Health Risk Associated with Nitrate Exposure from Groundwater Intake Among Respondents of Keting Village, Bachok District, Kelantan State, Malaysia

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ABSTRAK

Nitrate is one of the compounds of nitrogen found in the nitrogen cycle that is which originates from both natural and anthropogenic sources. Most rural areas in Kelantan state still depend on well water as their primary water source. Their main economic activity is agriculture which uses high amountsof nitrate fertilizer to nurture their crops. The increased use of nitrate fertilizers has a possible risk factor associated to health problems such as methemoglobinemia and cancers. Health risk assessment can be conducted to quantify the probability of harmful effects of nitrate to individuals or populations from certain human activities. To determine levels of nitrate in groundwater and to perform health risk assessment among respondents in Keting village, Bachok district, Kelantan state. A total of 47 respondents were chosen for this study and groundwater samples in duplicates were collected from the respondents' houses. The samples werethen analyzed by using a portable Hanna Instrument multimeter model HI98191 and probe model HI4113. while a set of questionnaireswereusedto collect information for health risk assessment of the exposure. Nitrate levels in groundwater did not exceed the maximum concentration value of Drinking Water Quality Standard (44.3 ppm nitrate – NO3) with a mean ± sd of 5.34 ± 4.94 (ppm). Spearman's rho correlation analysis shows that only depth of well (meter) is correlated (r = - 0.348) to nitrate levels (p<0.05). The Hazard Quotient (HQ)for the study population was less than 1. In terms of nitrate, the groundwater analyzed in the study area was considered safe for drinking and cooking purposes. The result for HQ indicated that the non-carcinogenic risk related to nitrate was not significant to the study population. However, nitrate levels in drinking water should be concerned by the consumers as it will give bad health impact to them in long-term exposures.

Kata kunci: Nitrate, Groundwater, Maximum Concentration Value, Hazard Quotient

INTRODUCTION

Nitrate is an inorganic compound that is made up from nitrogen and oxygen, NO_3^- (one nitrogen and three oxygen molecules) (Nitrate, 2018) and it is soluble in water, easily leaches through soil and then it accumulates in groundwater (Jaturong et al., 2015). Over the last century, nitrogen cycle dramatically altered by human activities and causes nitrate (NO_3^-) accumulating in water resources such as in groundwater and surface water (Aida Soraya et al, 2014).Some of the human activities that contributed to the contamination of nitrate are agriculture activities, farming activities, industrial activities, disposal of solid waste and etc. Based on Aida Soraya et al. (2016) stated that many studies showed there is correlation between contamination of nitrate with agriculture activities due to the extensive use of nitrate fertilizer. Furthermore, short distance of well water from agriculture activity potentially increase the contamination of nitrate in drinking water.

Nitrate contamination in groundwater is induced due to anthropogenic activities including the use of nitrogen fertilizer, animal

waste and organic manure (Ako et al., 2014). Some of the possible sources of nitrate in groundwater including animal feedlots, nitrogen – containing fertilizers and improper disposal of sanitary wastes (Edokpolo et al., 2016). Nitrate contaminates the groundwater by excessive use of fertilizer that leaches into the soil and migrate to the level where most of the groundwater is present. Physical processes such as rain and irrigation induce nitrate infiltration through the soil down to the water table before entering the groundwater (Vinod, Chandramouli & Koch, 2015).

A significant concern about nitrate that present in drinking water is contamination of nitrate can lead to health problem such as methemoglobinemia among infants and cancers in digestive tract of adults. Age, gender, genetics or other health condition are the factors of severity of methemoglobinemia and infants under 6 months is susceptibility to this syndrome (Jaturong at al., 2015). Moreover, women during first trimester of pregnancy probability will having birth defects due to the exposure of high nitrate content in drinking water from groundwater (Brender et al., 2013). In addition, Parvizishad et al. (2016), mentioned that if consuming drinking water and food that contain high nitrites and nitrates level can cause health effects such as methemoglobinemia, cancer, diabetes mellitus, enlargement of the thyroid gland and so on. Plus, the study also mentioned that nitrate and nitrite have positive effects at low concentration such as maintain blood pressure regulation, as a protective effect on cardiovascular system, and maintain homeostasis (the stability) of vessels in the body.

Health risk assessment is the process to evaluate the probability of adverse health effect in human due to exposure to an environment stressor (United States Environmental Protection Agency, 2016). Health risk assessment also play an important role in health promotion and disease prevention both in individually and population level since 1950s (Orlando et al., 2018). According to theMalaysian Drinking Water Quality Standards, the maximum acceptable value in drinking water of nitrate-nitrogen (NO_3-N) are 10mg/L nitrate - N, or 44.3 ppm nitrate-NO_3.

In this study, Bachok district in Kelantan state is one of the districtswhere a large number of the population still use well water as the main source of water to fulfill their daily needs. They rely on groundwater (well water) due to limited piped water supply in the area (Muhamad Nur Fakhri and Shaharuddin, 2017). Furthermore, the wells are located near the agricultural areas such as tobacco, paddy, rubber plantation and orchards.So, the problem to be highlighted is whether the level of nitrate in groundwater at the study area is safe or not for drinking and cooking purposes. The data obtained were then compared withthe Malaysian Drinking Water Quality Standards and were also used to determine the HazardQuotient from exposure to nitrate in groundwater.

METHODOLOGY
Description of Study Area
The study location was located at Keting village, Bachok, Kelantan, Malaysia(Figure 1).The total population of Keting village is 1608 people and 262 houses with an area of 1.64 km². The sampling method that was used in this was purposive sampling and based on inclusive and exclusive criteria. The inclusive criteria were respondent with age 18 years and above, long live residents ($\geq$ 6 years), and use groundwater as their main source of drinking water supply. Respondent that used drinking water source other than groundwater and using water infiltration system was excluded in this study.

Well Water Sampling and Analysis
High density polyethylene (HDPE) bottles were used to collect and store well water samples. In order to get the average value of nitrate levels, the water samples were replicate by three (3) times. Then, the water samples were analyzed by using Portable PH/ORP/ISE Meter model HI98191 and Probe Model HI4113. Also, a set of questionnaire was used to obtain demographic and nitrate exposure data.

Statistical Analysis
IBM SPSS (Statistical Package for Social Science) version 22 was used to analyze the data. Statistical analysis used in this study was Spearman Correlation test to determine the association between age of well, depth of well,

and distance of well from paddy field with nitrate level.

Health Risk Assessment

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

CDI= (C ×DI)/BW
Where,
CDI= Chronic Daily Intake (mg/kg/day),
C = Nitrate level in groundwater (mg/L),
DI = average daily intake rate of water (L/day),
BW = body weight (kg)

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

HQ= CDI/RfD
Where,
CDI = Chronic Daily Intake (mg/kg/day)
RfD = Reference dose (mg/kg/day)

If the HI value show more than 1 (HI>1), it is show that there is a significant risk level. The higher the value, the greater the likelihood of adverse non-carcinogenic health impact. RfD value for nitrate in this study is 1.6mg/kg/day (United States Environmental Protection Agency, 2017).

RESULTS AND DISCUSSION

Total respondents who participated in this study was 47. The collection of data was conducted from 26 January 2019 until 03 February 2019. During that time, it was paddy pre-planting season in Bachok district.

Nitrate Levels in Groundwater

In this study, the mean ± SD of the nitrate level was 5.34 ± 4.94 ppm, while the range was from 0.40 ppm to 23.65 ppm (Table 1).

Table 1
Nitrate Levels in Groundwater (n=47)

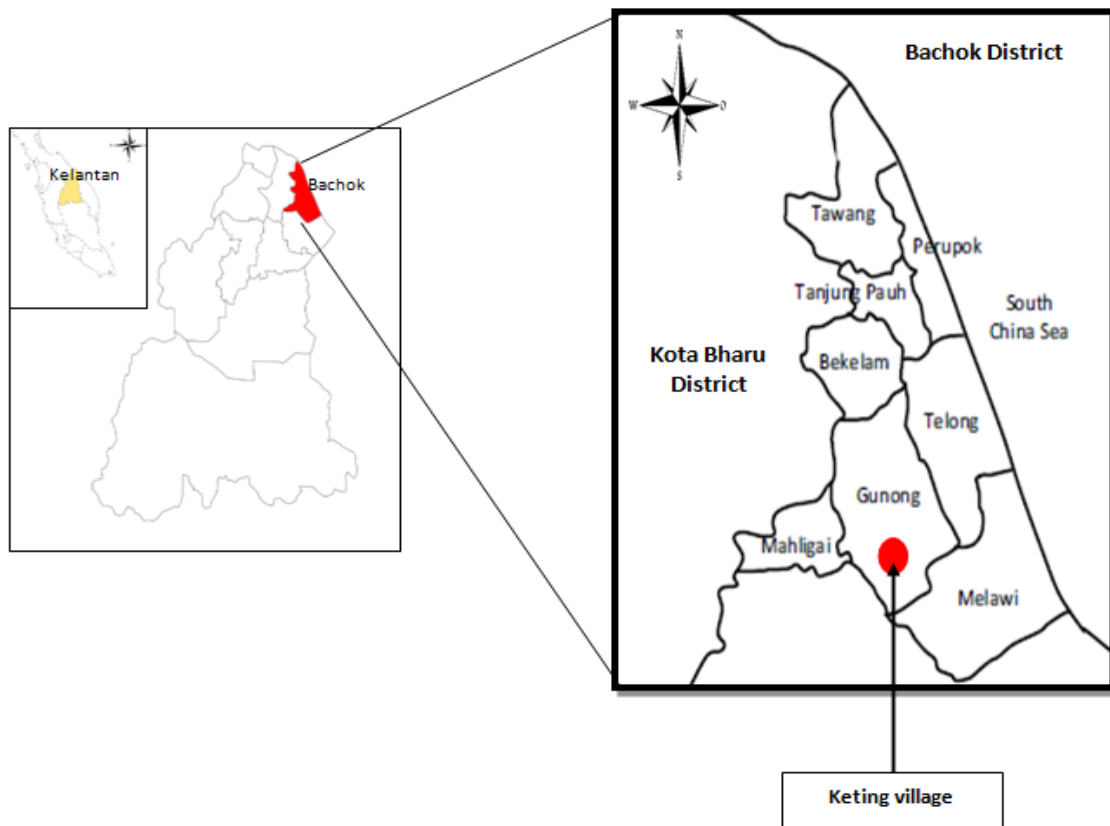| Variable	Mean ± SD (ppm)	Range (ppm)
Nitrate	5.34 ±4.94	0.40 – 23.65

Source: Processed Data

Figure 2
Study Location

The Association Between Age of Well, Depth of Well and Distance of Well from Paddy Field with Nitrate Level

The characteristics of wells (age, depth and distance of well from paddy field) and the association with nitrate level is shown in **Table 2**. In this study, the test that was used to find the association between the age of well, the depth of well and the distance of well from paddy field with nitrate level is Spearman Correlation test. Both age (years) and distance (meter) had no significant association with nitrate levels (p>0.05). However, there is a significant association between depth(meter) and nitrate level (p < 0.05) with correlation coefficient, r = -0.348 (**Table 3**).

Table 3
Spearman Correlation Test

Variable	N = 47	
	r	p - value
Age(years)	0.03	0.84
Depth (meter)	-0.348	0.017
Distance from source (meter)	0.226	0.127

Source: Processed Data

Comparison of nitrate levels with Malaysian Drinking Water Quality Standards (DWQS)

Referring to the Malaysian Drinking Water Quality Standard (DWQS), the maximum acceptable value for nitrate in drinking water is 10 mg/L nitrate - N, or 44.3 ppm nitrate- NO_3. Based on Figure 2, it showed that nitrate level from all sampling sites were below the maximum acceptable value of DWQS.

Health Risk Assessment

Table 4 shows the result of Chronic Daily Intake (CDI) estimation of the respondents. It shows that, the mean ± SD for CDI was 0.11 ± 0.10 (mg/kg/day) and ranged between 0.01 – 0.41 (mg/kg/day).The result in Table 5 showed that the Hazard Quotient (HQ) was less than 1 (HQ< 1) for all respondents. This indicates that the health risk related to nitrate contamination is not significant to the respondents.

Discussion
Nitrate Level in Groundwater

Regarding to the results of nitrate level, the mean ± SD of nitrate level was 5.34 ± 4.94 ppmand the maximum level of nitrate was 23.65 ppm nitrate – NO_3 which is still below than maximum acceptable value. Although the highest level was less than maximum acceptable value, consumption of excess nitrate through drinking water could pose serious health risk and toxicity in humans (Ahada & Suthar, 2018).

Data collection was conducted during main season, which was from August to February every year (Kemubu Agricultural Development Authority, 2018). Surface water was used as the main source of water to irrigate for paddy cultivation during this season. Noraziah et al. (2013) stated that nitrate level will increase in groundwater when the water table increased and also due to leachate of nitrogenous fertilizer into well water during rainy season.

Table 2
Age, Depth and Distance of Well from Nitrate Source

Variables	Frequency(%)	Mean ± SD (meters)	Range (meters)
Age of Well			
< 5 years	7 (14.9%)		
5 – 10 years	10 (21.3%)		
11 – 15 years	2 (4.3%)		
16 – 20 years	9 (19.1%)		
> 20 years	19 (40.4%)		
Depth of Well			
< 5 meters	0		
5 – 10 meters	28 (59.6%)		
11 – 15 meters	16 (34%)		
> 15 meters	3 (6.4%)		
Distance of Well From Paddy Field	47 (100%)	157.3 ± 102.1	20.0 – 500.0

Source: Processed Data
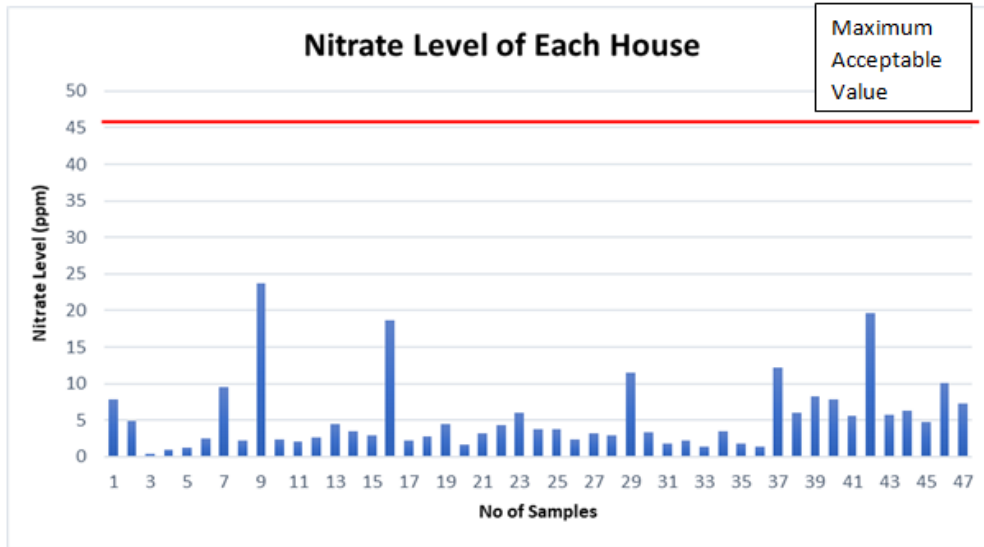
Source: Processed Data

Figure 3
Comparison of nitrate level with DWQS

Table 4
Chronic Daily Intake (CDI) Estimation

Variable	Nitrate level (ppm)	*DI (L/day)	*W (kg)	*CDI (mg/kg/day)
Mean	5.34	1.23	63.72	0.11
SD	4.94	0.25	12.59	0.1
Range	0.40 - 23.65	0.6 - 1.6	35.0 – 105.0	0.01 - 0.41

N = 47; *W = weight(kg); *DI = Daily Water Intake(L/day); *CDI = Chronic Daily Intake(mg/kg/day)
Source: Processed Data

In addition, two types of fertilizers used during paddy cultivation in Kelantan state are urea (46% N, 20% P, 10% K) and nitrogen compound (17% N, 20% P, 10% K) (Skim Baja Padi Kerajaan Persekutuan, 1998). These fertilizers can induce nitrate level in groundwater, especially those located near paddy fields. Muhamad Nur Fakhri and Shaharuddin(2017) also mentioned that nitrate fertilizers can contaminate the groundwater by leaching into the soil and enter the nearest groundwater.

Nitrate levels at all sampling sites were below than the standard and this may be due to the data collection which was during the paddy pre-planting period. During this time, fertilizer has not been applied and subsequently, this phase had the lowest reading of nitrate levels in groundwater compared to other phases, which is the planting and harvesting phases (Amirah, Shaharuddin & Sharifah Norkhadijah, 2014).

The Association Between Age of Well, Depth of Well and Distance of Well from Paddy Field With Nitrate Level

Based on the analysis, there was no significant association between age of wells and nitrate levels. This indicates that age did not contribute to nitrate contamination in this study. However, a study by Swistock, Clemens & Sharpe. (2009) had different results, where age of wells was related to nitrate levels in groundwater. The authors also stated that the older wells were typically shallowand may lead to nitrate-rich in water.

The analysis also shows that there was no significant association between distance of wells from paddy fieldswith nitrate levels. However, a previous study showed that agricultural activities have the potential to contaminate the groundwater. Aida Soraya et al.(2016), in a study, stated thatwellswith a distance below 50 meters to the livestock area may contained

high nitrate levels. Plus, groundwater flow direction also should be taken account which is an important factor in nitrate contamination (Koh & Kim, 2015). Therefore, the presence of high nitrate levels in groundwater may be due to factors such as atmospheric deposition, leaking sewers and discharge from the septic tank (Pastén-zapata et al., 2014).

In addition, depth of wells was the only variable that has significant correlation with nitrate levels in this study. The result obtained between these two variables was a negative and fair correlation (r = -0.348). This indicates that nitrate levels tend to decrease with increasing depth ofwells. This was consistent with previous studies where private and shallow depth wells contained higher nitrate levels (Khademikia et al., 2013) and more liable to contamination compared to deep wells due to anaerobic environment (Sahele, Zewdie& Narayanan, 2018).

Comparison of Nitrate Levels with Drinking Water Quality Standards (DWQS)

Each country has different standards for nitrate in groundwater to ensure that groundwater is safe to consumers. In Malaysia, the standard for nitrate level as stated in the Drinking Water Quality Standard (DWQS) is 10 mg/L nitrate - N, or 44.3 ppm nitrate-NO_3. Thus, nitrate levels found in this studywere below the standard.

From a previous study in Bachok and Kota Bharu districts, nitrate levels were within the acceptable limit and the health risk also were acceptable (Amirah et al., 2014). Another study by Alif Adham and Shaharuddin (2014) also stated that nitrate levels were below than the acceptable limit from all sampling sites in Pasir Puteh district, also in Kelantan state.

The variation of nitrate levels at different places were determined by various factors. Factors such as chemical fertilizers used in agriculture, urban activity and industrial development may result in effluent disposal and increase nitrate and sulphate level in groundwater (Devic, Djordjevic& Sakan, 2014). In addition, nitrate levelsin groundwater also depends on geological background, land-use pattern, soil-drainage capacity, and type of aquifer (Wongsanit et al., 2015).

Health Risk Assessment

Value of Hazard Quotient (HQ) for all respondents wereless than 1 (HQ<1). This indicates that the risk was acceptable to all respondents. This was consistent with a study by Noraziah et al. (2013), where the hazard quotient was less than 1 and it indicated that the risk was not significant. However, the resultsobtained were different from the study by Aida Soraya et al.(2016),where the Hazard Quotient (HQ) value that exceeds safe limit was 2.34% from study population. In that study, discharge from septic tanks and leaking sewers were identified as factors that contribute to the high levelsof nitrate in groundwater concerned.

CONCLUSION

Nitrate level were found to be below the maximum acceptable value of nitrate-NO_3 (44.3 ppm). The Hazard Quotient was less than 1 (HQ< 1). This indicate that there was no adverse health effect to the respondents due to nitrate exposure. However, the condition of nitrate in the groundwater will vary from time to time, especially during different phases of paddy planting. Thus, effort to minimize any further exposure of nitrate towards human as well as ecosystem and environment should be put as vital concern.

Table 5
Hazard Quotient estimation

Hazard Quotient (HQ)	No. of Respondent	Percentage (%)
HQ< 1	47	100
HQ> 1	0	0

Source: Processed Data

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