Effect of Monsoon Flood to Groundwater Quality in Kuala Krai, Kelantan, Malaysia

N Nayan*, M Hashim, Y Saleh, H Mahat and K L See
Department of Geography and Environment, Faculty of Human Sciences, Sultan Idris Education University, 35900 Tanjong Malim, Perak, Malaysia.

*nasir@fsk.upsi.edu.my

Abstract. Evaluation of water sources quality plays an important role during floods especially the groundwater. This study aimed to assess the effect of floods on the quality of groundwater in Kuala Krai. Six sampling stations were selected involving six main parameters, namely dissolved oxygen (DO), pH, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS) and ammonia nitrogen (NH$_3$N). The assessment was conducted according to the Interim National Water Quality Standards Malaysia (INWQS) and the water quality index (WQI) classification, which has been established by the Department of Environment (DOE). The study found that flooding could affect groundwater quality, especially the DO, pH and BOD parameters. Based on WQI classification, most of well water stations are in Class III which is moderately polluted except the T6 station which is in Class II with clean status. This condition shows that the quality of groundwater in Kuala Krai is in the moderately polluted category and a full treatment is required for drinking water supply, especially during flooding events.

1. Introduction
Groundwater is a part of important freshwater sources available below the ground surface. Groundwater is stored in aquifers through infiltration [1-3]. Approximately 30.1% of global freshwater is groundwater [4]. Therefore, groundwater is widely used by man for domestic, industrial and agricultural purposes throughout the world. Based on the statistical use of groundwater globally, about 40% of the drinking water sources are from the groundwater, about 97% of village residents use groundwater for drinking purposes, and about 30-40% use for agricultural purposes is from the groundwater [5]. Among the countries that most of their population depends on groundwater is the United States, Pakistan, Nigeria, Bangladesh, Africa and India.

In Malaysia, Kelantan is one of the states highly dependent on groundwater, especially Kuala Krai. Kuala Krai population dependence on groundwater is caused by water disruptions due to its hilly terrain. However, the situation worsened when the floods hit Kuala Krai which caused groundwater quality to be affected. This is because the rain would form surface runoff and carry pollutants into the water retention area and groundwater and contaminate the entire water in the aquifer [6]. The situation creates difficulties for flood victims to acquire a clean water during the flood. This situation can be seen based on the occurrence of flood disaster that hit Kuala Krai by the year 2014 which population of Kuala Krai was the area worst affected. Flooding in the year 2014 is known as 'the yellow flood'. Extreme flood disaster occurrence in Kuala Krai during the year resulted in a total of 202,000 people flood victims have to be evacuated to an evacuation flood centers [7]. The height of the floods was
more than 5 to 10 meters which were capable of flooding a building to the level 3 or 4 [8]. The increase to the dangerous water level had sunk some low areas in Kuala Krai and caused enormous destruction to property of the victims (Figure 1). The flood disaster had also led to population losses of about RM 106 million, which includes the destruction of crops, public facilities and local property [9].

![Figure 1. Post-flood aftermath in 2014.](image)

2. Methods

2.1. Sampling stations

The study was conducted in Kuala Krai involving four evacuation centers in which selection was based on two criteria, namely the affected evacuation centers during the floods and the highest number of evacuees (500 or 400 people). Next, the well water observation stations were determined for each selected evacuation center. Table 1 shows the list of well water observation stations for four relief centers selected. Observation station is determined by the distance of the nearest well with the selected evacuation center and not submerged. These observations were made during the Northeast monsoon season which was in December 2016/January 2017. Figure 2 shows the location of each well water stations and evacuation centers selected.
Table 1. Water sampling stations.

| District        | Flood victim center | Victim flood coverage village affected | Station | Latitude       | Longitude       | Proximity to the nearest flood victim center (km) |
|-----------------|---------------------|----------------------------------------|---------|----------------|----------------|-----------------------------------------------|
| Batu Mengkebang | SMK                 | Kg. Keroh                              | T 1     | 5° 30' 51.3"   | 102° 11' 54.66"| 8.895                                         |
|                 | Sultan              | Kg. Batu                               | T 2     | 5° 30' 51.3"   | 102° 16' 22.7" | 8.991                                         |
| Olak Jeram      | SMK                 | Lepan Meranti                          | T 3     | 5° 19' 22.1"   | 102° 15' 45"   | 6.942                                         |
|                 | Manek Urai Lama     | Kg. Budi                               | T 4     | 5° 19' 57.5"   | 102° 16' 49.6" | 7.316                                         |
|                 | SMK Laloh           | Lepan Meranti                          | T 3     | 5° 19' 22.1"   | 102° 15' 45"   | 1.583                                         |
|                 | Kg. Budi            |                                         | T 4     | 5° 19' 57.5"   | 102° 16' 49.6" | 2.573                                         |
|                 | Olak Jeram          | Lepan Meranti                          | T 3     | 5° 20' 45.65"  | 101° 58' 57.13"| 10.056                                        |
|                 | Kh. Durian Hijau    |                                         | T 6     | 5° 20' 26.88"  | 101° 58' 58.32"| 10.308                                        |

Figure 2. Well sampling stations (T1-T6) and selected flood victim centers.
2.2. Sampling methodology
The study used the fieldwork method to carry out water quality observations. Water quality observation technique was divided into two, which were in-situ and send into the laboratory. Among the measuring parameter carried out in the field were pH and dissolved oxygen (DO) by using YSI Multi-Parameter System. While the biochemical oxygen demand (BOD), chemical oxygen demand (COD), suspended solids (SS) and ammonia nitrogen (NH$_3$N) parameters were analyzed at the Laboratory of Physical Geography, Universiti Pendidikan Sultan Idris. Well water samples were taken using the bucket method with a depth of 0.5 meters from the surface of the well water. This well water sampling method as well as researchers abroad such as in his study by collecting well water samples from a depth of 0.5 metre from the surface of the well water [10-15].

Given the water samples must be sent to the lab, there were several preservation steps that had been taken to prevent a change in the content of water samples. Water samples that were being filled into HDPE bottles needed to avoid the formation of air bubbles and cured using aluminium foil. The purpose of aluminium foil wrap is to slow down the biological activity and reduce the physical and chemical changes of water [6]. Then, the samples were incubated in an ice box filled with ice cubes at 4°C.

2.3. Water quality index methodology (WQI)
This study applied WQI analytical method to assess the quality of well water source. The measuring of water quality was based on the Interim National Water Quality Standard (INWQS) as determined by the DOE in classifying the status of water quality by using the WQI special formula. This measurement was used because there is no specific water quality measurement to evaluate the status of well water quality. Additionally, these guidelines were used by the DOE for monitoring and controlling water quality so that pollution can be controlled. Here, are the formula used by the DOE consisting of six parameters, namely DO, BOD, COD, NH$_3$N, SS, and pH in determining the value and class of WQI.

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

Where,
- SIDO = sub-indeks DO (%)
- SIBOD = sub-indeks BOD
- SICOD = sub-indeks COD
- SIAN = sub-indeks NH$_3$N
- SISS = sub-indeks SS
- SIpH = sub-indeks pH

\(0 \leq \text{WQI} \leq 100\)

WQI classes; class I - very good (>92.7), Class IIA/IIB - good (76.5 - 92.7), Class III - moderate (51.9 - 76.5), Class IV - contaminated (31 - 51.9) and class V - very polluted (<30) (Table 2).
Table 2. Water quality classification and the uses.

| Class | WQI (%) | Status     | Usefulness                                                                 |
|-------|---------|------------|-----------------------------------------------------------------------------|
| 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 are 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)

3. Results and discussion

Figure 3 shows the content values of DO, BOD, COD, NH₃N, SS and pH parameters at each observation station. Dissolved oxygen (DO) is a measure of the amount of free oxygen in the water when in contact with air in the atmosphere [16,17]. A normal DO value has to be 7 mg/l and above [18]. However, based on Figure 3a shows that most of the DO of well water sources are in 1.83mg/l to 2.51mg/l range, which is below the standard set by the DOE. This situation is due to the presence of pollutants from domestic waste from the residential neighborhood [17]. The pH value is a measurement of the degree of water acidity or alkalinity based on a scale of 0 to 14, where 7 is neutral (good). A good pH value is in the range of 6.5 to 8.5. According to Figure 3b, the pH value of all observation stations was in the 5.23 to 6.21 range, which is below the standard set by the DOE. This condition shows that the well water is slightly acidic [18].

Biochemical Oxygen Demand (BOD) refers to the measurement of dissolved oxygen used by some microorganisms for decomposition of organic compounds found in water. A good BOD of water should be at levels less than 1 mg/l [18]. Figure 3c shows the values of BOD concentration for each observation station were in 0.18mg/l to 4.94mg/l range. A total of 4 observation stations have low BOD concentration, namely T2 (0.18mg/l), T5 (0.76mg/l) and T6 (0.70mg/l). Other stations show high BOD values which are T1 (3.39mg/l), T2 (4.94mg/l), T4 (2.39mg/l) due to the high content of organic material in the domestic waste disposal and animal sewage [19]. While as for Chemical Oxygen Demand (COD) parameter, it is the amount of oxygen required for the oxidation of a substance compounds [17]. A good COD value is in the range of 6.5 to 8.5. According to Figure 3d, the COD concentration for all stations is in the 2 mg/l to 43mg/l range. A total of 4 observation stations have low COD concentration and meet the standards of DOE, namely T2 (4 mg/l), T4 (5mg/l), T5 (9mg/l) and T6 (2mg/l), while there are 2 observation stations with high value of COD concentration, namely T1 (43mg/l), T3 (20 mg/l) due to the presence of contaminants from the disposal of chemical [17].

In addition, the NH₃N parameter was also measured to assess the amount of ammonia or toxic pollution in water bodies as a result of sewage, liquid manure and other liquids related to organic waste materials. Based on standards, a good NH₃N value is less than 0.1 mg/l [18]. Figure 3e shows the NH₃N values are in the 0.0mg/l to 0.40mg/l range. There are 4 stations that recorded zero value which are T1, T2, T4, and T6, while other stations recorded NH₃N concentration values exceed a predetermined limit, namely T3 (0.40mg/l) and T5 (0.15mg/l). The high value of NH₃N is usually influenced by the use of plant fertilizer (agriculture), animal waste and domestic sewage. In addition, the SS parameter involves a measurement of dryness and particles weight with a size larger than 0.001 mm [17]. The measurement level of a clean SS value is less than 25 mg/l [18]. Figure 5f shows the SS values for each station were in the 10 mg/l to 40 mg/l range. There are 5 stations that recorded SS
concentration value below 25 mg/l and meet the standards of DOE, namely T1 (20mg/l), T2 (0mg/l), T4 (0mg/l), T5 (0mg/l) and T6 (0mg/l), while T3 station that recorded a high concentration which was T3 (40 mg/l). The high presence of SS in well water was caused by rains that had caused surface runoff of to carry suspended solid materials into the well water.

3.1. Water quality index
Table 3 shows SI value, WQI, class, and water quality status for every observation station. The results found that well water stations are in class III in which the WQI is in the 61.31% to 75.95% range, except T6 station is in class II WQI with 80.99% which is a good status. This resulted in the well water sources need to be treated fully as drinking water source.
Table 3. SI value, WQI, class dan water quality status.

| Station | SIDO  | SIBOD | SICOD | SIAN  | SISS  | SIPH  | WQI  | Class            | Status       |
|---------|-------|-------|-------|-------|-------|-------|------|------------------|--------------|
| T 1     | 17.30 | 86.06 | 50.72 | 100.50| 86.17 | 65.62 | 65.17| III              | Polluted-Moderate |
| T 2     | 19.10 | 79.50 | 93.78 | 100.50| 97.50 | 91.34 | 75.95| III              | Polluted-Moderate |
| T 3     | 17.07 | 99.64 | 72.50 | 66.75 | 76.40 | 65.98 | 64.44| III              | Polluted-Moderate |
| T 4     | 14.67 | 90.29 | 92.45 | 100.50| 91.63 | 64.56 | 72.81| III              | Polluted-Moderate |
| T 5     | 16.02 | 97.19 | 87.13 | 84.75 | 97.50 | 67.41 | 72.33| III              | Polluted-Moderate |
| T 6     | 23.25 | 97.44 | 96.44 | 100.50| 97.50 | 93.83 | 80.99| II               | Clean         |

The results show that the DO concentration of well water was still low. Some well water stations did not meet the water quality standards set by the DOE such as measurement of NH$_3$N, SS, COD and BOD parameters. Additionally, the pH value of all well water samples was also low and slightly acidic. This condition will cause well water to have a bitter metallic taste and corrosion. This condition clearly shows that flooding events are capable of affecting the quality of groundwater due to rain factors that carry pollutants into groundwater. The findings of this study are similar to those reported who conducted a study on the impact of floods on groundwater quality at Sanjiang Square, China found that the 2013 extreme floods were not only responsible for refilling groundwater reserves, but also changing the water quality by reducing the chloride concentration and nitrate nitrogen and electrical conductivity in areas near the river and increasing the chloride concentration and nitrate nitrogen and electrical conductivity in intensive agricultural areas [20].

The 2013 floods in Nigeria had had a direct impact on groundwater quality [6]. However, the quality of groundwater was not only influenced by pollutants from the ground surface, but was also influenced by the various concentration of chemical compounds derived from the geological origin [21]. Excessive exploitation of groundwater may also affect the quantity and quality of groundwater [22,23].

4. Conclusions
Groundwater sources play an important role in fulfilling the water supply needs of the Kuala Krai residents for domestic activities. Therefore, groundwater quality analysis is one of the important issues in a groundwater study especially when the floods or rainy seasons hit the Kuala Krai area. This is because polluted water is able to risk the health of flood victims if they consume contaminated water. Therefore, periodic controlling and monitoring of groundwater sources plays an important role in the water sources management of an area.

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