Analysis of Well Water Quality in the District of Pasir Puteh, Kelantan, Malaysia

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Abstract. This study was conducted to examine well water quality in areas of different land use in Pasir Puteh, Kelantan, Malaysia. A total of four water sampling locations were selected to represent specific land use types, including Pasir Puteh town (urban land use), Padang Pak Amat (industrial land use), Bukit Gedombak (landfill site) and Kampung Jelor (agricultural land use). Well water sampling was carried out twice, in March 2018 and April 2018. Water quality samples were analysed both in-situ and in the laboratory based on the Water Quality Index (WQI) as determined by the Malaysian Department of Environment (DOE). Water quality parameters analysed included Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammonia Nitrogen (NH₃N), pH and Total Suspended Solids (TSS). The findings showed that although values of the six parameters observed did not exceed the specified standards, well water quality in all four types of land-use areas belonged to WQI Class III, with values ranging between 61.5 and 74.5. Class III quality indicates that the water should be treated first if it is to be used as drinking water supply. Well water quality in the area subject to agricultural land use exhibited the lowest WQI value of 61.5, reflecting the influence of local rice paddy activities. Continuous monitoring and immediate measures must therefore be undertaken, as these water sources remain exploited by locals for everyday use.

1. Introduction

Groundwater represents an alternative fresh water source other than surface water sources such as rivers, lakes and ponds. Groundwater sources are important not only for domestic use, but also for the irrigation of agricultural areas and industrial activities, in both developing and developed countries. However, changes in land use often take place in developing countries to the extent that they may affect groundwater quality. In general, the majority of domestic water supply in Malaysia is derived from surface water sources, with groundwater use making up only two to three per cent [1]. However, the use of groundwater sources for domestic water supply is more common in several states in Malaysia, including Kelantan.

In Malaysia, the agency responsible for monitoring the status of groundwater quality is the Department of Environment (DOE). The DOE [2] recently implemented a national groundwater quality control programme involving 78 wells in Peninsular Malaysia, 12 wells in Sarawak and 15 wells in Sabah. Well locations were selected to cover specific land use types, such as agriculture, urban/suburban, rural and industrial, as well as sites of specific importance such as landfills, to determine groundwater quality status in each area.

Changes in land use can affect groundwater quality and quantity [3], with particularly rapid changes taking place worldwide from forestry to agricultural land use, as well as industrialisation, urbanisation and landfill [4-10]. Meanwhile, exploration of groundwater sources in coastal areas has resulted in the penetration of seawater, causing the groundwater to become unsuitable for both irrigation and domestic use.
The aim of the present work was to identify the number of wells used as a source of domestic water supply and to assess the level of well water quality in areas of different land use in Pasir Puteh, Kelantan, Malaysia. This research was prompted by the fact that local residents continue to use well water as a source of domestic water supply.

2. Location and Methodology
This study of well water quality was conducted in four areas of differing land use in Pasir Puteh, Kelantan. Kelantan was selected as the study region due to the widespread use of wells by locals to obtain groundwater resources. Pasir Puteh district is one of 10 in Kelantan and is adjacent to Bachok, Kota Bharu and Machang districts (Figure 1). Pasir Puteh’s area of 433.80 sq km comprises eight sub-districts, with current land use including agricultural (81.97 per cent of the total district area), residential (0.4%), industrial (0.3%), business (0.02%), government (2.8%) and forest (14.51%) [11]. Well water quality was determined via the selection of areas covering four different types of land use, namely Pasir Puteh (representing urban land use), Kampung Jelor (agricultural), Bukit Gedombak (landfill) and Padang Pak Amat (industrial) (Table 1 & Figure 1).

![Figure 1. Location of well water quality observation stations in Pasir Puteh district, Kelantan](image)

| Station | Area Name       | Type of Land Use | Latitude      | Longitude     |
|---------|-----------------|------------------|---------------|---------------|
| A       | Bandar Pasir Puteh | Built-up/Urban   | 5° 83’ 53.9”  | 102° 40’ 17.8” |
| B       | Kampung Jelor   | Agriculture      | 5° 88’ 09.9”  | 102° 39’ 46.1” |
Well water sampling was conducted twice in all four areas, in March 2018 (during the Northeast Monsoon period) and April 2018 (during the Monsoon Transition period). Water samples were tested either directly in the field or transported to the laboratory for analysis. A total of six water quality parameters were used to determine well water quality: Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Ammonia Nitrogen (NH₃N), pH and Total Suspended Solids (TSS). These six parameters were selected based on their adoption by the Malaysian DOE in establishing the Water Quality Index (WQI). This WQI is used to classify water quality into six classes, as shown in Table 2, with analysis based on standards set by the American Public Health Association (APHA) [12]. The WQI is determined according to the formula set out by the DOE as follows:

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WQI = (0.22 \times S_{DO}) + (0.19 \times S_{BOD}) + (0.16 \times S_{COD}) + (0.15 \times S_{AN}) + (0.16 \times S_{SS}) + (0.12 \times S_{pH})
\]

\[
\text{Parameter/Class} & \quad \text{Class I} & \quad \text{Class II} & \quad \text{Class III} & \quad \text{Class IV} & \quad \text{Class V} \\
\hline
\text{Ammonia Nitrogen (mg/l)} & \text{< 0.1} & \text{0.1 – 0.3} & \text{0.3 – 0.9} & \text{0.9 – 2.7} & \text{> 2.7} \\
\text{BOD (mg/l)} & \text{< 1} & \text{1 – 3} & \text{3 – 6} & \text{6 – 12} & \text{> 12} \\
\text{COD (mg/l)} & \text{< 10} & \text{10 – 25} & \text{25 – 50} & \text{50 – 100} & \text{> 100} \\
\text{DO (mg/l)} & \text{> 7} & \text{5 – 7} & \text{3 – 5} & \text{1 – 3} & \text{< 1} \\
\text{pH} & \text{> 7} & \text{6 – 7} & \text{5 – 6} & \text{< 5} & \text{< 5} \\
\text{TSS (mg/l)} & \text{< 25} & \text{25 – 50} & \text{50 – 150} & \text{150 – 300} & \text{> 300} \\
\text{Water Quality Index (WQI)} & \text{> 92.7} & \text{76.5 – 92.7} & \text{51.9 – 76.5} & \text{31 – 51.9} & \text{< 31} \\
\hline
\text{Contamination status} & \text{Not Contaminated} & \text{Slightly Contaminated} & \text{Moderately Contaminated} & \text{Contaminated} & \text{Highly Contaminated}
\]

Source: Malaysian Department of Environment [13]

3. Results and Discussion

3.1 Distribution and Number of Wells in Pasir Puteh, Kelantan

Wells continue to be used by locals to obtain groundwater in Pasir Puteh, Kelantan. Most wells are exploited daily for domestic uses such as washing, bathing and drinking water. According to the survey conducted in the field, the highest number of wells (14) was found in Kampung Jelor. Many inhabitants of Kampung Jelor use well water not only as a source of domestic water but also for irrigation purposes. Padang Pak Amat, where eight wells were found, is an industrial area containing a paddy processing plant. The fewest wells were found in Bukit Gedombak (five) and the town of Pasir Puteh (two) (Figure 2).
3.2 Well Water Quality Analysis based on the Malaysian Water Quality Index

Dissolved Oxygen (DO)

DO refers to the oxygen requirement in water bodies and is measured in terms of oxygen concentrations, with high DO values indicative of good water quality [14-16]. According to the Malaysian DOE WQI, DO values in water bodies should be at least 7 mg/l to achieve Class I status. During the first observation period the highest DO value in the study area of 7.53 mg/l was recorded at station B and the lowest of 6.34 mg/l recorded at station C. During the second observation period, the highest DO value of 7.07 mg/l was recorded at station C and the lowest of 5.79 mg/l was recorded at station A (Figure 3). Average DO values ranged between 6.12 mg/l - 6.92 mg/l, falling in DOE WQI Class II.
Chemical Oxygen Demand (COD)

COD represents the amount of oxygen required to oxidise organic matter in the water, with higher COD values indicating a higher amount of pollutants present. According to the Malaysian DOE WQI, water COD values should be less than 10 mg/l to be classified as Class I. COD levels of 16 mg/l were recorded at station D during the first observation period, slightly decreasing to 15 mg/l during the second observation period. The lowest COD levels were recorded at station C on both occasions, at 11 mg/l and 9 mg/l, respectively (Figure 4). However, COD values at all four stations fell within Class II (10-25 mg/l), with averages ranging from 10 to 15.5 mg/l.

Figure 3. Water quality analysis based on Dissolved Oxygen (DO) content

Figure 4. Water quality analysis based on Chemical Oxygen Demand (COD)
Ammonia Nitrogen (NH₃N)

The NH₃N parameter is used to detect pollutants originating from the use of agricultural fertilisers, as well as animal faeces and domestic sewage [16]. The Malaysian DOE WQI specifies that NH₃N values should be less than 0.1 mg/l for Class I water. NH₃N concentrations in the present study were highest at station B during both the first and second observation periods, at 0.42 mg/l and 0.17 mg/l, respectively. These high levels are likely due to the use of fertilisers in the agricultural areas located near station B, with NH₃N penetrating into the ground after precipitation events. Zaini et al. [17] found that similar high NH₃N concentrations resulted from the release of fertilisers, animal faeces and domestic sewage into rivers through surface runoff during rain and subsequently as groundwater flow, thus affecting water quality in the surrounding area. Here the lowest NH₃N concentrations were recorded at station D during the first observation period (0.02 mg/l) and at station C during the second observation period (0.02 mg/l) (Figure 5).

![Figure 5. Water quality analysis based on Ammonia Nitrogen (NH₃N)](image)

Biochemical Oxygen Demand (BOD)

BOD refers to the amount of dissolved oxygen required by organisms in water bodies to dissociate organic matter within a certain period of time and at a certain temperature. According to the Malaysian DOE WQI, BOD levels in Class I clean water should be less than 1 mg/l. In the present study, the highest BOD values during the first observation period of 0.72 mg/l were recorded at station D, with the highest value of 0.7 mg/l during the second observation period recorded at station B. In contrast, the lowest BOD values for these two periods were recorded at station A (0.2 mg/l) and station C (0.22 mg/l), respectively (Figure 6). Overall, all stations recorded BOD values of less than 1 mg/l and average BOD values of 0.25 mg/l to 0.66 mg/l, thus falling within Class I.
The pH parameter is a measure of acidity or alkalinity, with values of 1 to 6 indicating acidity, 7 neutral and 8 to 14 alkalinity. According to the Malaysian DOE WQI, Class I water should have a pH value >7. During both observation periods the highest pH values were recorded at station C at around 6.7. Similarly, the lowest pH values during both observation periods were recorded at station B, at 4.76 and 3.06, respectively (Figure 7). Overall, well water was found to be acidic at all four stations throughout the study period.
Total Suspended Solids (TSS)
Suspended solids indicate the presence of impurities, including both inorganic substances such as soil and industrial waste, and organic matter such as dead plants, living organisms and sewage [18]. Here the highest TSS value during the first observation period was recorded at station B (6 mg/l), with a high of 5 mg/l recorded at both station A and station B during the second observation period. In contrast, the lowest TSS values recorded during both the first and second observation periods were observed at station C (2 and 3 mg/l, respectively) (Figure 8). In summary, TSS values recorded at all four stations did not exceed the standard specified by the Malaysian DOE WQI for Class I water of less than 25 mg/l.

3.3 Comparison of Well Water Quality in Areas of Different Land Use in Pasir Puteh District Based on the Malaysian WQI

In order to determine the current status of well water quality across the study area, the Malaysian DOE WQI was used to assign classes to four different types of land use. According to the WQI, values from 81 to 100 indicate clean water, values from 60 to 80 indicate moderately contaminated water and values from 0 to 59 indicate contaminated water. Overall, water in the study region under these four types of land use was moderately contaminated and can be assigned to Class III (Table 3). Water in the area of agricultural activity achieved the lowest WQI value, likely due to the presence of paddy fields in Kampung Jelor. This finding is similar to that reported by Arno et al. [19] for the Cameron Highlands, where rapid agricultural development has affected the quality of both surface and groundwater sources. Salem et al. [9] have pointed out that concentrations of nitrate in groundwater will increase due to the use of chemical fertilisers in agriculture and will thus affect water quality.

The areas of urban and industrial land use in the study region also exhibited moderately contaminated (Class III) well water unsuitable for use as domestic water supply, especially for drinking purposes. Locals in these areas thus have to treat their water before use. Studies conducted by Farzaneh et al. [20] and Mahmood et al. [21] have similarly shown that although groundwater was suitable for use as drinking water, it required further treatment prior to consumption.

Well water in the former landfill site located in Bukit Gedombak achieved a better WQI value than the other three areas, at 74.5. This result indicates that well water in this area is no longer subject to the...
impact of solid waste disposal from adjacent sites. However, Mishra et al. [7] reported that although groundwater near a landfill site was in good condition, it was not suitable for use as a drinking water supply because it contained nitrates and iron minerals at levels exceeding the standards specified by the World Health Organisation (WHO). Well water quality analysis at former landfill sites and surrounding areas should therefore be conducted as part of land use planning, particularly regarding the identification of uncontaminated water sources for local domestic use.

| Station | Land Use             | WQI (March 2018) | WQI (April 2018) | Overall WQI | Water Class | Water Quality Status |
|---------|----------------------|------------------|------------------|-------------|-------------|---------------------|
| A       | Urban                | 68               | 68               | 68          | III         | Moderately contaminated |
| B       | Agriculture          | 62               | 61               | 61.5        | III         | Moderately contaminated |
| C       | Former landfill site | 74               | 75               | 74.5        | III         | Moderately contaminated |
| D       | Industrial           | 66               | 66               | 66          | III         | Moderately contaminated |

4. Conclusion
Six water quality parameters were analysed to determine the status of well water in Pasir Puteh, Kelantan, Malaysia, including DO, BOD, COD, NH$_3$N, pH and TSS. The results revealed that well water in the study region meets the standards specified in the Malaysian DOE WQI for almost all of the analysed parameters. However, the overall well water quality under four different types of land use in Pasir Puteh can be classified as moderately contaminated or Class III, with WQI values ranging from 66 to 74.5. As such, although this water can be used as drinking water it requires further treatment before consumption, being suitable only for agricultural irrigation and fishery activities if untreated. Continuous monitoring of well water quality in the study area must therefore be conducted, as some locals continue to use the well water as a source for their domestic water supply.

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