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NITRATE CONCENTRATION IN GROUNDWATER: A CROSS-SECTIONAL STUDY IN THREE VILLAGES NEAR PADDY FIELDS IN BACHOK DISTRICT, KELANTAN DURING THE HARVEST SEASON

Shaharuddin MS*, Muhammad Azri MY, Mohd Akmal Asyiq Z

Department of Environmental and Occupational Health, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia, Selangor MALAYSIA

Corresponding author: Shaharuddin Mohd Sham; shaha@upm.edu.my
Department of Environmental and Occupational Health, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia.

ABSTRACT

Introduction: Nitrate (NO_3^-) is essential for producing healthy plants. However, excessive nitrate not taken up may eventually accumulate in groundwater, which is detrimental to human health if consumed. The maximum acceptable concentration for nitrate in drinking water is 44.3 ppm. **Methodology:** Keting, Kuchelong and Telaga Ara villages in Bachok district, Kelantan were chosen because of their proximity to paddy fields. Houses using groundwater for drinking and cooking purposes were selected and other data such as age and depth of wells, and distance to nitrate source were recorded. Data were collected during the harvest season of October and November of 2018 and two replicates of water samples were analysed using a portable meter with an attached nitrate electrode. **Result:** A total of 136 wells were selected. Nitrate concentration in Kuchelong village ranged from 0.09 to 8.12 ppm (mean 0.74 ± SD 1.82 ppm), in Keting village ranged from 0.81 to 28.8 ppm (mean 3.76 ± SD 5.49 ppm) and in Telaga Ara village ranged from 0.95 to 43.0 ppm (mean 8.34 ± SD 7.70 ppm). Nitrate readings did not exceed the maximum acceptable concentration. One-way ANOVA analysis shows that there is a significant difference in nitrate concentration between villages ($p<0.05$), while Spearman's rho correlation analysis shows that there are no significant relationships between nitrate concentration and variables ($p>0.05$). **Conclusion:** Water samples have nitrate with concentrations below the maximum acceptable level. Periodical analysis of groundwater should be performed to ensure nitrate remain below the maximum acceptable level.

Keywords: Nitrate, Well water, Bachok, paddy, lower

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1. Introduction

Nitrogen gas (N_2) is the most abundant element in the atmosphere (78%), but it cannot be readily used by plants for growth purposes. However, by the process of fixing and changing atmospheric N_2 into organic nitrogen (N) forms by certain symbiotic and non-symbiotic organisms in the soil, these can then be transformed into inorganic ammonium (NH_4^+) in the ammonification process, which plants can utilize (USDA, 1995). Organic N is naturally occurring but can also be added into the soil as plant residues and manure.

Nitrate (NO_3^-) is a polyion made up from one nitrogen and three oxygen atoms and it is extensively used in agricultural activities as fertilizers. In the natural world, nitrate, which is a component of the Nitrogen Cycle, is synthesized from ammonia (NH_3) in the soil by nitrifying aerobic bacteria, including from the genera *Nitrosomonas* which converts ammonia to nitrites (NO_2^-), and *Nitrobacter*, which then converts nitrites to nitrate (Encyclopaedia Brittanica, 2019). Nitrate-rich soils can be found in many parts of the world, including deserts (Erickson, 1981). Man-made sources of nitrate include septic tanks, fertilizers and wastewater treatment (WHO, 2011).

Groundwater is important for residents especially in the rural areas in order to fulfill their daily needs. It can be contaminated by nitrate originating from human activities such as agriculture, industries and disposal of solid waste, among others (Aida Soraya et al., 2014). In China, a study by Ju et al. (2006) found that extremely high fertilizer N inputs has resulted in large amounts of nitrate accumulated in the vegetable soils and the shallow groundwater was heavily contaminated by nitrate-N. In addition, N is more easily lost to streams and groundwater from ecosystems than any other essential elements (Vitousek et al., 2002).

The presence of nitrate in groundwater can pose a health risk to residents. Parvizishad et al. (2016) stated that consumption of drinking water and food containing high nitrites and nitrates may cause diseases such as cancer, methemoglobinemia, enlargement of the thyroid gland and diabetes mellitus. However, nitrate may only pose a risk to human health when its concentration exceeds the maximum acceptable value of nitrate in drinking water. In Malaysia, the maximum acceptable value for nitrate in drinking water is 10mg/L NO_3-N (Engineering Services Division, Minitry of Health, Malaysia, 2010).

According to the United Sates Environmental Protection Agency (USEPA), among the water quality problems associated with nitrification are nitrite/nitrate formation, dissolved oxygen depletion and increases in heterotrophic plate count (HPC), ammonia oxidizing bacteria (AOB) and nitrite oxidizing bacteria (NOB) (USEPA, 2002).

About 70% of residents in Kelantan still rely on groundwater as their main source of drinking water (Aida Soraya et al., 2016) and this indicates the important water safety aspect in the context of soluble chemicals that can have health effects on residents. Nas and Berktay (2006) stated that approximately 75% of the water supply in the city of Konya in Turkey relies on groundwater, which is supplied by 198 wells.

Most houses in Bachok district in Kelantan state are located near paddy fields (Muhammad Nur Fakhri and Shaharuddin, 2017) and agricultural activities are the main occupation for residents in the area (Aida Soraya et al., 2016).

The aims of this study were to determine nitrate concentration in groundwater during the harvest season as usage of fertilizer (source of nitrate) in Bachok district, Kelantan, to determine any significant difference in nitrate concentration between villages, and to determine any significant relationships in nitrate concentration with age and depth of wells, and distance from nitrate source. The problem to be highlighted here is whether nitrate concentration in groundwater in the study areas was safe for drinking purposes as the residents rely on groundwater as their main water source.

2. Materials and Method

2.1 Description of study area

Three villages were chosen for this study, namely Kuchelong, Keting and Telaga Ara villages. (Figure 1).

2.2. Well water sampling and analysis

A Hanna Instrument HI98191 Professional Waterproof Portable ph/ORP/ISE Meter with a HI4113 Nitrate Combination Ion Selective Electrode (ISE) was used to analyze the water samples. Samples were collected in three replicates and were then stored in high density polyethylene (HDPE) bottles before analysis.

2.3. Statistical analysis

The collected data were analyzed using IBM SPSS (Statistical Package for Social Science) version 22. The distribution of variables in this study was analyzed using descriptive statistic including standard deviation, mean and median.

3. Results and discussions

This study was conducted from 27 October 2018 until 02 November 2018. At the time, it was the paddy harvest season in Bachok district. A total of 136 wells were analysed for nitrate from three villages in Bachok district. The villages were Kuchelong with 43 wells, Keting with 36 wells and Telaga Ara with 57 wells (Table 1). These villages were located approximately 20 kilometres southeast of Kota Bharu, the capital of Kelantan state. Table 1.2 highlight the age, depth and distance of the well from nitrate resources.

Table 1: Number of wells according to villages

Village	No. of wells
Kuchelong	43
Keting	36
Telaga Ara	57

N=136

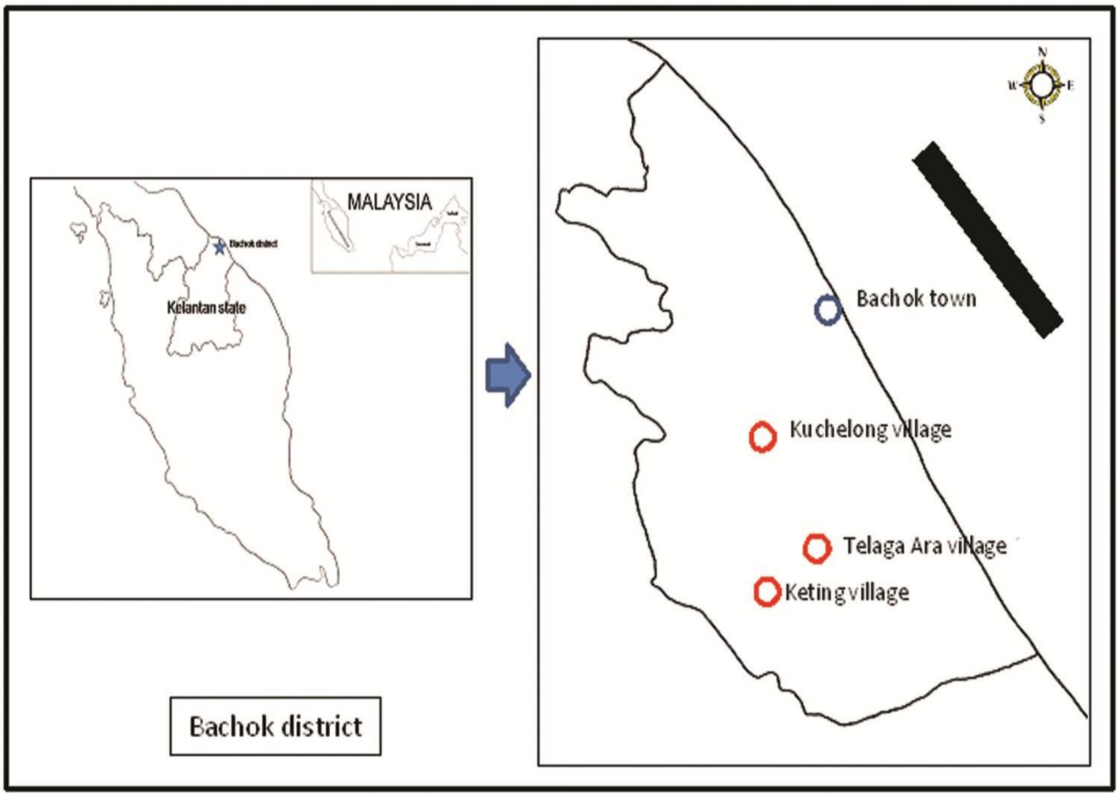

Figure 1: Map showing location of study area. Inset: Map showing Bachok district within Kelantan state.

Nitrate concentration in Kuchelong village ranged from 0.09 to 8.12 ppm with a mean of 0.74 $\pm$ SD 1.82 ppm, while in Keting village, it ranged from 0.81 to 28.8 ppm with a mean of 3.76 $\pm$ SD 5.49 ppm. In Telaga Ara village, nitrate concentration ranged from 0.95 to 43.0 ppm with a mean of 8.34 $\pm$ SD 7.70 ppm (Table 2 and Figure 2). From 136 wells, none of the wells had readings above the recommended level (44 ppm) by the Malaysian health authority. It was found that all readings from the three villages were below the maximum acceptable level of 44.3 ppm NO_3^- as stated by WHO (Table 3).

In this context, the water sampling period was conducted during the harvest season in the study area. As such, no more fertilization of soil is occurring as it is not needed for plant growth and therefore, concentration of nitrate in soil and water adjacent to the paddy fields are lower. In a case study conducted at lower Mae Klong river basin in Thailand, Jaturong, et al. (2015) found that from 73 wells sampled for nitrate, only 4 samples exceeded the acceptable level of groundwater quality for drinking purposes. The authors also mentioned that land-use patterns played an important role in nitrate contamination. Where there were agricultural areas such as sugarcane planting areas and mixed orchard area, the concentration detected was more than the acceptable level. This can also be said for this study, where a number of wells where concentration of nitrate was higher than the mean were located near sources of nitrate contamination.

One-way ANOVA was used to compare nitrate concentrations between villages. Analysis showed that there is a significant difference between all three villages, where $p<0.05$ (Table 4). Observations on sampling sites with readings higher than the mean which shows that the wells in question were near a source of nitrate. For example, one well in Keting village with a nitrate concentration of 28.8 ppm was located near the paddy field and animal farm.

Table 1.2 : Age, depth and distance of well from nitrate source.

Village		Keting	Kuchelong	Telaga Ara
No. of wells	N	36	43	57
Age	<5 years	4	15	10
	6-10 years	7	4	5
	11-15 years	1	3	3
	16-20 years	9	5	7
	>20 years	15	16	32
Depth of well	<5 meter	0	3	0
	5-10 meter	18	29	23
	11-15 meter	15	9	22
	>15 meter	3	2	12
Distance from source (meter)	Mean	158.38± 111.31	483.72± 297	212.84± 271.212

Table 2: Mean and range of nitrate concentration in water samples from the three villages (N= 136)

Village	Mean (ppm)	Range (ppm)
Kuchelong	0.74 ± SD 1.82	0.09 – 8.12
Keting	3.76 ± SD 5.49	0.81 – 28.8
Telaga Ara	8.34 ± SD 7.70	0.95 – 43.0

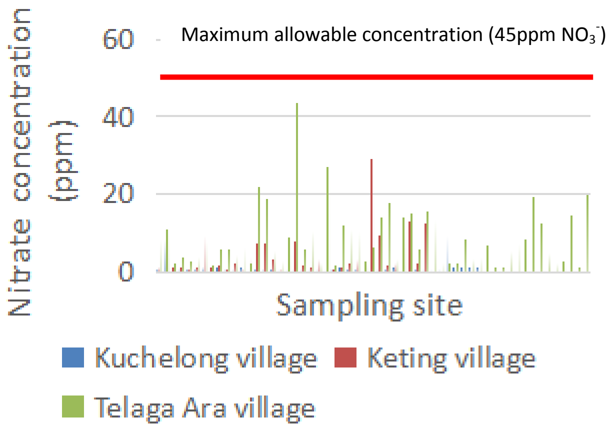

Figure 2: Concentration of nitrate based on villages

Table 4: One-way ANOVA for comparison of nitrate concentration between villages

Village	Mean	SD	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Sig.
Keting (n = 36)	3.76	5.49	1.8981	5.6147	<0.001
Kuchelong (n = 43)	0.72	1.82	.1628	1.2856	
Telagara (n = 57)	8.34	7.70	6.2985	10.382	

Another example, a well in Telaga Ara village with a nitrate concentration of 43.3 ppm, was also located near the paddy field and animal farm. Sahoo, Kim and Powell (2016) has stated that all livestock operations should be located at least 100 – 200 ft (30.5 – 61 m) away from any wells to reduce the risk of water pollution.

Spearman's rho correlation test was conducted to see any significant relationship in nitrate concentration with three variables, namely age and depth of well and distance from nitrate source (Table 5).

Table 5: Correlation test between nitrate concentration with three variables i.e. age, depth and distance to nitrate resources

		Age	Depth	Distance From Nitrate Source
Keting village	r	.192	.082	.165
	Sig.	.262	.634	.336
Kuchelong village	r	-.122	-.206	.152
	Sig.	.435	.186	.331
Telaga Ara village	r	.031	.191	.022
	Sig.	.822	.155	.873

Note: Spearman's rho

From the analysis, it was found that there are no significant relationships with all three variables. Age and depth of well and distance from nitrate source did not play a role in nitrate concentration in the wells studied. These results were different from a study done by Swistock, Clemens and Sharpe (2009) who stated that nitrate concentration was correlated with the distance to the nearest cornfield and crop fields. Also, from the same study, the authors found that age of the well was statistically important, while depth of well is modestly significant.

4. Conclusion

In conclusion, all groundwater samples have nitrate concentration lower than maximum acceptable level. One reason behind this is that the sampling period is conducted during the harvest season. Recommendations should be made to residents with higher concentration of nitrate in their drinking water on ways to decrease nitrate to an acceptable level can reduce the health effects of nitrate pollution in the long term. Awareness on water quality problems should be instilled into residents by way of education in order for them to be resilient. In conclusion, all groundwater samples have nitrate concentration lower than maximum acceptable level. One reason behind this is that the sampling period is conducted during the harvest season. Recommendations should be made to residents with higher concentration of nitrate in their drinking water on ways to decrease nitrate to an acceptable level can reduce the health effects of nitrate pollution in the long term. Awareness on water quality problems should be instilled into residents by way of education in order for them to be resilient.

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References

Aida Soraya S, Sharifah Norkhadijah SI, Shaharuddin MS & Emilia ZA (2014). Nitrate in Groundwater and Excretion of Nitrate and Nitrosamines in Urine: A Review, *International Journal of Sciences: Basic and Applied Research (IJSBAR)*, *15*(2), pp 176-191.

Aida Soraya S, Sharifah Norkhadijah SI, Emilia ZA, Ho YB & Hafizan Ju (2016). Contamination of Nitrate in Groundwater and Evaluation of Health Risk in Bachok, Kelantan : A Cross-Sectional Study. *American Journal of Applied Science 2016*, *13*(1), 80-90.

Encyclopaedia Brittanica (2019). Nitrifying bacterium. Retrieved on 16 January 2019 from https://www.britannica.com/science/nitrifying-bacterium

Erickson, GE (1981). Geology and origin of the Chilean nitrate deposits. Geological Survey Professional Paper 1188.United States Department of the Interior. Retrieved on 16 January2019fromhttps://pubs.usgs.gov/pp/1188/report.pdf

Ju XT, Kou CL, Zhang FS & Christie P (2006). Nitrogen balance and groundwater nitrate contamination: Comparison among three intensive cropping systems on the North China Plain. *Environmental Pollution* 143:117e125

Parvizishad M, Dalvand A, Mahvi AH & Goodarzi F (2016). A Review of Adverse Effects and Benefits of Nitrate and Nitrite in DrinkingWater and Food on Human Health. *Health Scope*, *6*(3).

Muhamad Nur Fakhri MR & Shaharuddin MS. (2017). Nitrate (NO3-) In Groundwater: A Health Risk Assessment At Two Villages In Mukim Tualang Salak In Bachok, Kelantan. *Asia Pacific Environmental and Occupational Health Journal (ISSN 2462 -2214), 3*(2), 20 – 24.

Nas B & Berktay A (2006). Groundwater contamination by nitrates in the city of Konya, (Turkey): A GIS perspective. Journal of Environmental Management 79:30–37.

Engineering Services Division, Ministry of Health, Malaysia (2010). National Drinking Water Quality Standards (NDWQS). [Retrieved on 15 January 2019] from http://kmam.moh.gov.my/public-user/drinking-water-quality-standard.html

Sahoo PK, Kim K & Powell MA (2016). Managing Groundwater Nitrate Contamination from Livestock Farms: Implication for Nitrate Management Guidelines. *Curr Pollution Rep*, 2:178–187

Swistock BR, Clemens S & Sharpe WE (2009). Drinking Water Quality in Rural Pennsylvania and the Effect of Management Practices. School of Forest Resources and Institutes of Energy and the Environment, Pennsylvania State University.Retrieved on 17 January 2019 from http://www.rural.palegislature.us/drinking_water_quality.pdf

USDA – United States Department of Agriculture (1995). Fate and Transport of Nutrients: Nitrogen. Working Paper No. 7. Retrieved on 16 January2019fromhttps://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs143_014202

USEPA - United States Environmental Protection Agency (2002). Nitrification. Office of Water. Office of Ground Water and Drinking Water. Distribution System Issue Paper. Retrieved on 16 January 2019 fromhttps://www.epa.gov/sites/production/files/2015-09/documents/nitrification_1.pdf

Vitousek, P, Mooney H, Olander L & Allison S (2002). Nitrogen and nature. *Ambio* 31(2):97-101

Wongsanit J, Teartisup P, Kerdsueb P, Tharnpoophasiam P & 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* DOI 10.1007/s11356-015-4347-4.

WHO - World Health Organization (2011). Nitrate and Nitrite in Drinking-water Background document for development of WHO Guidelines for Drinking-water Quality. Retrieved on 17 January2019fromhttps://www.who.int/water_sanitation_health/dwq/chemicals/nitratenitrite2ndadd.pdf