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NITRATE IN GROUNDWATER: DETERMINING ASSOCIATED HEALTH RISK AMONG RESIDENTS IN TUMPAT, KELANTAN USING HAZARD QUOTIENT (HQ) CALCULATION

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ABSTRACT

Objective: The aim of this study was to determine the levels of nitrate in groundwater and health risk assessment in Cherang Melintang village in Tumpat, Kelantan, located in north-east of Peninsular Malaysia.

Method: A cross-sectional study was conducted in January 2020 to determine the associated health risk due to nitrate exposure from groundwater usage. Data for this study were obtained from water analysis and questionnaires. Nitrate levels were determined using a portable pH/ORP/ISE meter Model HI98191 from Hanna Instrument with an attached nitrate electrode.

Result: Nitrate in all water samples did not exceed the maximum acceptable level in drinking water (10 ppm). Mean nitrate level was 2.91 ± SD 2.57 ppm, while the range was between 0.42 – 8.78 ppm. In addition, mean for age and depth of wells as well as distance of wells from source of nitrate was 3.24 ± SD 1.8 years, 2.40 ± SD 0.78 m and 14.04 ± SD 8.42 m. Hazard Quotient (HQ) for all respondents were found to be less than 1 (HQ < 1).

Conclusion: Residents in Cherang Melintang village are exposed to groundwater with safe levels of nitrate and therefore, can expect no adverse health impact due to the pollutant.

Keywords: *Nitrate, Groundwater, Hazard Quotient, Kelantan*

1. Introduction

Nitrate and nitrite are contains natural ions which are component of the nitrogen cycle. The nitrate ion NO_3^- is the stable form of combined nitrogen for oxygenated systems (Guidelines & Quality, n.d.). Nitrogen in water can initiate from both natural and anthropogenic source that may penetrate surface water and reach groundwater. But, compared to the agricultural sector, natural sources contribute minimally to high water nitrate levels. Excessive use of nitrogen-based fertilizers, degradation of nitrogen waste products in human and animal waste, including septic tanks is the source of nitrate which is from natural sources (WHO Guidelines for Drinking-water Quality). Nitrate can easily move through water and soil when there is excessive rainfall and excessive nitrate from agricultural fertilizer.

Nitrogen is an important nutrient that is needed for agriculture. In addition to fertilizer, nitrogen occurs naturally in the soil in organic forms from decaying plant and animal residue. Throughout the soil, the bacteria convert different types of nitrogen to nitrate, a nitrogen/oxygen ion NO_3^- is beneficial, because most of the nitrogen used by plants is consumed throughout nitrate form.

When high amount of inorganic nitrogen is use as fertilizer in a rice cultivation, the fertilizer will be decomposed to an ammonia and it will be oxidized to nitrite and nitrate (Guidelines & Quality, n.d.). Nitrogen from fertilizer will easily move to the groundwater and high concentrated nitrate in groundwater will affect the residents who use groundwater as their drinking water source. Residents who use well water (groundwater) as their source of drinking water will be higher probability to expose to higher level of nitrate because they use it without any treatment and monitoring (Shamsuddin, Norkhadijah, Ismail, Abidin, & Bin, 2018). The health issues related to high concentration of nitrate in drinking water to human health is methemoglobinemia among infant under 6 months and cancer in digestive tract of adults (Guidelines & Quality, n.d.). Methemoglobinemia among infant is cause by use of excessive concentrations of nitrate by mistake or as a medical procedure (Jaturong at al., 2015).

Health risk assessment and determination of nitrate concentration has been conducted to assess whether villagers have been exposed to the disease. Nitrate concentration was determined by using water sample from each residents' house that are directly from well by using High Density Polyethylene (HDPE) bottle and replicated by two times. Then, the nitrate level in the water sample will be analysed by using Portable PH/ORP/ISE Meter model HI98191 and Probe Model HI4113. The questionnaire was given to the respondent to collect the information.

2. Materials and Method

2.1 Description of Study Area

This study was carried out in Cherang Melintang village at Tumpat, Kelantan (latitude 6°14N and 6°09N and longitudes 102°14E and 102°07E). Tumpat district is located at northern part of Malaysia and it is the smallest district in Kelantan with an area encompassing 177 km^2 and a population of 147,179 people (2010 census). Cherang Melintang village had a population of 3,522 people with 740 living quarters (Majlis Daerah Tumpat, 2019).

2.2 Sampling Method

The sampling method used in this research was purposive sampling. Respondents were chosen based on the inclusive and exclusive criteria. They were limited to residents using groundwater as their primary source of drinking water supply and did not use any type of water filtration systems. A set of questionnaires was used to collect socio-demographic and groundwater information.

2.3 Study Instrument

Information on respondents and residential areas were obtained by using the questionnaire that was completed by the respondents themselves. Well characteristics information such as age and depth were also obtained by filling up the same questionnaire. Global Positioning System (GPS) was used to determine the distance of well from nitrate sources.

Water samples were obtained from each sampling site using a pre-cleaned High Density Polyethylene (HDPE) bottle and samples were taken twice. Nitrate levels were determined using a portable pH/ORP/ISE Meter Model HI98191 and Probe Model HI4113, both from Hanna Instrument.

2.4 Health Risk Assessment

To calculate the health risk of respondents due to the exposure of nitrate in groundwater, the Average Daily Dose (ADD) formula was used as follow (U.S. EPA Region 6, 2005);

$$ADD = C \times IR \times EF \times \frac{ED}{(BW \times AT)}$$

where,

C = Nitrate Concentration (mg/L)
IR = Intake rate (1L/day for children and 2L/day for adults)
EF = Exposure Frequency (365 day per year)
ED = Exposure Duration (6 years for children and 30 years for adults)
BW = Body Weight (15 kg for children and 60 kg for adults)
AT = Average time (365 days/year x 6 years for children and 365 days/year x 30 years for adults)

Next, Hazard Quotient is calculated to estimate the non-carcinogenic risk which the respondents are exposed to as follow;

$$HQ = \frac{ADD}{Rfd}$$

Where,

ADD= the sum of nitrate intake via drinking water
Rfd = Nitrate reference dose which is 1.6 mg/kg/day (IRIS 2012).

An HQ value > 1 indicated a significant non-carcinogenic risk level (U.S. EPA Region 6 2005).

3. Results

3.1 Nitrate Levels in Groundwater

The value that was used for data collection was in nitrate (NO3-) level. Table 1 shows the mean nitrate level was 2.91 ± SD 2.57 ppm, ranged between 0.42 – 8.78 ppm. Overall, nitrate level was below the maximum acceptable value which is 10 mg/L nitrate- N.

3.2 Comparison of Nitrate Level in Groundwater sample with the National Standard

According to the National Drinking Water Quality (NDWQ) standard, the maximum acceptable nitrate level in drinking water is 10mg/L. Nitrate concentration for all samples were below the maximum acceptable value of NDWQS (Figure 2).

3.3 The Association between distance of well from source of nitrate with nitrate level

Distance of well from source of nitrate (meter) and nitrate levels ($p < 0.05$) were significantly correlated at the coefficient of correlation, $r = - 0.40$. The age of well (years) and depth (meter) were not significantly correlated with the nitrate levels ($p > 0.05$) (Table 1).

3.4 Health Risk Assessment

The Hazard Quotient (HQ) was calculated to estimate the non-carcinogenic risk which the respondents exposed. The result of Hazard Quotient (HQ) showed that Hazard Quotient (HQ) was less than 1 (HQ < 1) for all respondents (N = 50). This indicated that the risk of nitrate exposure through groundwater consumption was at acceptable level.

4. Discussion

Data collection was conducted during the rainy season, therefore this may result in excessive surface water impacting nitrate concentrations in groundwater. Ki et al., (2015) stated that the level of nitrate in groundwater was dominated more through hydrological processes than through biochemical process which is seasonally variable rainfall and irrigation patterns.

Even though the concentration of nitrate was below than maximum acceptable value, the data for nitrate level in Cherang Melintang village nearly exceeded the maximum acceptable value. This is because the data collection was conducted during rainy season which will affected the concentration of nitrate in groundwater when nitrate was accumulated in the soil during the dry season can be transported to the groundwater. (Ki et al., 2015).

Besides that, most of the wells at Cherang Melintang village was built near the septic tank, which is one of the source of nitrate contamination in groundwater. A study in Mashhad, Iran, found that urea hydrolysis in human waste was the main cause of nitrate pollution (Zendehbad et al., 2019). This is because urea hydrolysis in human sewage undergoes the NH4+ nitrification cycle and result in nitrate accumulation in groundwater.

In Malaysia, the nitrate level standard as stated in the Malaysian National Drinking Water Quality Standard (NDWQS) is 10 mg/L nitrate-N. Based on the data collected in January 2020, nitrate levels in the study area's groundwater was below the Malaysian National Drinking Water Quality Standard (NDWQS) Maximum Permissible Limit and the USEPA International Standard (10 mg/L) (Jamaludin et al., 2013). Besides that, a similar study conducted at Bachok and Kota Bharu, Kelantan by Alif & Shaharuddin (2014) and Amirah et al., (2014) also stated that nitrate levels in groundwater did not exceed the maximum level of nitrate in drinking water stated by the National Drinking Water Quality Standard (NDWQS).

Nitrate absorption by crops through nitrate fertilizers as a nutrient is responsible for nitrate levels in groundwater. However, low concentration of nitrate in the groundwater was possibly due to the rainfall during the sampling where potentially wash of the fertilizer from the crops and prevents the leaching of excess nitrate into groundwater (Jamaludin et al., 2013). Shams et al. (2009) stated that the weather factor should be considered because it could affect chemical (nitrate) concentration in groundwater. Furthermore, data was collected during the rainy season which may affect nitrate accumulation in groundwater (Ki et al., 2015).

Data analysis showed that there was no significant correlation between age and depth of wells with nitrate level. These findings were different from study conducted by Lasagna et al., (2016) that increasing in depth of wells will reduce nitrate concentration in the groundwater. It is because water is drawn from a shallow aquifer for domestic and agricultural use that is exposed to a high risk of nitrate due to human activities on the soil (Shamshuddin et al., 2013). Furthermore, deep wells usually experience low nitrate concentrations due to a high level of protection of natural surface pollutants relative to shallow aquifers. (Lasagna et al., 2016). In addition, a study conducted at San Joaquin Valley in California by Lockhart et al., (2013) showed that nitrate levels decrease significantly as well as increase in depth. Besides, the data for age of well shows that it was no significant correlation with level of nitrate in groundwater which is in line with the analysis carried out by Shaharuddin et al., (2019).

On the other hand, there was a significant correlation between the distance of wells from the source of nitrate with a strong negative linear correlation. Previous studies by Nemc & Jazbec, (2017), Huan et al., (2020) and Nemčić-Jurec et al., (2013) stated that there was a significant correlation between distance of wells and the point source of nitrate pollution. It was also stated that nitrate levels in groundwater at 6m from the source of nitrate was twice higher compared to wells located 60m from the contamination.

4.4 Health Risk Assessment

From the result obtained, mean Average Daily Dose (ADD) estimation for the respondents was 0.09 ± SD 0.08 mg/kg/day and ranged between 0.01 – 0.29 mg/kg/day. The results were then used to calculate Hazard Quotient (HQ) using the equation stated beforehand. The Hazard Quotient (HQ) values for all respondents were less than 1 (HQ<1). This indicated that the risk was tolerable to all respondents.

A study conducted by (Pawełczyk, 2012) also stated that the Hazard Quotient (HQ) for all respondents who consumed drinking water contaminate with nitrate is below than 1, so this indicated that there is no risk from nitrate exposure to the respondents. Besides, a study conducted at Bachok, Kelantan also stated that the groundwater is safe for consumption in case of nitrate exposure because the Hazard Quotient is below than 1. (Aida Soraya, 2018).

5. Conclusion

This study found that the nitrate level in drinking water at Cherang Melintang village, Tumpat Kelantan was below than maximum acceptable value of 10 ppm. The result obtained for Hazard Quotient (HQ) for all respondents was below than 1 and this shows that in the case of nitrate, residents in Cherang Melintang village can still consume drinking water source from groundwater. This also shows that there was no adverse health effect on residents due to exposure to nitrate. However, the nitrate content of groundwater varies from time to time and must be checked at regular intervals.

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Conflicts of Interest

The author declares no conflict of interest.

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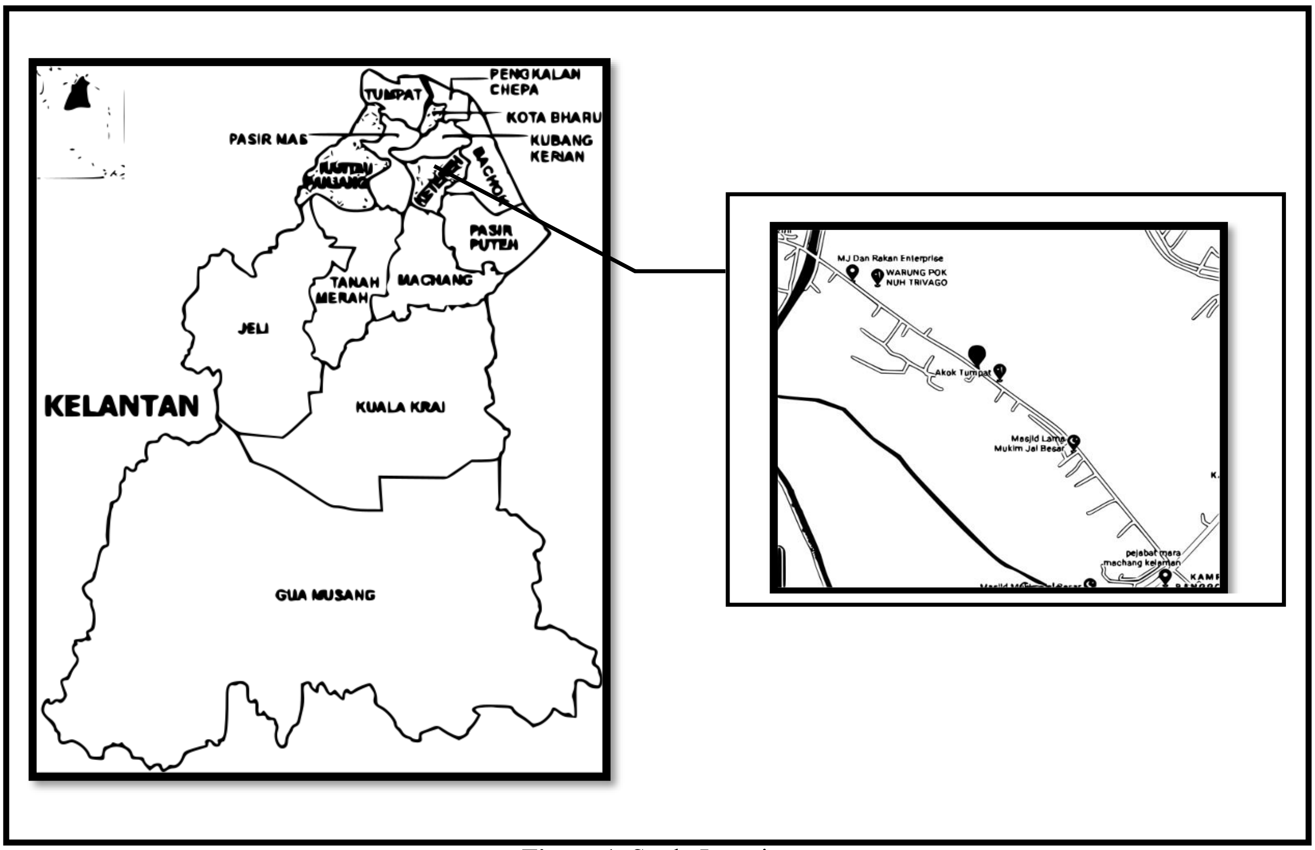

Figure 1: Study Location

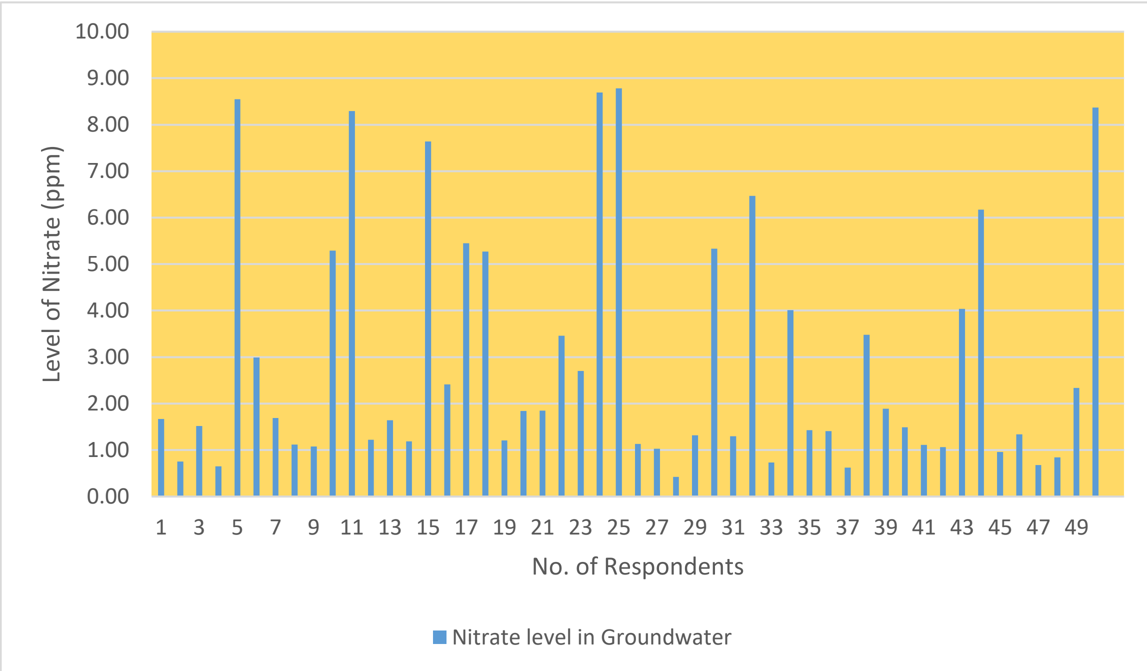

Figure 2: Comparison of Nitrate Level (ppm) with National Drinking Water Quality Standard

Table 1: Nitrate level in groundwater and correlation test for variables

Variables		
Nitrate	***Mean ± S.D (ppm)***	2.91 ± 2.57
	Range (ppm)	0.42 – 8.78
Relationship between distance from source of nitrate with nitrate concentration	r-coefficient	- 0.40 (p = 0.04)
Relationship between age of wells with nitrate concentration	r-coefficient	0.25 (p = 0.81)
Relationship between depth of wells with nitrate concentration	r-coefficient	- 0.37 (p = 0.79)