Asia Pacific Environmental and Occupational Health Journal (ISSN 2462 -2214), Vol 3 (2): 20 – 24, 2017

Nitrate (NO_3^-) In Groundwater: A Health Risk Assessment At Two Villages In Mukim Tualang Salak In Bachok, Kelantan

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ABSTRACT

Objectives: To determine nitrate levels in groundwater and to perform health risk assessment from nitrate exposure among residents in Mukim Tualang Salak, a subdistrict in Bachok, Kelantan.

Method: This study was conducted among residents from two villages, namely Tualang Salak village and Kuchelong village in Mukim Tualang Salak. Fifty (50) respondents were chosen based on the inclusive and exclusive criteria and they were initially interviewed in order to obtain demographic data and groundwater usage information. Groundwater samples were taken from each of the respondent's house who used groundwater exclusively for drinking and cooking. The samples were then analyzed using a HACH brand DR 1900 direct reading spectrophotometer. Risk assessment of the exposure to nitrate was also calculated.

Result: Nitrate levels ranged from 0.4 to 6.5 mg/L, with a mean of 1.834 $\pm$ SD 1.335 mg/L. All readings obtained did not exceed the national standard and there was no significant risk of nitrate contamination in groundwater (where HI <1).

Conclusion: Residents from the two villages studied were exposed to low levels of nitrate in groundwater and in the case for nitrate, it was safe to be used for drinking and cooking.

Keywords: *Agriculture, nitrate, groundwater, methemoglobinaemia, carcinogenic, health risk assessment.*

1. Introduction

Nitrate (NO_3^-) is a main ingredient of inorganic fertilizers and in Malaysia, they are used to increase production of various crops. It also involves massive use of pesticides and herbicides. Nitrate can reach both surface and groundwater as a consequence of agricultural activities.

In addition, nitrate is one of the most common contaminants in groundwater that originate from either fertilizers or raw sewage that leads to contamination of groundwater. Usually, urea (CH_4N_2O) and NPK (N=nitrogen, P=phosphorus, K=potassium) fertilizers are used to support plant growth.

Groundwater (well water) is commonly used by villagers in Kelantan for their daily needs. The groundwater can be contaminated with nitrate when the fertilizer leaches into the soil and enters the level where most of the groundwater is present. Therefore, using that water for drinking and cooking may pose a health threat to those who consume it. Nitrate may affect human health when its level exceeds 10 mg /L of NO_3N, and one of them is blue baby syndrome or cyanosis (United States Environmental Protection Agency, 2013).

The residents of Bachok district are highly depended on well water for domestic use due to limited piped water supply in that area. The problem to be highlighted here is whether the level of nitrate in well water studied is safe for drinking and cooking. Some parts of rural Kelantan, especially in Bachok, are equipped with the rural water supply system, in which residents use groundwater as the main water source (Siti Halwani, 2012).

2. Materials and Method

2.1. Description of study area

The study location chosen was Mukim Tualang Salak, Kelantan which consists of Tualang Salak and Kuchelong villages (Figure 1).

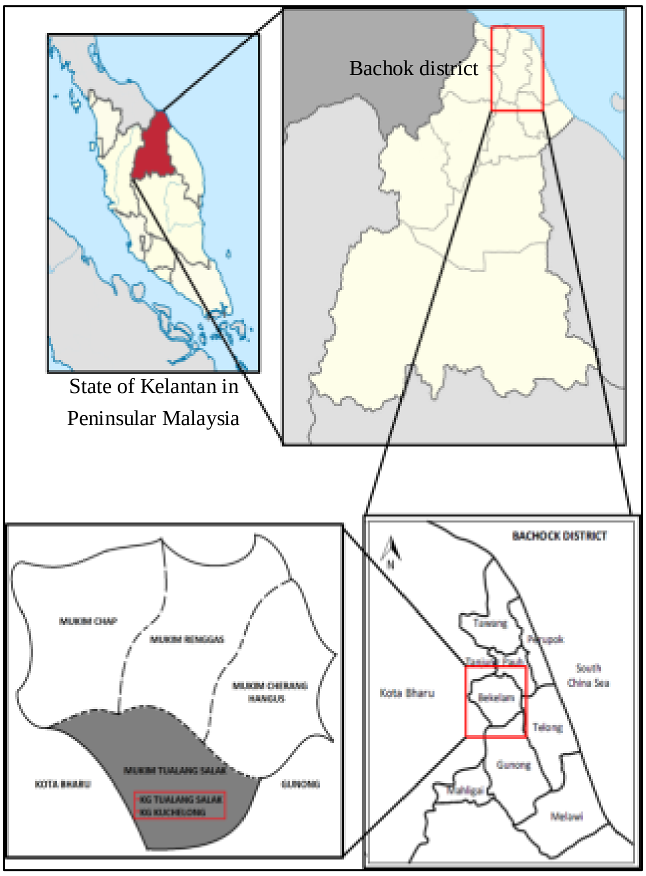

Figure 1. Map showing location of study areas

Most of the residents still rely on groundwater for their daily needs. These two villages were chosen because paddy planting is the main economic activity and most of the houses are located near the paddy fields. The sampling method used in this study was purposive sampling. The respondents were selected based on the inclusion and exclusion criteria. For the inclusion criteria, respondents were aged 18 years old and above, a lifelong resident of the villages and use groundwater exclusively as their main source of water supply. The exclusion criteria included having a water source other than groundwater and using water filtration systems.

2.2. Well water sampling and analysis

The well water was collected and stored into high density polyethylene (HDPE) bottles. Three (3) replicates of water samples were collected in order to obtain the average value of nitrate levels. The water samples were analyzed using a HACH brand DR/1900 direct reading spectrophotometer. A questionnaire was used to collect demographic and nitrate exposure data.

2.3. Statistical analysis

Data collected was analyzed using IBM SPSS (Statistical Package for Social Science) version 22. Descriptive statistic including mean, median, and standard deviation was used to analyze the distribution of all variables in this study. Statistical analysis used were Independent T-test in order to compare nitrate level of water with the standard limit value and Mann-Whitney U test, used to determine the relationship between nitrate levels with the various sampling locations.

2.4. Health risk assessment

Chronic Daily Intake (CDI) was used to calculate the health risk associated with nitrate exposure in well water, using the following equation:

$$CDI = (C \times DI)/BW \qquad \text{Eq. 1}$$

Where,

CDI=Chronic Daily Intake (mg/kg/day),

C = nitrate level in groundwater (mg/L),

DI = average daily intake rate of water (L/day) and

BW is body weight (kg).

For non-carcinogenic health effects posed by nitrate in drinking water, the Hazard Index (HI) was calculate by using the following equation:

$$HI = CDI / RfD \qquad \text{Eq. 2}$$

Where,
CDI = Chronic Daily Intake (mg/kg/day)
Rfd = reference dose (mg/kg/day).

If the HI value is more than 1 (HI>1), that would show a significant risk level. The higher the value, the greater the likelihood of adverse non-carcinogenic health impact. The RfD value is 1.6 mg/kg/day (United States Environmental Protection Agency, 2000).

3. Results

In this study, the total numbers of respondents was 50, and was equally divided among the two villages. All respondents were Malay.

3.1 Nitrate levels in groundwater

The mean nitrate level was 1.834 ± SD 1.335 while the range was 0.4 to 6.5 mg/L (Table 1).

Table 1. Nitrate levels in groundwater (n=50)

Variable	Mean± SD (mg/L)	Range (mg/L)
Nitrate	1.834 ± 1.335	0.4 to 6.5

3.2 Comparison of nitrate levels between different study locations

The results obtained showed that Tualang Salak Village had the higher mean nitrate level (2.044 ± SD 1.573 mg/L) compared to Kuchelong Village (1.624 ± SD 1.075 mg/L). Please refer to Table 2. In this study, nitrate levels between sampling sites in both villages were compared using Mann-Whitney U test. As the p-value is more than 0.05 (0.179), this indicate that there was no significant difference in nitrate levels among different sampling sites.

Table 2. Nitrate levels in groundwater between different study locations (n=50)

Village	No. of samples	mean ± S.D (mg/L)	Range (mg/L)	p-value
Tualang Salak	25	2.044 ± SD 1.573	0.50 - 6.50	0.179
Kuchelong	25	1.624 ± SD 1.075	0.40 - 4.40	

* p is significant when <0.05

3.3 Comparison of nitrate levels to NDWQS

With regards to the National Drinking Water Quality Standards (NDWQS) of Malaysia, the maximum concentration limit (MCL) for nitrate is 10 mg/L (Engineering Services Division, Ministry of Health Malaysia, 2016). Figure 2 indicates that nitrate levels from all sampling sites were below 10 mg/L.

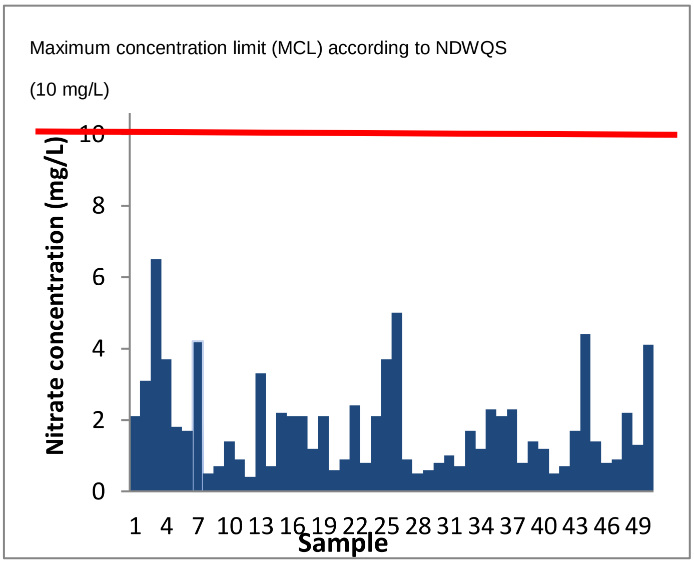

Figure 2. Comparison of nitrate levels with NSDWQ

4. Discussion

In this study, the mean nitrate level (read as NO_3-N) level was 1.834 ± SD 1.335 while the range was 0.4 to 6.5 mg/L. This amount is considered as a safe level of nitrate in groundwater. The maximum allowable level for nitrate is 10 mg/L for nitrate nitrogen (NO_3-N) in public- or groundwater supplies (Engineering Services

Division, Ministry of Health Malaysia, 2016). This would be equivalent to 44 mg/L of nitrate (NO_3^-). However, the level of nitrate can increase due to a few factors including use of fertilizers and waste disposal especially from animal farms and septic tanks (Haycock, 1990). Irrigated agriculture practices utilize huge amounts of fertilizers, which may lead to groundwater contamination (Kamaludin, Rahim & Radam, 2013).

Low levels of nitrate found in this study are most probably caused by the rainy season. Peninsular Malaysia received an additional 20% more rainfall in the month of February 2017, especially in northern Kelantan. The expected amount of monthly rainfall was slightly above the current average (Malaysian Meteorological Department, 2017). During the rainy season, nitrogen is primarily lost on the surface (Hussain et al., 2013). Due to the high rainfall in February, the applied nitrogen was denitrified in the top zone of the soil profile. The high rainfall did not only stimulated denitrification but also caused dilution of the nitrogen content in the groundwater at the lower depth after the relatively dry month (Wang at al., 2015). In addition, nitrate that accumulates in the soil during the dry season (January 2017) may cause decreased mobilization of nitrate into stream and groundwater, thus resulting in lower nitrate levels in groundwater (Canadian Council of Ministers of the Environment (CCME), 2009).

4.1 Comparison of nitrate levels between sampling locations

Results showed that samples from Tualang Salak Village has the highest mean of nitrate level compared to those from Kuchelong Village. The quantity or rate of fertilizer application during the previous season might be another factor. The leaching process of excess nitrate into the groundwater might have happened. Excessive fertilizer application will lead to nitrate pollution of groundwater (Kamaludin, Rahim & Radam, 2013). However, it was found that there was no significant difference of nitrate levels between all sampling locations ($p>0.05$).

4.2 Comparison of nitrate levels to NDWQS

In this study, the mean nitrate level was 1.834 ± SD 1.335 mg/L while the range was 0.4 to 6.5 mg/L. A previous study by Alif Adham and Shaharuddin (2014) also reported a similar trend that all nitrate levels did not exceed 10 mg/L.

4.3 Exposure and health risk assessment

Chronic daily intake (CDI) data was used to estimate individual daily exposure of nitrate (United States Environmental Protection Agency, 2013). HI values for all respondents were less than 1 and this indicated the risk of adverse effect of nitrate pollution in groundwater in the study areas was negligible. A study by Noraziah, Shaharuddin and Sharifah Norkhadijah (2013), also in Bachok district, found that the Hazard Index of respondents exposed to low levels of nitrate (mean 1.66 ± SD 2.11 mg/L, range 0.0 – 9.6 mg/L) in groundwater was less than 1.

5. Conclusion

Nitrate levels between sampling sites in Tualang Salak Village and Kuchelong Village have no significant difference among each other. The highest reading of nitrate level was 6.5 mg/L and it is still safe because it did not exceed the level that may cause adverse health effects. Hence, groundwater in these two villages is considered safe for drinking and cooking purposes. In addition, Hazard Index (HI) obtained was below 1 which may indicate that there is no adverse effect due to nitrate exposure. However, villagers and everyone using groundwater should be concerned about nitrate levels due to increased usage of fertilizers and the leaching into groundwater systems.

Acknowledgement

The authors would like to thank respondents from Tualang Salak and Kuchelong villages for their participation, and Universiti Putra Malaysia for supporting this research.

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