Nitrate Levels in Groundwater and Health Risk Assessment In Three Villages in Pasir Puteh, Kelantan

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ABSTRACT: Nitrate exposure in groundwater especially in agricultural areas has become a major public health issue in recent years. Methemoglobinemia is among the more common diseases that is related to nitrate exposure found in groundwater. This cross-sectional study was conducted in March 2014 in Pasir Puteh, Kelantan with the objectives of determining nitrate levels in groundwater and to perform health risk assessment among respondents in the respective study areas. Three villages in the district of Pasir Puteh, were chosen for this study involving seventy respondents. Groundwater samples were collected from fifty wells and were analysed using a HACH DR/2500 spectrophotometer. A set of questionnaires was used to determine, among others, socio-demographic background and respondents' daily water intake. Body weight of respondents was measured using a Seca body weight scale. Hazard Index (HI) was calculated using the Chronic Daily Intake (CDI) divided by Reference Dose (RfD). Our results showed that readings were below the maximum concentration limit (MCL) of nitrate (National Drinking Water Quality Standard of Malaysia, NDWQS – 10 mg/L) with the mean ± SD of 2.11 ± 1.24 mg/L, ranging from 0.20 to 5.20 mg/L. There was no significant differences in nitrate levels among the three villages and also among sampling locations ($p>0.05$). The mean ± SD for CDI was 0.06 ± 0.038 mg kg/day and HI was <1. This indicated that the health risk of respondents from nitrate exposure in the groundwater studied was acceptable and the respondents were not in danger from current nitrate levels.

Keywords: Nitrate, groundwater, maximum concentration limit, chronic daily intake, hazard index, Pasir Puteh

Introduction

Agriculture activities in Malaysia have been increased from time to time. Modern agriculture is practiced by farmers to increase their productivity. This involves high use of inputs such as capital, labor, and heavy use of pesticides, herbicides, insecticides and chemical fertilizers relative to land area.

Fertilizers used by farmers contain nitrates (NO_3^-) which are known essential components for making protein in plants. As a result, plants grown on nitrogen fertilizers are healthier and yields are better and bigger. However, exposure to nitrate can also result in undesirable health effects. Groundwater contamination is frequently associated with agricultural activities such as paddy planting. Fertilizers that are used on the fields or stored can actually leach and thus contaminate groundwater supply when nitrate that originates from these fertilizers reaches to a well. Nitrate could affect human health when its level in water exceeds 45 mg/L of NO_3 (US EPA, 1991).

High nitrate levels in water can cause methemoglobinemia or blue baby syndrome, a condition found especially in infants under six months and, in the long term, could be potentially carcinogenic to humans (CCME, 2009). US EPA (1991) suggested a threshold for nitrate in drinking water of between 50 and 90 mg/L of NO_3 and points out that no risk for human health has been observed for infants consuming water containing less than 44 mg/L of NO_3. The protection of groundwater sources in regions with intensive agriculture often creates conflicts. On one hand, farmers grow crops and produce food to satisfy consumer demand, but on the other hand, health authorities must protect public health by ensuring safe drinking water from the ground. The aim of this study was to determine nitrate levels in groundwater used for daily purposes such as drinking and cooking and to determine the health risk from consuming the water.

Materials and method

Description of Study Area

The study locations were Kampung Wakaf (KW), Kampung Panggong (KP) and Kampung Batu Sebutir (KBS) in Pasir Puteh, Kelantan. These locations were chosen due to agricultural activities are the main economic activity and most of the houses are quite near to the paddy fields (less than 30 meters). Most residents still rely on groundwater for their daily needs. Respondents were aged from 28 to 68 years old. The sampling method used in this study was purposive sampling. The respondents were selected based on the inclusive and exclusive criteria. For the inclusion criteria, respondents chosen were aged 18 years old and above, a lifelong resident of the villages, and they use groundwater as their main source of water supply. Among the exclusion criteria included having a water source other than groundwater and using water filtration systems.

Well Water Sampling and Analysis

The equipment used in this study were plastic bottles and a bucket. The plastic bottles were used to store samples while the bucket was used to collect water from the well. The samples were then analysed using a HACH brand DR/2500 Spectrophotometer. A questionnaire was used to collect the data of demography and nitrate exposure to nitrate data.

Statistical Analysis

Data was analysed using the Statistical Program for Social Science software (SPSS for Windows) version 22.0. For descriptive data, univariate analysis was performed to determine nitrate level, socio demographic information of respondents, water consumption and results of water analysis.

Health Risk Assessment

In order to determine exposure of nitrate in drinking water, chronic daily intake (CDI) was first calculated using the following equation:

$$CDI = \frac{C \times DI}{BW} \qquad \text{(Equation 1)}$$

where,

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

C = Nitrate concentration in water (mg/L),

DI = Average daily intake rate of water (L/day),

BW = Body weight (kg).

Then, to conclude the significant different exposure and overall potential for non-carcinogenic health effects caused by nitrate in drinking water, the Hazard Index (HI) was calculated using the following equation:

$$HI = \frac{CDI}{RfD} \qquad \text{(Equation 2)}$$

where,

HI = Hazard Index,

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

RfD = Reference dose (mg/kg/day)

A HI value more than 1 (HI>1) will show a significant risk level, where the higher the value, the greater the likelihood of adverse non-carcinogenic health impact. The RfD value that was used in this study was 1.6 mg/kg/day (USEPA, 2000).

Results

Social Demographic Data

Respondents comprised of 31 (44.3%) females and 39 (57.7%) males, totaling 70, aged between 28 to 68 years old. The mean ± S.D for respondent age was 49.3 ± 9.92. The majority of respondents were more than 47 years old. From the 70 respondents, 24 (34.3%) was from KW, 21 (30.0%) was from KP and 25 (35.7%) was from KBS. The majority of respondent (17 – 24.3%) had never had any formal education and most of them (23 – 32.9%) worked as farmers.

The majority of the respondents' income was between RM500 to RM1000 (Table 1). The majority of respondents lived in the study areas for more than 20 years and all of them have wells using electrical pumps. Almost all of the wells (49 wells – 98.0%) were more than 15 years old (Table 2).

Table 1: Socio-demographic information

Variable	**No. of Respondents**	**%**
Race		
Malay	70	100
Chinese	0	0
Indian	0	0
Other	0	0
Occupation		
Farmer	23	32.9
Unemployed	18	25.7
Self-employed	22	31.4
Others	7	10.0
Income (RM)		
<500	13	18.6
500-1000	37	52.9
1001-1500	16	22.9
1501-2000	1	1.4
>2000	3	4.3
Period of Residency		
>20 years	60	85.7
11-20 years	6	8.6
1-10 years	3	4.3
<1 year	1	1.4

Table 2: Well information

Variable	No. of Samples	%
Type of well:		
Pump well	50	100.0
Manual well	0	0.0
Age of Well :		
<1 year	0	0.0
1-5 years	1	2.0
6-10 years	0	0.0
11-15 years	0	0.0
>15 years	49	98.0

Nitrate levels in well water

A total of 50 wells were sampled. The mean ± S.D for nitrate levels mg/L was 2.11 ± 1.24, ranging from 0.20 to 5.20 mg/L. Kruskal-Wallis test was used to compare nitrate levels between the three villages. The highest mean ± S.D of nitrate levels (mg/L) was obtained at KBS (2.28 ± 0.9). The mean ± S.D (mg/L) for KW was 2.06 ± 1.59 and for KP was 1.98 ± 1.21 (Table 3).

Table 3: Comparison of nitrate level between 3 villages

Village abbreviation	No. of well	Mean ± S.D (mg/L)	Range (mg/L)	p-value
KW	17	2.06 ± 1.59	0.2-5.2	
KP	16	1.98 ± 1.21	0.5-4.1	0.608
KBS	17	2.28 ± 0.9	0.8-3.5	

Comparison of nitrate level with national standard

With regards to National Standard of Drinking Water Standard (NSDWQ), the maximum concentration limit (MCL) for nitrate is 10mg/L (MOH Malaysia, 2010). Figure 1 indicated that nitrate levels from all sampling sites were below 10mg/L, which was the maximum limit of NSDWQ.

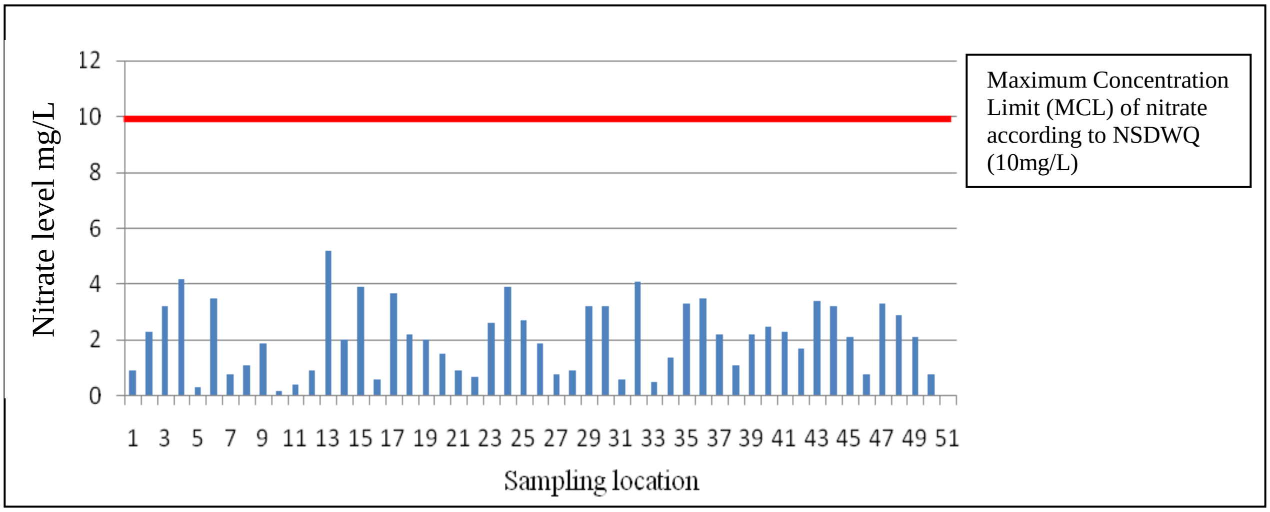

Figure 1: Comparison of nitrate level with national standard

Health Risk Assessment

To estimate non-carcinogenic risk, the Hazard Index (HI) was calculated by dividing the CDI value with reference dose (RfD). Referring to the United State Environmental Protection Agency (USEPA), the reference dose (RfD) for nitrate is 1.6 mg/kg (USEPA, 2000). A Hazard Index reading of greater than 1 should be referred to further evaluation (Joel, 2014). The range of HI obtained in this study was from 0.003-0.08. The mean ± S.D was 0.037 ± 0.024 (Table 4).

Table 4: Chronic Daly Intake (CDI) estimation

	Nitrate level (mg/L)	***DI (L/day)**	***W (kg)**	***CDI (mg/kg/day/**
Mean	2.11	1.83	63.96	0.060
Median	2.10	1.75	62.00	0.059
SD	1.24	0.32	10.52	0.038
Range	0.20-5.20	1.25-2.5	45-98	0.005-0.13

Discussion

In this study, the mean ± SD of nitrate level was 2.11 ± 1.24 and ranged from 0.20 to 5.20 mg/L. This was a normal level of nitrate in groundwater. According to Schmoll *et al.* (2006), normal concentration of nitrate in surface or groundwater is between 0 to 18 mg/L. However, the level of nitrate can increase due to a few factors including use of fertilizers, waste disposal especially from animal farms, and septic tanks (Haycock, 1990). Irrigated agriculture practice utilizes a huge amount of fertilizers, which may lead to groundwater contamination (Ghaderi *et al.,* 2012).

Low levels of nitrate found in this study were most probably caused by the rainy season. Nitrate sampling was performed after the rainy season (March 2014). Rainfall influences the concentration of nitrate, as it entering the groundwater at a high rate at the beginning of the rainy season, decreases throughout the rainy season and remain at a constant low level during the dry season, where the water table rises and nitrate in unsaturated zones (such as soil) become mobilized into groundwater. Hence, nitrate levels are high at this condition. On the other hand, nitrate accumulates in soil during the dry season, therefore decrease of mobilization into stream and groundwater, thus resulted in lower nitrate concentration in the groundwater (CCME, 2009).

Another factor that can be considered was sampling time. Water sampling activities was performed after the paddy had been harvested. After harvesting, the land was left to be rehabilitated and no fertilizer was applied to the fields.

Comparison of nitrate levels between villages and sampling locations

The highest mean ± S.D of nitrate levels (mg/L) was obtained from samples from KBS (2.28 ± 0.9 mg/L) followed by KW (2.06 ± 1.59 mg/L), and lowest from KP (1.98 ± 1.21 mg/L). The quantity or rate of fertilizer application during the previous season may be another factor. The leaching process of excess nitrate to the groundwater in this study area might have happened. Excessive fertilizer application will lead to nitrate pollution in groundwater (Roy *et al.,* 2000). However, it was found that there was no significant difference of nitrate levels between these three villages and also among sampling locations ($p>0.05$).

Comparison of nitrate level to NSDWQ

The highest reading obtained was 5.20 mg/L. Thus, readings did not exceed the maximum concentration limit (MCL) for nitrate (10mg/L) (MOH Malaysia, 2010). In a study to determine nitrate levels in groundwater, Tirado (2007) found that 30% of all groundwater sampled in sites in Thailand and the Philippines were above the levels recommended by WHO, and it was highest in the most intensive crops.

Exposure and health risk assessment

Chronic daily intake (CDI) data was used to estimate individual daily exposure of nitrate (USEPA, 2005). The mean ± S.D for CDI (mg/kg/day) was 0.060 ± 0.038. The range for CDI was from 0.005 – 0.13 mg/kg/day. HI value in this study ranged from 0.003-0.08. The mean ± S.D for HI was 0.037 ± 0.024. 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.

Conclusion

There was no significant difference in nitrate levels between the three villages or between sampling sites. Highest reading of nitrate level in this study was 5.20 mg/L. Hazard Index (HI) obtained was below one for all respondents which indicate no adverse effect due to nitrate exposure. Nevertheless, periodic assessment of nitrate in groundwater used for human consumption should be done as to ensure it is within the permissible levels.

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