NITRATE IN GROUNDWATER AND HEALTH RISK ASSESSMENT: A CROSS-SECTIONAL STUDY IN THREE VILLAGES IN TANAH MERAH DISTRICT, KELANTAN, MALAYSIA DURING PADDY PRE-PLANTING SEASON

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ABSTRACT

Introduction: Contamination of nitrate is one of the most common groundwater problems worldwide. Around 70% of residents in the state of Kelantan still rely on groundwater as their primary source of water supply. Extensive usage of fertilizer in agricultural areas may cause nitrate leaching into the groundwater. This study aimed to determine the level of nitrate in groundwater and health risk assessment at three villages in Tanah Merah District, Kelantan, Malaysia.
Subjects and Method: This was a cross-sectional study conducted at Tanah Merah district, Kelantan, in January 2020. A total of 52 residents was selected by purposive sampling. The inclusion criteria for study subjects were long life residents, age ≥18 years old, and groundwater as a primary source of drinking supply. The study variables were (1) Level of nitrate in groundwater measured according to age (year), depth (meter), and distance (meter) of well from the agricultural area; and (2) Health risk assessment measured by hazard quotient (HQ). A set of questionnaires consisted of four sections to gather information related to socio-demographic, water usage, living environment, and health status. Groundwater samples were collected in duplicates and were analysed using a Hanna Instruments portable pH/ORP/ISE meter with an attached nitrate electrode. The data were reported descriptively.
Results: Nitrate levels were found to be under the maximum acceptable value of 10 mg/L, as stated by the Drinking Water Quality Standard of Malaysia. Nitrate level ranged from 0.22 to 8.81 mg/L (Mean= 2.94; SD= 2.27). Spearman rho correlation showed that nitrate level was significantly and negatively correlated the age of wells (r= -0.31; p= 0.025). Nitrate level was not significantly correlated with the depth (r= 0.19; p= 0.183) and distance of wells (r= -0.05; p= 0.751). Hazard quotient (HQ) for all study subjects was <1, which means that exposure to nitrate contained drinking water in study subjects was not detrimental to health.
Conclusion: Nitrate levels were below the maximum acceptable value, but continuous monitoring from health authorities is essential since other seasons of paddy planting may contribute higher deposition of nitrate into groundwater.

Keywords: nitrate, groundwater, levels, hazard quotient, Tanah Merah

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BACKGROUND

Nitrate contamination is one of the world's most common groundwater issues (Ako et al., 2014). Nitrate is water-soluble, quickly drains from the soil and then deposited in groundwater (Wongsanit et al., 2015). According to Almasri (2007), nitrate contamination in groundwater can be derived from different sources including from point source (industrial activity, livestock waste) and non-

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point source (extensive usage of nitrogen fertilizer, atmospheric deposition). Nitrogen fertilizers are widely used in agricultural production to increase crop yield, but excess nitrogen supplies can contaminate water, air, and soil. One of the most common and detrimental consequences of agricultural overuse of nitrogen fertilizers is the deterioration of groundwater quality and pollution of drinking water sources, which may present significant threats to human health (Wick et al., 2012). Several studies had shown that there is a correlation between nitrate contamination and agricultural activity as a result of heavy use of nitrate fertilizer (Shamsuddin et al., 2016). Greer and Shannon (2005) mentioned that infants who consumed formula milk prepared using water contaminated with nitrate could lead to methemoglobinemia.

Methemoglobinemia or "Blue Baby Syndrome" disturbs the blood cells ability to carry oxygen (Ward et al., 2018). An ecological study from Slovakia found a positive association between colorectal cancer and cancers in all digestive system with nitrate levels in drinking water (Schullehner et al., 2018). Risk of bladder cancer reported being increased among postmenopausal women that associated with long-term ingestion of nitrate in drinking water (Jones et al., 2018). Health risk assessment may be carried out to determine whether or not consumers have been exposed to diseases. A health risk assessment is a method of assessing the extent and possibility of adverse health effects to individuals who may be subjected to contaminants in environmental media (USEPA, 2016). As mentioned in the National Drinking Water Quality Standard (NDWQS) formulated by the Ministry of Health, Malaysia, the maximum acceptable limit of nitrate in drinking water is 10 ppm (Ministry of Health, Malaysia, 2010).

Association of Water and Energy Malaysia (2011) stated that water supply provided by Kelantan state government was dirty and smelly, frequent water disruption and low coverage performance. Hence, it leads about 70% of residents in Kelantan to still rely on groundwater as their main source of water supply (Safeen and Azmi, 1998; Azwan et al., 2010). This event strongly indicated the significance of water safety aspect because it is very much linked to the health of consumers. Most houses in Tanah Merah are situated near to agriculture areas.

The aims of this study were not only to determine the nitrate concentration in groundwater at Buloh, Pasir Besar, and Bukit Merbau Villages in Mukim Ulu Kusial, Tanah Merah, Kelantan, but also focused on determining any significant relationship between nitrate concentration with age, depth, and distance of wells from nitrate source. The problem to be emphasized here was whether there was any significant health risk from daily consumption of groundwater contaminated with nitrate.

SUBJECTS AND METHOD

1. Study Desaign

This was a cross-sectional study conducted at Tanah Merah district, Kelantan, in January 2020.

2. Population and Sample

It was the paddy pre-planting season in Tanah Merah district at the moment of data collection. The study population involved residents from Buloh, Pasir Besar, and Bukit Merbau Villages in Tanah Merah district, Kelantan. Fifty-two respondents were chosen based on inclusion criteria such as long-life residents, age above 18 years old, and using groundwater as their primary source of drinking supply. In addition, the respondents were excluded when they were using the water filter system and having drinking water sources other than groundwater. Purposive sampling was used as the sampling methods in this study.

3. Study Variables

The inclusion criteria for study subjects were long life residents, age ≥18 years old, and groundwater as a primary source of drinking supply. The study variables were (1) Level of nitrate in groundwater measured according to age (year), depth (meter), and distance (meter) of well from the agricultural area; and (2) Health risk assessment measured by hazard quotient (HQ).

4. Study Instrument

A set of questionnaires consist of four sections was provided to the respondents in order to gather the information related to socio-demographic, water usage, house living environment, and health status. Global Positioning System (GPS) was used to measure the distance of the well from the nitrate source. Besides, it was more convenient and easier to use this application rather than measuring tape.

5. Data Analysis

Water samples from the house of each respondent were taken directly from the well using a High-Density Polyethylene (HDPE) bottle. They were collected in duplicates and analyzed using a Hanna Instruments portable pH/ORP/ISE meter with an attached nitrate electrode.

For the health risk assessment, the Adverse Daily Dose (ADD) was first calculated using the following formula for determining the exposure of nitrate in drinking water in the following equation:

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

Where, ADD was Average Daily Dose (mg/kg/day). C was Nitrate Concentration (mg/L). IR was Intake Rate (1 L/day for children and 2 L/day for adults). EF was Exposure Frequency (365 days/year). ED was Exposure Duration (6 years for children and 30 years for adults). BW was Body Weight (15 kg for children and 60 kg for adults). AT was Averaging time (365 days/year×6 years for children and 365 days/year×30 years for adults).

Hazard Quotient (HQ) is calculated using the formula in equation (2):

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

Where, HQ was Hazard Quotient. ADD was Adverse Daily Dose (mg/kg/day). Rfd was Reference Dose (mg/kg/day). An HQ value >1 indicated a significant non-carcinogenic risk level and RfD is nitrate reference dose which is 1.6 mg/kg/day (USEPA, 2013). The collected data were then analysed using IBM Statistical Package for Social Science (SPSS) version 22 and it was presented as one whole Mukim Ulu Kusial.

RESULTS

1. Sample Characteristics

Table 1 below displayed the characteristics of study subjects' wells which covered the information regarding age, depth, and distance of well from the nitrate source. As illustrated in Table 2, the samples collected from the well-aged below 5 years were 6 (11.5%). While, the sample taken from age of well 5 to 10 years, 11 to 15 years, 16 to 20 years, and above 20 years were as much as 10 (19.2%), 5 (9.6%), 1 (1.9%), and 30 (57.7%) respectively.

The most samples were collected from the depth above 15 meters which are 20 (38.5%). Followed by 5 to 10 meters, 11 to 15 meters and below 5 meters (<5) which was 13 (25.0%), 11 (21.2%) and 8 (15.4%) respectively. Besides, the result showing the distance of well from the nitrate source was mean= 64.06; SD= 36.39 meters, while the range was from 5.0 to 176.0 meters.

From Table 2 below, it showed the range of nitrate level in groundwater was from 0.22 to 8.81 ppm, while the Mean=

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2.94; SD= 2.27 ppm. Clearly, the data obtained was below the maximum acceptable limit, which is 10 ppm. Average Daily Dose (ADD) and Hazard Quotient (HQ) for all respondents had been calculated using the formula mentioned in equation 1 and 2. The ADD estimation result for obtained was Mean= 0.10; SD= 2.27 and range from 0.01 to 0.29. All respondents had the Hazard Quotient (HQ) below 1, which meant the respondents did not pose a significant health risk due to exposure of nitrate in drinking water.

2. Bivariate Analysis

Based on the result in Table 3, there was correlation coefficient between the age of well and nitrate level r= -0.310 and significant difference (p= 0.025). However, the depth of well and distance of well from the nitrate source showed there was no significant difference with the nitrate level (p>0.183).

Table 1. Sample Characteristics (categorical data)

Characteristics	Categories	Frequency	Percentage
	<5 years	6	11.5%
Age of well	5-10 years	10	19.2%
	11-15 years	5	9.6%
	16-20 years	1	1.9%
	>20 years	30	57.7%
Depth of well	<5 years	8	15.4%
	5-10 years	13	25.0%
	11-15 years	11	21.2%
	>15 years	20	38.5%
Hazard quotient	HQ <1	52	100%
	HQ >1	0	0

Table 2. Sample Characteristics (continuous data)

Variables	Mean	SD	Min.	Max.
Distance of Well from the Agriculture Area (meters)	64.06	36.39	5.00	176.00
Nitrate level in Groundwater (ppm)	2.94	2.27	0.22	8.81

Table 3. Spearman Rho correlation test of the association between age of wells, depth of wells, and distance of wells from nitrate source with nitrate level

Variables	Nitrate Level	
	r	p
Age (Year)	-0.310	0.025
Depth (meter)	0.188	0.183
Distance from agriculture area (meter)	-0.045	0.751

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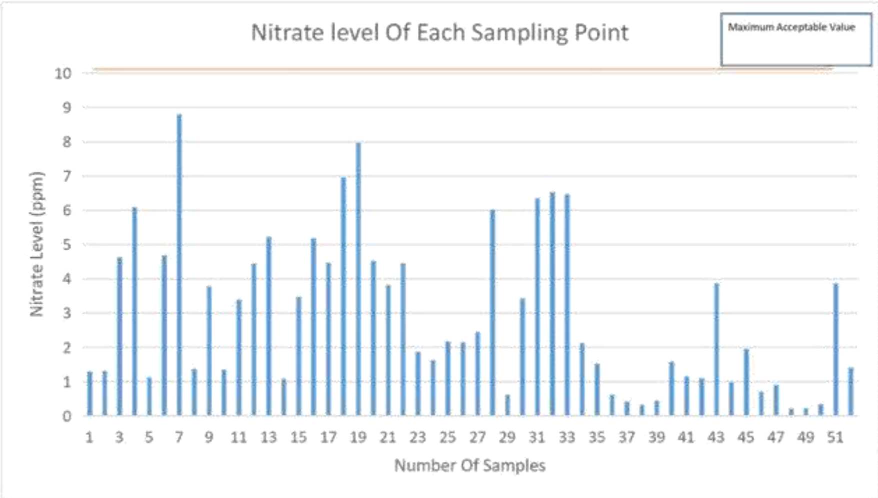

Figure 2. Nitrate levels from each sampling points

DISCUSSION

As presented in Table 1, no sampling sites exceeded the maximum concentration limit of the Drinking Water Quality Standard. The nitrate obtained in this study was considered as in normal value (Mean= 2.94; SD= 2.27). This study was in line with the study conducted by Jamaludin et al (2013) the Mean= 1.66; SD=2.11 of nitrate level in well water of the study in ppm.

This study was conducted during rainy seasons and pre-planting phase for paddy plantation. This occurrence may be the reasons of low nitrate level measured in groundwater. According to Wang et al (2015) rainfall has affected the nitrate concentration as it reaches the groundwater, the nitrate concentration increases at the beginning of the rainy season, decreases throughout the rainy season, and stays at a constant low level during the dry season. During the pre-planting phase, the nitrate level was low because the farmers have not yet started the application of fertilizers to the crops. The nitrate level is likely to increase during the planting phase as compared to pre-planting and harvest phase (Amirah et al., 2014).

Based on the analysis, there was a significant association between the age of wells and the nitrate levels in groundwater. This indicated the age of the wells did contribute to the nitrate contamination in this study. Swistock et al. (2009) stated the age of well were statistically important in relation with nitrate level in groundwater. Generally, older wells were more susceptible to nitrate contamination (USEPA, 2002). However, this study showed the age of well had fair negative correlations with nitrate level in groundwater. This occurrence may be because of small numbers for age of wells that less than 20 years included in this study. Another factors such as wells with leaking or damaged fittings or casings and dug wells with casings that are not watertight also may contribute to this result (Minnesota Department of Health, 2020).

Next, nitrate levels in groundwater samples were not associated with the depth and distance of well from the agricultural area. This can be related to varying levels of difference in the depth and distance of wells from the nitrate source. These results were partially in line from a study done by Sharuddin et al. (2019) who stated that the age, depth, and distance of well from the source of nitrate did not play a significant role in the concentration of nitrates in the wells studied. However, Shamsuddin et al. (2016) stated that the high nitrate was de-

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tected in the well <50 m to the agricultural area. Plus, groundwater flow direction also should be taken into account, which is an essential factor in nitrate contamination (Ki et al., 2015).

The result indicated that all respondents had the Hazard Quotient (HQ) below 1, which the study subjects did not pose a significant health risk due to exposure of nitrate in drinking water. This study was in line with Jamaludin et al (2013) as there was no result obtained for Hazard Index (HI) were more than 1.

This study showed that the nitrate level from all the sampling points was below the maximum acceptable limit, which is 10 ppm according to National Drinking Water Quality Standard. The highest reading recorded was 8.8 ppm. The result indicated that all study subjects had the Hazard Quotient (HQ) below 1, which meant the study subjects did not pose a significant health risk due to exposure of nitrate in drinking water. However, the continuous monitoring from health authority is essential so that the contamination of nitrate in groundwater can be prevented in the future. It is suggested for the future study to increase the sample size of the study subjects and conduct the water sampling during different sampling time (preplanting, planting, and harvesting phase), in order to get more generalized data to the population involved and able to observe significantly different of nitrate levels between each phase.

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REFERENCES

Ako AA, Eyong GET, Shimada J, Koike K, Hosono T, Ichiyanagi K, Richard A, Tandia BK, Nkeng GE, and Roger NN (2014). Nitrate contamination of groundwater in two areas of the Cameroon Volcanic Line (Banana Plain and Mount Cameroon area). Appl Water Sci, 4: 99–113. doi: 10.1007/s13201-013-0134-x

Almasri MN (2007). Nitrate contamination of groundwater: A conceptual management framework. Environ Impact Assess Rev, 27(3): 220–242. https://-doi.org-/10.1016/j.eiar.2006.11.002

Roslan AA, Sham SM, and Ismail SNS (2014). Nitrate levels in well water and population health risk of Kota Bharu and Bachok, Kelantan in different planting phases. Adv Environ Biol, 8(15): 7–12.

Azwan M, Yusoff MK, Hussain H, and Nasir S (2010). Nitrate-nitrogen concentration variation in groundwater flow in a paddy field. The Journal of the Institution of Engineers, Malaysia, 71(4): 2–10. doi: http://dspace.unimap.edu.my/123456789/13713.

Association of Water and Energy Research Malaysia (2011). National water services industry restructuring – Kelantan state case study. Kuala Lumpur: Association of Water and Energy Research Malaysia (AWER).

Engineering Services Division, Ministry of Health, Malaysia (2010). National drinking water quality standards (NDWQS). [Retrieved on 15 January 2019] Retrieved from: http://kmam.moh.gov.-my/publicuser/drinking-waterquality-standard.html

Greer FR and Shannon M (2005). Infant methemoglobinemia: The role of dietary nitrate in food and water. Pediatrics, 116(3): 784–786. doi: https://doi.-org/-10.1542/peds.2005-1497.

Jamaludin N, Sham SM, and Ismail SNS

(2013). Health risk assessment of nitrate exposure in well water of residents in intensive agriculture area. Am J Appl Sci, 10(5): 442–448. doi: https://doi.-org/10.3844/ajassp.2013.442.448.

Jones RR, Weyer PJ, Dellavalle CT, Inoue-Choi M, Anderson KE, Cantor KP, Krasner S, Robien K, Beane Freeman LE, Silverman DT, and Ward MH (2016). Nitrate from drinking water and diet and bladder cancer among post-menopausal women in Iowa. Environ Health Perspect, 124(11): 1751–1758. doi: https://doi.org/10.1289/EHP191.

Ki MG, Koh DC, Yoon H, and Kim H (2015). Temporal variability of nitrate concentration in groundwater affected by intensive agricultural activities in a rural area of Hongseong, South Korea. Environ Earth Sci, 74(7): 6147–6161. doi: https://doi.org/10.1007/s12665015-4637-7

Minnesota Department of Health (2020). Retrieved from: https://www.health.-state.mn.us/communities/environment/water/contaminants/nitrate.html#OtherEfforts

Schullehner J, Hansen B, Thygesen M, Pedersen CB, and Sigsgaard T (2018). Nitrate in drinking water and colorectal cancer risk: A nationwide population-based cohort study. Int J Cancer, 143(1): 73–79. doi: https://doi.org-/10.1002-/ijc.31306

Sham SM, Azri MY, Asyiq Z, and Afif MAH (2019). Nitrate pollution in ground-water: a cross-sectional study in three villages in Bachok District, Kelantan, Malaysia during the paddy pre-planting season. Malays J Med Sci, 15(1): 160–163.

Shamsuddin AS, Ismail SNS, Abidin EZ, Bin HY, Juahir H, Ho YB (2016). Con-tamination of nitrate in groundwater and evaluation of health risk in bachok, kelantan: A cross-sectional study. Am J Appl Sci, 13(1): 80–90. doi: https:-//doi.org/10.3844/ajassp.2016.80.90.

Swistock BR, Clemens S, and Sharpe W (2009). Drinking water quality in rural pennsylvania and the effect of management practices. Retrieved from: http://-www.rural.palegislature.us/drinking_water_quality.pdf

USEPA (2002). The benefits of reducing nitrate contamination in private domestic wells under CAFO regulatory options. Retrieved from: http://purl.access.gpo-.gov/GPO/LPS44781.

USEPA (2013). Integrated Risk Information System (IRIS). United States Environment Protection Agency.

USEPA (2016). Human heatlh risk assesment. Retrieved from: https://www.-epa.gov/risk/human-health-risk-assessment

Wang H, Gao JE, Li XH, Zhang SL, and Wang HJ (2015). Nitrate accumulation and leaching in surface and groundwater based on simulated rainfall experiments. PLoS ONE, 10(8): 1–18. doi: https:-//doi.org/10.1371/journal.pone.0136274

Ward MH, Jones RR, Brender JD, de Kok TM, Weyer PJ, Nolan BT, Villanueva CM, and Breda SG (2018). Drinking water nitrate and human health: An updated review. Int. J. Environ. Res. Public Health, 15(7): 1–31. doi: https://-doi.org/10.3390/ijerph15071557

Wick K, Heumesser C, and Schmid E (2012). Groundwater nitrate contamination: Factors and indicators. J Environ Manage, 111, 178–186. doi: https://-doi.org/10.1016/j.jenvman.2012.06.030

Wongsanit J, Teartisup P, Kerdsueb P, Tharnpoophasiam P, and Worakhunpiset S (2015). Contamination of nitrate in groundwater and its potential human health: a case study of lower Mae Klong river basin, Thailand. Environ Sci Pollut Res, 22(15): 11504–11512. doi: https://doi.org/10.1007/s11356-015-4347-4

https://doi.org/10.26911/the7thicph-FP.01.08