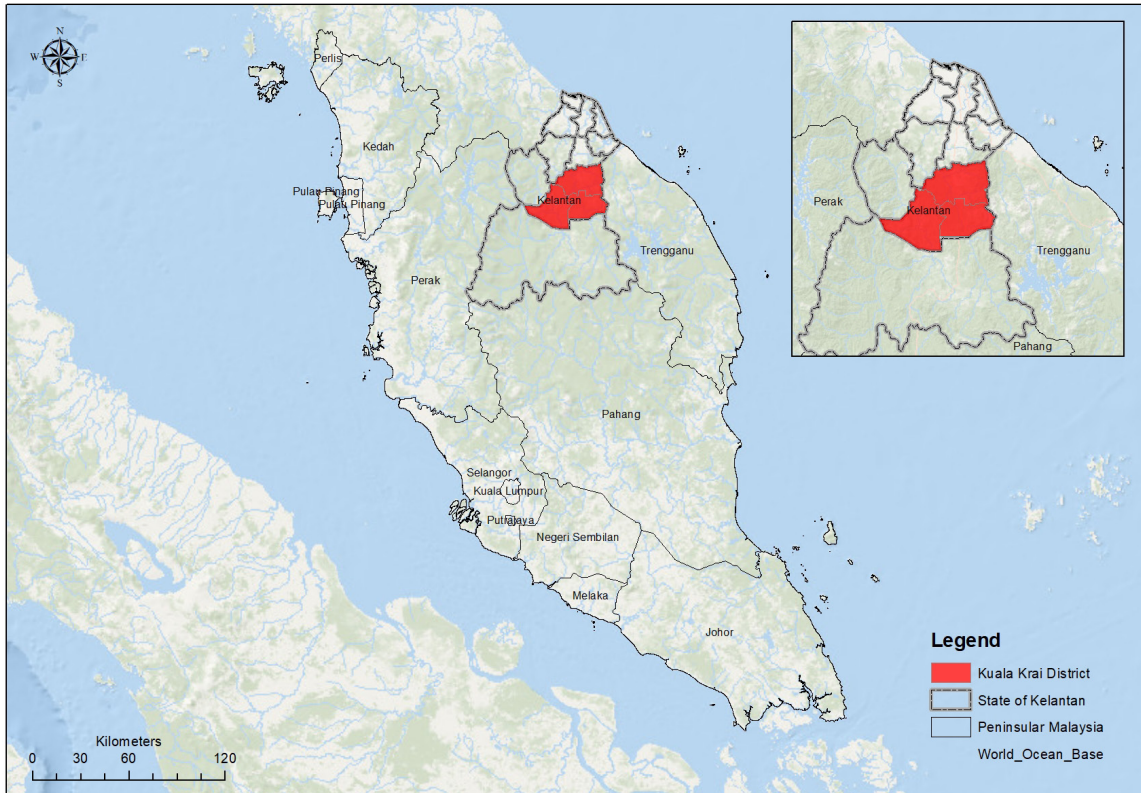


Figure 1. Study area

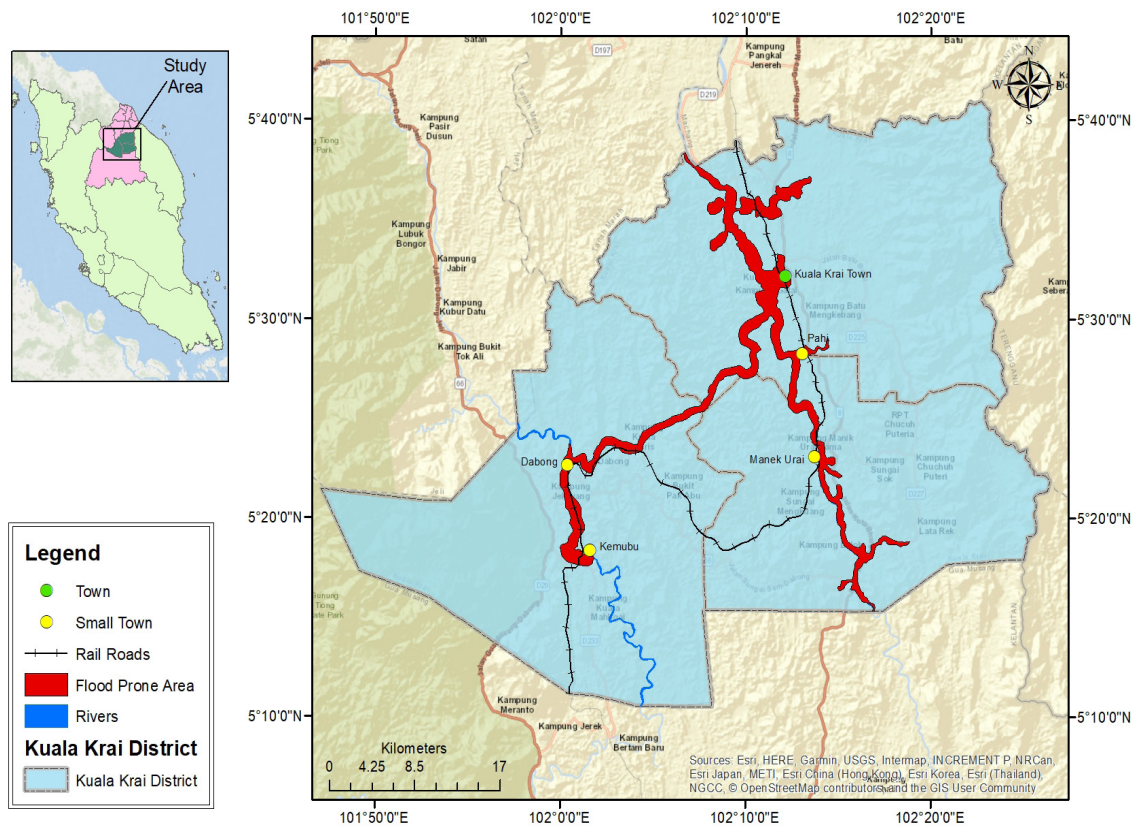


Figure 2. Flood prone areas in Kuala Krai District

increase in water borne diseases such as cholera, skin diseases, diarrhea, dysentery, and typhoid and so on. Other than that, contaminated groundwater also causes a decline in drinking water quality, loss of water supply, the high cost of treatment (Balachandar et al., 2010). Therefore, the objective of this study is compare the quality of groundwater during the wet and dry seasons in Kuala Krai district.

This study was conducted in Kuala Krai, Kelantan which was located on the East Coast of Peninsular Malaysia. This area consists of three sub districts which include Batu Mengkebang, Olak Jeram and Dabong (Figure 1). Batu Mengkebang District is the most developed area compared to the other districts as there is Kuala Krai Town which is the focal point of the local population.

In the aspect of landform, Kuala Krai district is categorized as hilly areas. The west and east borders of Kuala Krai district are highland areas with a height of more than 300 meters and less than 100 meters in Kuala Krai Town (Department of Town and Country Planning, 2011). The highest peak in Kuala Krai district is the summit of Mount Stong with an altitude of 1,800 meters. Therefore, areas that are often vulnerable to floods are Kuala Krai Town, Pahi, Manek Urai, Lela Jasa and Dabong as these are the low areas along the Kelantan River. The main factor that causes flooding in the areas was heavy rain during the monsoon season causing the overflow of Kelantan River, Lebir River and Galas River (Figure 2).

2. The Methods

Sampling stations

This study was focused on four selected relief centers in Kuala Krai based on the two main criteria which are the affected relief centers during the floods and the highest number of the victim, between 400

to 500 people. Then, the location of the wells was determined based on the nearest distance between the well and the selected relief center, not submerged by flood water and was an open well. There were six well water observation stations for the four selected relief centers as in Table 1. Figure 3 shows the location of the selected flood victim relief centers and the well water stations (T1-T6).

This study was in the form of exploratory research design to find out and explore new ideas about the problems of the studied water sources. Field study method was used in this study to observe the quality of groundwater. The observations were done during the wet season (December 2016-January 2017) and the dry season (May 2017-June 2017). Water quality observation technique had involved in-situ observations and was sent to the laboratory to be analysed. Among the in-situ observation parameters were pH, dissolved oxygen (DO) and temperature using YSI Multi Parameter System. While other parameters were sent to the laboratory for analyses on turbidity, chemical oxygen requirements (COD), biochemical oxygen requirements (BOD), ammonia nitrogen (NH₃N) and suspended solids (SS).

Well water sampling technique was done using a bucket at 0.5 metres from the surface of the well water which was practised by most researchers such as Wang et al. (2011); Sundaram et al. (2009); American Public Health Association (2005) and Chilton (2006) as well as overseas researchers in their study by collecting well water samples at a depth of 0.5 metres from well water surface. Besides that, there were several steps in the preservation of well water samples to prevent changes to the contents of the water samples when transported to the laboratory. During the filling of the water sample into HDPE bottle, the formation of air bubbles was avoided and preserved by using aluminium paper.

Table 1. List of Wells Sampling Stations

Sub district	Flood victim center	Villages affected	Station	Latitude	Longitude
Batu Mengkebang	SMK Sultan Yahya Petra II	Kg. Keroh	T 1	5° 30' 51.3"	102° 11' 54.66"
		Kg. Batu Mengkebang	T 2	5° 30' 51.3"	102° 16' 22.7"
Olak Jeram	SMK Manek Urai Lama	Lepan Meranti	T 3	5° 19' 22.1"	102° 15' 45"
		Kg. Budi	T 4	5° 19' 57.5"	102° 16' 49.6"
	SMK Laloh	Lepan Meranti	T 3	5° 19' 22.1"	102° 15' 45"
		Kg. Budi	T 4	5° 19' 57.5"	102° 16' 49.6"
Dabong	SK Kuala Gris	Kg. Jelawang Tengah	T 5	5° 20' 45.65"	101° 58' 57.13"
		Kg. Durian Hijau	T 6	5° 20' 26.88"	101° 58' 58.32"

Table 2. Water Quality Classification and The Uses

Class	WQI (%)	Status	The uses
I	> 92.7	Very good	Suitable for drinking water supply, almost need no water treatment.
IIA/IIB	76.5 – 92.7	Good	A good source for drinking water supply, normal water treatment is needed. A good source for recreational uses which water contact needed.
III	51.9 – 76.5	Moderate	Full treatment is needed and source for drinking water.
IV	31 – 51.9	Polluted	Suitable for drainage uses.
V	< 30	Highly polluted	Not suitable for any uses.

Source: DOE (2015)

The purpose of aluminium paper wrapping was to delay biological activity and reduce the physical and chemical changes of water (Saeed & Attaullah, 2014; Margaret, 2014). Then, the water samples were stored in an ice box containing ice at 4°C.

This study used descriptive analysis to compare the quality of groundwater during wet and dry seasons. Among the descriptive analyses used were minimum, maximum and percentage change. The study also used the Water Quality Index (WQI) analysis which includes six parameters of Sub-Indeks (SI) based on the Malaysian Interim National Water Quality Standard (INWQS) standards set by the Department of Environment (DOE) in classifying water quality status. This standard is used by DOE in monitoring and controlling the quality of water so that water pollution can be controlled. The classification of water quality status was determined using the following WQI specific formulae:

$$\text{WQI: } (0.22 \times \text{SIDO}) + (0.19 \times \text{SIBOD}) + (0.16 \times \text{SICOD}) + (0.15 \times \text{SIAN}) + (0.16 \times \text{SISS}) + (0.12 \times \text{SIpH}) \quad [1]$$

where,

- SIDO = Sub-Indeks DO (%)
- SIBOD = Sub-Indeks BOD
- SICOD = Sub-Indeks COD
- SIAN = Sub-Indeks NH3N
- SISS = Sub-Indeks SS
- SIpH = Sub-Indeks pH

$$0 \leq \text{IKA} \leq 100$$

Source: DOE (2015)

The formulae involved six main parameters namely as DO, BOD, COD, NH3N, SS, and pH. The sub-index of all parameters and WQI been calculated with the calculation of river water quality status done in Microsoft Office Excel version 2007 in the Department of Environmental (DOE) template forms. Values taken from the template, the water quality class has been defining the five WQI classes such as Class 1- very good (>92.7), Class IIA/IIB –good (76.5 – 92.7), Class III – Intermediate (51.9 – 76.5), Class IV – Polluted (31 – 51.9) and Class V – Extremely polluted (<30) (Table 2).

3. Results and Discussion

Water quality assessment for groundwater by parameters

Figure 4 shows the concentration values of DO, pH, BOD, COD, NH3N, SS of each observation station. The groundwater quality assessment is based on the Interim National Water Quality Standards set by the DOE. The dissolved oxygen (DO) is the measure of the amount of free oxygen found in water when it comes in contact with air in the atmosphere (DID, 2009; Nurain & Ang, 2015). Based on the standard value set by DOE (2015), a good DO value is 7mg/l and above. However, DO test results in Figure 4a show that all of the water samples during the wet and dry seasons are below the standards set by the DOE, during the wet season were at 1.83mg/l to 2.51mg/l and during the dry season at 1.83mg/l to 4.76mg/l (Figure 4a). This is because groundwater quality is influenced by the presence of pollutants from the domestic waste of the nearby residential (Nurain & Ang, 2015).

The pH value is the most important parameter in measuring the level of acidity and alkalinity of groundwater. Measurement of pH is based on a scale of 0 to 14 where the value of 7 is considered neutral (good). The pH value set by DOE (2015) is between 6.5 and 8.5. Based on Figure 4b, the observation results show that most of the water samples during the wet and dry seasons do not meet the standards set by DOE where during the wet season the values were between 5.23 and 6.21 and during the dry season between 5.15 and 6.15. This condition indicates that the well water during the wet and dry seasons was slightly acidic. However, there is one station with a pH value that meets the standard of dry season which is the T4 station with a pH value of 6.86.

In addition, biochemical oxygen demand (BOD) test is important in monitoring water quality as it serves as a measurement of the amount of oxygen used by bacteria during biological processes for decomposition of organic matter in water (Nasir et al., 2012). According to DOE (2015), a good water BOD value should be less than 1mg/l. Based on Figure 3c, the BOD concentration values during the wet season for each observation station were at 0.18mg/l to 4.94mg/l. The stations that meet the DOE standards are T3 (0.18mg/l), T5 (0.76mg/l) and T6 (0.70mg/l).

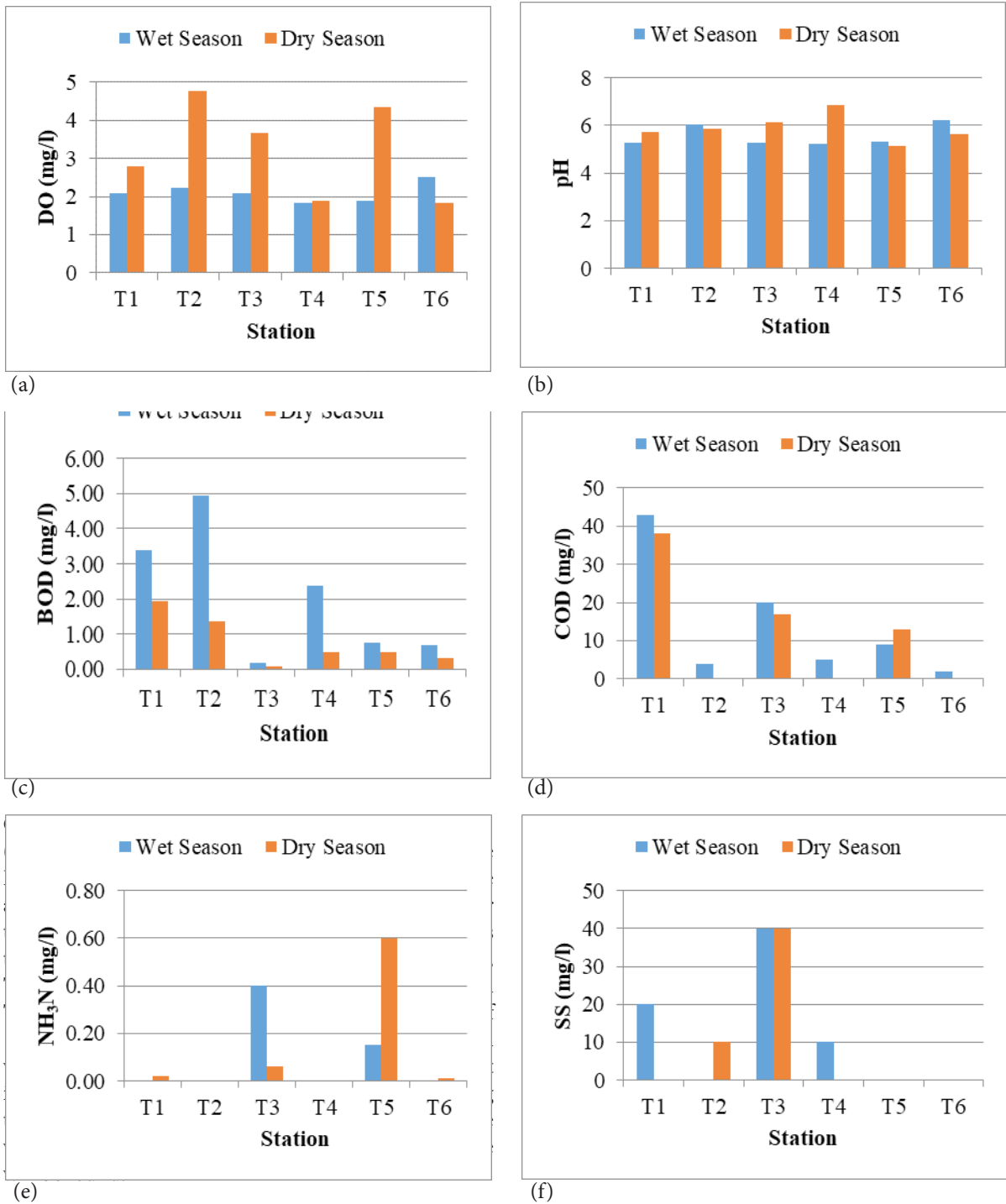


Figure. 4 Concentration value of (a) DO, (b) pH (c) BOD, (d) COD (e) NH₃N and (f) SS during wet and dry season by stations

As for Chemical Oxygen Demand (COD) parameter, it is the amount of oxygen required for the oxidation of a compound material (Nurain & Ang, 2015). Based on the DOE standards (2015), a good water COD value should be below 10mg/l. The COD test results in Figure 4d show that COD concentration values during the wet season are at 2mg/l to 43mg/l. Four observation stations had low COD concentrations and met the DOE standards which were T2 (4mg/l), T4 (5mg/l), T5 (9mg/l) and T6 (2mg/l), while two

observation stations with high COD concentrations which were T1 (43mg/l) and T3 (20mg/l). The values of COD concentration during the dry season were at 0mg/l to 38mg/l. Stations T2, T4 and T6 did not show any presence of COD contamination, while other stations recorded concentrations above the standards set by the DOE which was T1 (38mg/l), T3 (17mg/l) and T5 (13mg/l). High COD values were due to the presence of pollutants from chemical waste disposal (Nurain & Ang, 2015). Most of the well are situated at the populate area in the village surrounding of natural

but T1 and T3 were located at the urban area where chemical waste suspected come from.

As for NH₃N parameter, it was measured to determine whether the water source was contaminated with human and animal wastes which resulting from microbiological activity in groundwater (Nasir, et al., 2009). Based on the standards, a good NH₃N value is less than 0.1mg/l (DOE, 2015). Figure 4e shows the values of NH₃N during the wet season which were at 0.0mg/l to 0.40mg/l. There were four stations that recorded zero values which were T1, T2, T4, and T6, while other stations recorded NH₃N concentrations above the limit set by DOE which was T3 (0.40mg/l) and T5 (0.15mg/l). Since T1 is located in the urban area, it is understood that the value will be high coming from the domestic waste. But for the T5, where it located in the village surround with the agriculture and the high value suspected came from the agriculture fertilizer. During the dry season, NH₃N values were at 0.0mg/l to 0.60mg/l. All stations recorded values below the standards set by the DOE except for station T5 which recorded the highest NH₃N concentration during the dry season of 0.60mg/l which is came from the influence of agriculture fertilizer such as palm oil. High NH₃N values are typically influenced by the use of plant fertilizers (agriculture), animal feces and domestic wastewater (Nurain & Ang, 2015).

In addition, suspended solids (SS) parameter involves measuring of the dryness and weight of particles sized larger than 0.001 mm (Nurain & Ang, 2015). The level of measurement level value of net SS is less than 25mg/l (DOE, 2015). Figure 4f shows that the SS values during the wet and dry seasons were 0mg/l to 40mg/l. Most stations recorded SS concentrations below 25mg/l and met the DOE standards which include T1,

T2, T4, T5 and T6 except for station T3 which recorded high concentration during the wet and dry seasons at 40mg/l. The presence of high SS in wells was due to the rain which had caused surface runoff carrying suspended solids into the well water during the wet season. The presence of SS during the dry season was caused by domestic activity involving the use of water near the edge of the well causing the water runaway to carry suspended solids into the well.

Water Quality Index (WQI)

The location of wells has been identified to contribute to the volume concentration value in every water quality parameter such as in 5.1 topic. Station located in the centre of urban such as T1, T2 and T3 will tend to give a higher value of pollutants such as BOD, COD and NH₃N. While some of the station located out of urban and located at the palm oil farming area also give some high value in water quality parameters such as NH₃N at the station T5. To formulate the water quality index such as in the Table 2 either the water quality in every station either good or not to be used for domestic purpose in the evacuation centre a calculation has been done with the formulae 1. The SI is a short form for sub-index and it occur for all water quality parameters with the SI short form placed in front of the parameter names such as SIDO is for Sub-Index for dissolved oxygen. Table 3 shows the values of SI, WQI, classes, and water quality status of each well water observation station for the wet season. The result of the analysis shows that only station T6 was in class II which is classified as clean with a WQI value of 80.99 percent. While the other stations were in class III which is classified as moderately contaminated and that include stations T1, T2, T3, T4 and T5 where WQI values were

Table 3. Value of Wells SI, WQI, Classes and Water Quality Status in Wet Season

Station	SIDO	SIBOD	SICOD	SIAN	SISS	SIPH	WQI	Class	Status
T1	17.30	86.06	50.72	100.50	86.17	65.62	65.17	III	Moderate contamination
T2	19.10	79.50	93.78	100.50	97.50	91.34	75.95	III	Moderate contamination
T3	17.07	99.64	72.50	66.75	76.40	65.98	64.44	III	Moderate contamination
T4	14.67	90.29	92.45	100.50	91.63	64.56	72.81	III	Moderate contamination
T5	16.02	97.19	87.13	84.75	97.50	67.41	72.33	III	Moderate contamination
T6	23.25	97.44	96.44	100.50	97.50	93.83	80.99	II	Clean

Table 4. Value of Wells SI, WQI, Classes and Water Quality Status in Dry Season

Station	SIDO	SIBOD	SICOD	SIAN	SISS	SIPH	WQI	Class	Status
T1	28.05	92.19	55.20	98.40	97.50	86.22	73.23	III	Moderate contamination
T2	62.96	94.65	99.10	100.50	91.63	88.93	88.10	II	Clean
T3	45.56	100.02	76.49	94.20	76.40	93.05	78.78	II	Clean
T4	13.47	98.37	99.10	100.50	97.50	99.24	80.09	II	Clean
T5	59.30	98.37	81.81	59.65	97.50	61.76	76.79	II	Clean
T6	14.67	99.00	99.10	99.45	97.50	84.04	78.50	II	Clean

64.44 percent to 75.95 percent. This condition indicates that the well water sources need to undergo a complete treatment process for domestic consumption, especially for drinking.

Table 4 shows the values of SI, WQI, classes, and water quality status of each well water observation station during the dry season. The result of the study found that most well water stations were in class II which is classified as clean where the WQI values were at 76.79 percent to 88.10 percent. This condition indicates that most well water is suitable to be used as drinking water supply and regular treatment is needed. Only station T1 was in class III which is classified as moderately clean with a WQI value of 73.23 percent and needs to undergo a complete treatment process to be used as a drinking water source.

The finding of the study shows that there were significant differences in well water quality status between the wet and dry seasons. Among the stations that experienced an increase in WQI percentage were station T2 at 12.15 percent, station T3 at 14.34 percent, station T4 at 7.28 percent and station T5 at 4.46 percent. However, only station T1 experienced an increase in WQI percentage by 8.06 percent, but the quality status during the wet and dry seasons remained as moderately contaminated. While station T6 experienced a decrease in WQI percentage by 2.49 percent, but it was still clean for the people to use.

Comparative results can be concluded that the well water quality during the dry season is better than the wet season. This is due to the fact that the groundwater during the wet season was low with DO, BOD, and high with NH₃N. Normally this is due to the high volume of rain which caused the surface runoff carrying pollutants into the well. Well in the urban area will have higher value in certain parameters such as DO and NH₃N since the domestic waste will follow the flood and into the well. Wells in the agriculture area too, will have certain higher value parameter such as NH₃N and SS where erosion took place and bringing the upper soil to the well. This condition had caused the groundwater not suitable to be used by the people of Kuala Krai during wet seasons. A full treatment process needs to be done for domestic consumption, especially for drinking. On the other hand, the groundwater during the dry season is suitable to be consumed by Kuala Krai residents as drinking water and other domestic uses. However, a regular treatment is required to ensure that the groundwater supply is safe to be used by the residents. The findings of this study have similarities with the study conducted by Pathak et al. (2011) in Kathmandu Valley, Nepal. The findings show that the groundwater quality during the wet season had higher pollution level than during dry season which was influenced by the impact of the anthropogenic activity. Similarly, a study conducted by Adekunle et al. (2007) in southwestern Nigeria found that most pollutants concentration were increased in the groundwater during wet seasons

compared to dry seasons.

This condition clearly shows that the change in season can affect the concentration level of groundwater's physico-chemical properties (Idoko & Oklo, 2012). Therefore, groundwater quality assessment is one of the important issues in groundwater survey whether it is during the wet or dry seasons. This is because polluted water is risky to the health of the population if they consume contaminated water. Laurent et al. (2010) explain that the suitability of groundwater for drinking, irrigation, and industrial purposes depend on the quality. This is because good water quality will ensure the sustainability of socio-economic development (Ishaku, 2011). Therefore, the quality of groundwater needs to be properly maintained so that it is not polluted and does not affect the health of the people using it.

6. Conclusion

In conclusion, flood prone neighborhood groundwater quality in Kuala Krai District is vary, where in the wet season the water quality pretty much at the level of moderate contamination. Over 5 of 6 stations are in moderate contamination while only one at the level clean water. Of all 5 stations examined, either there are in the urban area or in the farming estate of palm oil. And the only one is situated not in the area of urban neither farming area. While during the dry season, most of the stations are in the clean status and only one station situated in the urban area detected with moderate contamination. Wells in the urban area found not suitable either in dry nor the wet season to use for water supplying. But if there are a case where the water still need to be used, then it should be underwent the filtering process. This is because groundwater is the main source of water supply to Kuala Krai residents either during the wet or dry seasons due to water supply disruptions that are often encountered by the population. In addition, groundwater needs are also important for Kuala Krai residents for economic purposes especially agricultural sector in mobilizing local area development. Therefore, regular groundwater controlling and monitoring play an important role in water sources management of an area.

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