ORIGINAL ARTICLE

Association Between Nitrate Exposure in Groundwater and Its Health Risk Among Residents in Machang District, Kelantan

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ABSTRACT

Introduction: Nitrate (NO3-) in groundwater originates from natural sources or human-made activities, including agriculture and industries. Anthropological activities can contribute to a substantial increase and may lead to health problems, such as methemoglobinaemia. The purpose of this research was to identify the level of nitrate in groundwater in villages located near paddy fields and to ascertain health risk towards residents. **Methods:** This research was carried out in January 2020 involving three villages in Machang district in Kelantan state, located north-east of Peninsular Malaysia. A total of 74 respondents were recruited with an equal number of wells studied. Nitrate levels were identified using the Hanna Instrument multi-meter with the nitrate electrode attached. Age, depth of wells and distance from paddy fields were also recorded. Weight of respondents was measured to calculate the hazard quotient related to nitrate exposure. **Results:** Nitrate levels in groundwater did not exceed the maximum limit of 10 mg/L set by health authorities. It ranged from 0.56 to 6.58 mg/L with a mean ± SD of 2.25±1.26 mg/L. Most wells were more than 20 years old (83.78%) and more than 15m deep (44.59%). Distance from paddy fields ranged from 3 – 150 m with a mean ± SD of 73.78±38.82 m. Level of nitrate between sampling sites were not significantly different ($p > 0.05$). The same goes for other variables ($p > 0.05$). **Conclusion:** Hazard Quotient for all residents was less than 1 ($HQ < 1$), as they were exposed to low levels of nitrate.

Keywords: Nitrate, Groundwater, Health Risk, Hazard Quotient, Kelantan

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INTRODUCTION

Nitrate, NO_3- is a water-soluble inorganic compound, easily leachable and made up of one nitrogen and three oxygen molecules. Extensive use of nitrate fertilizer in crops has disrupted the nitrogen cycle and polluted groundwater (1). The largest contribution of nitrate in well water is the heavy use of nitrogen fertilizers in agriculture. Nitrate concentrations in groundwater are generally higher than surface water due to the highly leachable and readily movable nitrate characteristics, making it easy for excess nitrate to leak into groundwater (2). The nitrate contamination is less probable as the government located in deeper groundwater aquifers, whereas private wells are typically shallower and closer to nitrate contamination sources. The concentration of nitrate in groundwater are different even though the sampling sites are close to each other (3). Many studies have shown that there is a correlation between agricultural practices and nitrate levels in groundwater is caused by the widespread use of nitrate-nitrogen fertilizers (4). In addition, adverse health impacts may be suffered by residents that consumed groundwater that contaminated with nitrate as their daily lives. Some health problems are associated with gastric cancer, methemoglobinemia, non-Hodgkin's lymphoma, colorectal cancer, and gastrointestinal tract disease (5). Consumption of contaminated water can cause methemoglobinemia to the infants and can be carcinogenic to the body. A study done in Kenya recorded about 53.5% of groundwater users are getting the risk to methemoglobinemia with 11% of the samples are above 10 mg/L despite the maximum concentration limit for nitrate is at 10 mg/L as per stated by United States Environmental Protection Agency. Nitrate Ingestion brings much more risks towards health rather than the effects it brings to skin exposure. Infants and women are more susceptible to non-carcinogenic risk than in males (7).

Groundwater is the most reliable source of water for drinking, domestic and agricultural activities for the people of Kelantan, Malaysia (8). The aim of this study was to identify the levels of nitrate in groundwater in villages in Machang District and its health risk (by using the Hazard Quotient) to the consumers.

MATERIALS AND METHODS

Description of Study Area

This research was carried out in January 2020 before the paddy harvest season. The farmers have applied for compound fertilizers to ensure the crops' health. Pulai Chondong is a sub-district located in the north of Machang District, bordered by Ketereh sub-district in Kota Bharu District. The total area of Pulai Chondong sub-district is 54.98 Kilometre Square / 21.227 Square Stone / 13,585,853 Acres / 5,498 Ha.

Mukim Pulai Chondong is the largest area for agriculture (paddy fields and rubber) compared to other Mukim(s). This study is very much recommended to be conducted for its agricultural practices, usage of groundwater as the main source of drinking water for respondents, and the shortage of government water supply. The three (3) villages chosen were Kampung Belukar (5°51′56.0″N, 102°12′47.3″E), Kampung Mulong (5°52′16.7″N, 102°13′13.1″E) and Kampung Bukit (5°51′45.0″N, 102°14′19.0″E).

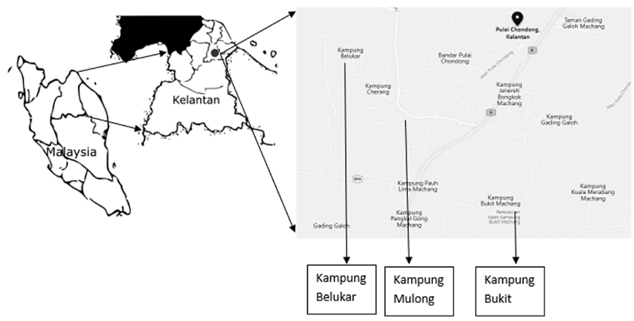

Fig. 1 : Location of Study Area. The study locations were chosen since many residents still rely on groundwater and are located adjacent to paddy fields. A total of 74 respondents were recruited with an equal number of wells studied.

Sampling Method

The method of sampling used was purposive sampling. The respondents were chosen based on the exclusive and inclusive criteria, including both males and females who are 18 years old and above and populations using groundwater as the primary source of water for drinking, cooking and another daily usage. On the other hand, populations who benefited from installed water filtration and other than groundwater systems were excluded. Total number of respondents enrolled was 74 with the equal number of wells studied. Each respondent represented each well for his/her house. Most of the wells were located near the house. All respondents were part of the local community that live near agriculture areas especially paddy fields.

Study Instrument

The respondents' health status and groundwater information were obtained by using self-administered questionnaires. No pre-test had been conducted since the questionnaires used in this study was adapted from a baseline, descriptive and time activity questionnaire used in the national human exposure assessment survey. Other information recorded were age and depth of wells, while distance of wells from paddy fields was measured by using Global Positioning System (GPS).

Water samples were collected from each respondents' house directly from the pipe into the bottles. Nitrate was determined using a HI98191 Professional Waterproof Portable pH / ORP / ISE Meter with an attached Ion-Selective Nitrate Combination Electrode (ISE) model HI4113. The value was used to determine Average Daily Dose (ADD) and Hazard Quotient (HQ).

Health Risk Assessment

To calculate the health risk of respondents due to the exposure of nitrate in groundwater, the Average Daily Dose (ADD) formulae was used (5).

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

Where,
C = Nitrate concentration (mg/L)
IR = Intake rate (1 L/day for children and 2 L/day for adults)
EF = Exposure frequency (365 day/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 = Averaging time (365 days/year × 6 years for children and 365 days/year × 30 years for adults)

Next, the Hazard Quotient (HQ) was used to determine the non-carcinogenic risk caused by ingestion.

$$HQ = \frac{AD}{RfD}$$

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

When the Hazard Quotient (HQ) value is more than 1 (HQ>1), the risk is significant. If the Hazard Quotient (HQ) value is less than 1 (HQ<1), the risk is not significant.

RESULTS

Nitrate Level in Groundwater

Table 1 shows the Mean ± SD for the nitrate level in groundwater for Kampung Belukar, Kampung Bukit and Kampung Mulong which were 1.92 ± 1.16, 2.51

± 1.40 and 2.26 ± 1.19, respectively with the range of 0.56 – 6.58 (mg/L).

Table : I Nitrate Concentration in Groundwater (N=74)

Variable	Mean ± SD	Range
Belukar Village (N=25)	1.92 ± 1.16	0.56 – 5.45
Bukit Village (N=24)	2.51 ± 1.40	1.07 – 6.58
Mulong Village (N=25)	2.26 ± 1.19	0.78 – 4.60

Comparison of Nitrate Level in Groundwater with National Standard

The National Drinking Water Quality Standard (NDWQS) is used for comparison purposes, where the maximum level allowed for nitrate is 10 mg/L. Fig. 2 shows that each sample did not exceed and were below the value of the national standard used.

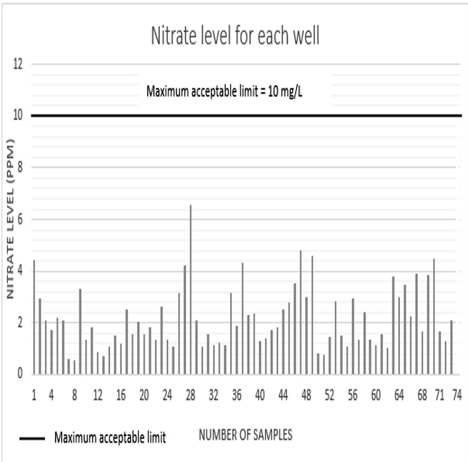

Fig. 2 : Nitrate Level in Groundwater for All Respondents. Nitrate level for each water sample collected was measured and analysed by using HI98191 Professional Waterproof Portable pH / ORP / ISE Meter with an attached Ion-Selective Electrode (ISE) HI4113 Nitrate Combination to determine whether the nitrate level exceed the maximum acceptable limit.

The relationship between the characteristics of well (age, depth of well and distance of well from paddy fields) and nitrate level in groundwater

Most wells were older than 20 years old (83.78%) and more than 15m (44.59%) deep. Distance of wells from paddy fields ranged from 3 – 150 m with a mean ± SD of 73.78±38.82 m.

Spearman Rho Correlation Test was used to determine the relationship between characteristics of well (age, depth of well and distance of wells from paddy fields) and nitrate levels in groundwater. There was no significant relationships between the characteristics of well (age, depth of well and distance of wells from paddy fields) and nitrate level ($p > 0.05$).

Table II : Relationship between the characteristics of wells and nitrate level in groundwater (N=74)

Variable	Nitrate Level in Groundwater	
	r	p-value
Age of Wells	0.135	0.252
Depth of Wells	- 0.205	0.08
Distance of Wells from Paddy Fields	- 0.180	0.125

Health Risk Assessment

Average Daily Dose (ADD) of respondents was calculated by using the formula from past studies. As a result, it shows that the Mean ± SD for ADD of respondents in Kampung Belukar, Kampung Bukit and Kampung Mulong were 0.065 ± 0.038, 0.084 ± 0.046 and 0.075 ± 0.04 (mg/kg/day), respectively.

Hazard Quotient (HQ) is used to determine the non-carcinogenic risk from ingestion exposure by respondents. From the result, it showed that HQ for all respondents is less than 1 (HQ<1). Thus, the risk due to nitrate exposure to respondents is not significant.

Table III : Hazard Quotient (HQ)

Hazard Quotient (HQ)	No. of Respondent For All Respondents	Percentage (%)
HQ < 1	74	100
HQ > 1	0	0

DISCUSSION

The amount of nitrate in groundwater samples might be different despite the close distance between wells existing. Geographical properties, subsurface condition and groundwater flow are playing a big role in influencing the nitrate concentration. The highly permeable subsurface condition leds to higher contamination of nitrate in groundwater (3). The same study has been conducted in different district of Kelantan revealed the same result as there were no sampling sites in Bachok State that exceed the maximum acceptable limit which the nitrate levels were below than 10 mg/L (9).

This study shows that nitrate levels in groundwater for each sampling site did not exceed and were below the national standard, < 10 mg/L. From previous study conducted, nitrate level in two different villages in Bachok District, Kelantan did not exceed the acceptable maximum value with the value was within the acceptable range (11). The data was collected in

January 2020 which is rainy season. Sampling time is the factor that affects nitrate levels in groundwater. Rainfall influences the nitrate concentration. It can reduce the nitrate concentration during rainy season as the water flow decreases the nitrate and moves to the stream (12).

There was no significance relationships between the characteristics of well (age, depth of well and distance of wells from paddy fields) and nitrate level in groundwater. Most wells were more than 20 years old (83.78%) and more than 15m deep (44.59%). Age of wells which usually ranged from 20 – 30 years-old can influence nitrate levels in groundwater (13). Depth of wells are inversely related to nitrate levels (14). This is also the same for the distance factor (3). The distance of wells to the paddy fields may be an essential factor in nitrate exposure in groundwater by considering the direction of groundwater flow (15).

Evaluation of the Hazard Quotient (HQ) was performed using questionnaires and direct approach (16). Potential health risk can be determined by using Hazard Quotient (HQ). After calculation, it shows that Hazard Quotient (HQ) for all respondents was less than 1 (HQ<1) (5). Thus, the risk is not significant. A past study reported that HQ for most of the respondents in Bachok District, Kelantan did not exceed 1, (HQ<1) (17). Thus, the risk was not significant, and the groundwater was safe for consumption.

CONCLUSION

This study revealed that nitrate levels recorded did not exceed the maximum acceptable value for NO_3-. Residents were exposed to low levels of nitrate, and health risk towards nitrate in groundwater was negligible.

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