NITRATE AND PHOSPHATE CONTENTS AND QUALITY OF WELL WATER IN NORTH-EASTERN DISTRICTS OF KELANTAN*

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Abstract. In the north-eastern district of state of Kelantan almost 40% of the populations are still relying on well water for their domestic uses and consumption. Generally, the wells are located within the vicinity of agricultural activities, such as tobacco, paddy, rubber plantation and orchards. There is possibility that the activities, especially related to application of chemical fertilizers, may pollute the well either through runoff or underground transportation. A study was carried out on fifteen wells in the district of Bachok, Pasir Puteh and Machang to determine the well water quality as well as the nitrate and phosphate contents of the water samples. The sampling was done twice, one in early October 2004 (representing dry season sampling), and the end of January 2005 (representing rainy season sampling). Data for turbidity, temperature, DO, and pH were determined in-situ, while the nitrate and phosphate contents, BOD and COD were determined in laboratory. Water Quality Index (WQI) of the samples was determined based on the method suggested by the Interim Water Quality Standard (INWQS) for Malaysia. The study found that nitrate contents ranged between 0.01 to 2.42 mg/L in rainy season and between non detectable to 0.3 mg/L in dry season. The corresponding phosphate contents for rainy and dry seasons are ranging between 0 – 2.2 mg/L and 0.5 – 1.5 mg/L respectively. In general, WQI of all the wells studied fall into class III or IV. However, WQI values of all the wells improved (increased) in wet season as compared to dry season. Based on the INWQS, these classes of water required extensive treatment before being regarded as suitable for public water supply.

Key words: Well-water, WQI, phosphate, nitrate.

Abstrak. Di timur laut negeri Kelantan Darulnaim, hampir 40% penduduk masih bergantung kepada air telaga untuk kegunaan domestik dan minuman. Amnya, kebanyakkan telaga terletak berdekatan dengan kawasan aktiviti pertanian seperti penanaman tembakau, padi, getah dan dusun. Dengan in terdapat kemungkinan aktiviti pertanian tersebut akan mencemar air telaga, terutamanya berkaitan penggunaan baja kimia, yang akan masuk ke telaga melalui aliran air atau perpindahan bawah tanah. Satu kajian telah dijalankan ke atas lima belas buah telaga di daerah Bachok, Pasir Puteh dan Machang, untuk menentukan kanduangan nitrat dan fosfat dan kualiti air telaga-telaga berkenaan. Pensampelan dijalankan dua kali, iaitu pada awal Oktober 2004 (mewakili musim kering) dan akhir Januari 2005 (mewakili musim hujan). Data untuk kekeruhan, suhu, DO dan pH ditentukan *in-situ*, manakala kandungan nitrat, fosfat, BOD dan COD ditentukan di dalam makmal. Indeks Kualiti Air (WQI) bagi sample-sampel yang dikaji ditentukan berdasarkan *Interim Water Quality Standard (INWQS) for Malaysia*. Kajian ini mendapati kandungan nitrat berjulat dari 0.01 ke 2.42 mg/L semasa musim hujan, dan antara tidak dapat dikesan dan 0.3 mg/L di musim kering. Kandungan fosfat di musim hujan dan musim kering pula masing-masing berjulat 0 – 2.2 mg/L dan 0.5 – 1.5 mg/L. Pada amnya nilai WQI bagi semua telaga dikaji jatuh dalam Kelas III dan IV. Walau bagaimanapun, nilai-nilai WQI bertambah baik (meningkat) di musim hujan di banding musim kering. Berdasarkan saranan INQWS air dalam kelas-kelas ini memerlukan rawatan yang menyeluruh sebelum boleh dianggap sesuai untuk kegunaan bekalan air awam.

Kata kunci: Air telaga, WQI, fosfat, nitrat.

Introduction

In line with the increasing awareness on the importance of good health among Malaysian, drinking water quality is becoming an increasing debating subject and important issue in Malaysia [1]. Demand for good quality water is ever increasing. Moreover the global demand in water consumption has doubled since

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1940, and expected to be doubled again within twenty years [2]. With this kind of demand and the inability of the relevant authorities to supply processed cleaned water, majority of people in less developed areas resort to consuming untreated raw well water.

The majority of people living in these less developed areas involved in agriculture and farming activities. Each year they cover their field in chemicals in order to obtain higher yields and faster growing crops. They spray their fields with increasing amount of fertilizers – containing phosphates and nitrates. The excess fertilizers eventually will find their way into pools and ponds and wells. [3, 4]. Besides fertilizers, phosphate salts used in detergents may also contribute to phosphate accumulation in well water. Animal wastes also contribute to phosphate and nitrate in runoff water [5].

Phosphate and nitrate are nutrient for plant growth. However they can also be the primary cause of lake (well) enrichment leading to the growth of algae and weeds. This process is known as eutrophication. The presence of algae and weeds will affect the water quality index. In fact the presence of 10 ppm nitrate-nitrogen in drinking water can cause methemoglobinemia (inability to use oxygen) in infants [6] and other health related risks may happen at higher concentration [7]. Thus, this may me the reason to concern about the concentration of phosphate and nitrate in water.

Although the presence of nitrate and phosphate in groundwater in agricultural areas has become the main concern in various countries [5, 8] not many study has been carried out in Malaysia. Since many households in agricultural areas in Malaysia still utilized untreated well water for their drinking and other domestic purposes, it is interesting to study the concentrations of phosphate and nitrate in well waters and their relation to the water quality index.

Methodology

Sampling Area

The study covered three districts, Bachok, Pasir Puteh and Machang, in Kelantan. From each district, five wells were selected. The depth of the wells ranged between 30 to 40 feet. However, the water volume in each well depends on various factors, such as season, location from river, height (elevation) from sea level. In general, water volume increases during rainy season. Table 1 summarizes the well location, usage and type of plantation around the wells. Majority of the wells were used as drinking water as well as other domestic usage such as washing, bath and cooking.

Sampling

Sampling was done twice, one in early October 2004 (representing dry season), and the other at the end of January 2005 (representing wet season). Water samples were collected using *'water theft'* coupled to a 1-liter plastic sample container, at a point about 15 cm from surface. The plastic container was first rinsed with the respective well water before being used in the collection procedures. After in-situ analysis, the water sample in the container is kept in closed cooler box at ice temperature, before being transported to chemical analysis laboratory. While in the laboratory the samples were kept at 4 ^{o}C until further analyses.

Analysis

In-situ measurements were carried out on the water samples parameters of pH, temperature, dissolve oxygen (DO) and turbidity. Other parameter measurements were carried out in laboratory. The Water Quality Index (WQI) was calculated using the method used by Mohd Talib Hj Latiff et al., [9], based on the formula suggested by the Department of Environment, Malaysia [10]. Table 2 summarizes the instruments and methods used in determining the magnitudes of the respective parameter.

Table 1. Sampling points.

District	Code	Location	Elevation (m)	Usage	Plantation
Bachok	**B1**	N06^o 07.314' E102^o 21.245'	8	Drinking, Domestic, Watering	Tobacco
	B2	N06^o 08.165' E102^o 21.075'	5	Drinking, Domestic, Watering	Tobacco
	B3	N06^o 08.118' E102^o 21.135'	5	Drinking, Domestic, Watering	Tobacco
	B4	N06^o 06.634' E102^o 20.118'	6	Drinking, Domestic, Watering	Paddy
	B5	N06^o 06.488' E102^o 19.412'	5	Abandon	Paddy
Pasir Puteh	**P1**	N05^o 55.961' E102^o 18.587'	16	Drinking, Domestic	Paddy
	P2	N05^o 55.491' E102^o 19.009'	19	Drinking, Domestic	Paddy
	P3	N05^o 55.513' E102^o 19.134'	25	Watering	Orchard
	P4	N05^o 55.513' E102^o 19.134'	21	Drinking, Domestic	Paddy
	P5	N05^o 55.500' E102^o 19.053'	23	Abandon	Paddy
Machang	**M1**	N05^o 51.951' E102^o 12.781'	32	Drinking, Domestic	Paddy
	M2	N05^o 51.932' E102^o 12.453'	45	Watering	Rubber
	M3	N05^o 51.700' E102^o 13.804'	36	Drinking, Domestic	Paddy
	M4	N05^o 51.661' E102^o 13.987'	38	Drinking, Domestic	Paddy
	M5	N05^o 51.654' E102^o 13.519'	34	Drinking, Domestic	Paddy

Table 2. Methods used to determine nitrate and phosphate, and the various parameters in the study.

Parameter/Ions	Instruments and Method
Nitrate	HACH quick programme 355, DR 2000 Spectrometer
Phosphate	HANNA Phosphate High Range ISM, HR HI 93717
pH	Portable pH meter, model WP-81, TPS
Temperature, ^oC	Portable Temperature meter, model WP-81, TPS
Dissolved Oxygen (DO), mg/L	HANNA portable DO probe
Turbidity, NTU	HANNA portable turbidity meter
Total Suspended Solid (TSS), mg/L	Total non-filterable residue, dried at 103 – 105 ^oC, using Whitmann GF/C filter
Chemical Oxygen Demand (COD), mg/L	Digestion. COD Reactor MERCK TR-420. Measured using HACH DR 2010 Spectrometer
Biochemical Oxygen Demand (BOD), mg/L	HACH BOD track sample and HACH incubator
N-NH_3, mg/L	HACH quick programme 380, coupled to HACH DR 2000 Spectrometer

Results and Discussion

Results of the study for the fifteen wells are shown in Table 3 and Table 4 for wet and dry season respectively. Although, there was temporal variation between wet season and dry season sampling, the average temperature of the samples between the two sampling periods are identical, 27.8 ^{o}C. However, there is observable variation of temperature between samples ranging between 25.5 ^{o}C to 30.7 ^{o}C during wet season and between 26.9 ^{o}C and 28.8 ^{o}C in dry season. This may be attributed to the location of the wells, either under shaded area or in the open areas, as well as the time of sampling, morning or afternoon.

Nitrate

Nitrate contents ranged between 0.01 to 2.42 mg/L in wet season. Generally well water samples in Bachok district contained higher nitrate than samples from any other districts. The locations of the wells studied in Bachok district are within the vicinity of the tobacco plantations and paddy fields. Being very soluble in water, nitrate from chemical fertilizers used in the plantation and fields can be transported into the wells either vertically or horizontally with the rainwater during rainy season. These concentration, however are lower than the limit of 10 mg/L suggested by the Interim Water Quality Standard of Malaysia (INWQS). During dry season, the concentrations of nitrate are relatively lower in the well water studied. In some samples nitrate are even non-detectable.

Table 3. Wet Season (Sample collected at the end of January 2005)

	B1	**B2**	**B3**	**B4**	**B5**	**P1**	**P2**	**P3**	**P4**	**P5**	**M1**	**M2**	**M3**	**M4**	**M5**
Nitrate, mg/L	0.23	1.28	0.22	0.32	2.42	0.07	0.03	0.01	0.76	0.01	0.03	0.10	0.01	0.35	0.21
Phosphate, mg/L	nd	0.9	0.4	0.9	2.2	0.4	nd	nd	1.4	nd	nd	0.9	1.0	1.5	1.1
pH	6.9	7.8	7.0	8.1	6.3	6.7	6.6	5.9	6.1	6.8	6.5	5.9	5.2	5.8	5.5
Class	I	I	I	I	IIA	I	I	III	IIA	I	I	III	III	III	III
DO, mg/L	1.41	1.37	1.25	0.65	1.03	3.14	1.83	1.31	1.84	1.02	1.11	2.24	1.26	1.52	1.91
Class	IV	IV	IV	V	IV	III	IV	IV	IV	IV	IV	IV	IV	IV	IV
COD, mg/L	40.9	35.1	30.5	27.2	37.1	41.9	31.1	25.5	29.4	33.6	32.2	33.0	36.5	39.2	33.1
Class	III	III	III	III	III	III	III	III	III	III	III	III	III	III	III
BOD, mg/L	0.6	5.0	4.0	6.2	13.0	1.4	1.7	1.8	5.8	2.4	5.8	3.1	3.8	0.8	3.6
Class	I	III	III	IV	V	IIA	IIA	IIA	III	IIA	III	IIB	IIB	I	IIB
$N\text{-}NH_3$, mg/L	0.19	0.32	0.45	0.79	0.30	0.33	0.67	0.40	0.16	0.44	0.29	0.41	0.02	0.22	0.25
Class	IIA	IIB	III	III	IIA	IIB	III	IIB	IIA	IIB	IIA	IIB	I	IIA	IIA
TSS, mg/L	15.5	13.4	6.5	6.32	9.21	3.7	5.9	13.5	5.3	14.6	3.4	4.6	2.8	2.4	3.1
Class	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
TDS, mg/L	76.2	78.0	53.0	100.7	56.9	82.5	38.7	33.3	26.2	62.3	16.1	27.6	20.4	35.7	14.5
Class	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
Turbidity, NTU	0.51	0.55	0.60	0.63	0.54	0.61	1.11	0.93	0.63	0.74	0.53	0.92	0.61	0.50	0.53
Class	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
Temp. (^{o}C)	28.9	30.7	28.7	28.8	28.3	25.5	27.7	27.2	27.1	27.0	26.5	27.9	27.8	27.3	27.5
WQI Value	65.5	63.0	49.6	49.2	66.9	57.1	47.7	48.4	48.6	58.8	57.1	49.3	49.6	49.9	47.5
OVERALL CLASS	**III**	**III**	**IV**	**IV**	**III**	**III**	**IV**	**IV**	**IV**	**III**	**III**	**IV**	**IV**	**IV**	**IV**

Table 4. Dry season (Sample collected at the end of October 2004)

	B1	**B2**	**B3**	**B4**	**B5**	**P1**	**P2**	**P3**	**P4**	**P5**	**M1**	**M2**	**M3**	**M4**	**M5**
Nitrate, mg/L	nd	0.1	nd	nd	1.0	nd	nd	nd	nd	2.0	0.1	0.1	0.3	0.2	0.2
Phosphate, mg/L	1.0	1.0	0.5	1.1	1.2	0.9	1.5	1.1	1.5	0.6	0.6	1.4	1.4	1.7	1.3
pH	5.5	6.8	5.5	6.9	5.5	6.4	5.9	5.4	5.1	6.4	4.7	6.8	4.3	5.1	5.0
Class	III	I	III	I	III	IIA	III	III	III	IIA	V	I	V	III	IV
DO, mg/L	3.45	1.93	1.03	4.61	1.86	5.64	2.92	1.50	2.25	1.70	0.99	3.55	3.18	2.06	1.70
Class	III	IV	IV	III	IV	IIB	IV	IV	IV	IV	V	III	III	IV	IV
COD, mg/l	26.4	20.1	17.9	15.7	21.7	9.1	6.8	5.9	7.9	7.1	7.3	5.4	13.6	11.6	8.4
Class	IIB	IIA	IIA	IIA	IIA	I	I	I	I	I	I	I	IIA	IIA	I
BOD, mg/L	6.8	11.8	8.7	10.3	9.2	27.4	17.3	9.5	12.7	19.4	11.3	12.8	11.5	13.7	13.0
Class	III	III	III	III	III	V	V	III	IV	V	IV	IV	IV	V	V
$N\text{-}NH_3$ (mg/L)	0.42	0.58	0.06	1.23	0.48	0.11	0.46	0.51	0.72	0.85	0.51	0.59	0.35	0.47	0.16
Class	IIB	IIB	I	IV	IIB	IIA	IIB	IIB	IIB	IIB	IIB	IIB	IIB	IIB	IIA
TSS, mg/L	13.6	12.9	4.2	5.3	12.2	4.3	7.8	13.8	7.9	13.2	3.6	2.1	1.6	3.7	2.4
Class	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
TDS, mg/L	113.5	121.0	42.6	98.3	90.1	86.0	65.4	24.2	23.0	53.1	20.3	67.1	16.8	29.6	14.7
Class	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
Turbidity (NTU)	0.51	0.58	0.50	0.71	0.61	0.57	1.56	1.76	0.83	0.93	0.64	1.23	0.76	0.61	0.59
Class	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
Temp. (^oC)	28.1	28.3	28.3	28.0	27.2	28.3	28.4	27.8	27.3	27.4	27.3	28.8	26.9	27.6	27.1
WQI Value	56.2	54.1	37.4	44.0	50.9	53.0	41.2	36.6	36.5	48.7	28.5	31.3	34.5	36.6	30.6
OVERALL CLASS	**III**	**III**	**IV**	**IV**	**IV**	**III**	**IV**	**IV**	**IV**	**IV**	**V**	**IV**	**IV**	**IV**	**V**

Phosphate

The maximum phosphate concentration in the samples studied is 2.2 mg/L during wet season and 1.7 mg/L during dry season. In some samples phosphate are non-detectable. There is no correlation trend between concentration during dry and wet season. However, generally samples from Machang district contained higher concentration of phosphate. Phosphate is not soluble in water, but when applied to soil it will get binds to the soil particles, thus it will not be transported easily through leaching or washing together with water in the soil profiles. Therefore, although phosphate may originated from chemical fertilizers applied to the plantation soil, the concentration trends shown by nitrate is not observable in the case of phosphate.

PH Value

In wet season pH of the well water studied ranged between 5.2 to 8.1, with an average of 6.5. While during dry season the well water samples become more acidic, with pH ranging between 4.7 and 6.9, with an average of 5.7. Based on the INWQS the wet season average falls into Class I, while the dry season falls into Class III category. This observation might be attributed to the great reduction in water volume in the wells during dry season.

Dissolved Oxygen, DO

Dissolved oxygen the water samples studied ranged between 1.02 mg/L to 3.14 mg/L and averaged to 1.53 mg/L during wet season. The average increased to 2.56 mg/L in dry season, ranging between 0.99 to 5.64 mg/L. Generally this falls into Class IV category. High DO for both seasons was for sample P1, with 3.14 mg/L and 5.64 mg/L in dry and wet season respectively.

Chemical Oxygen Demand, COD

Generally the COD measurements were higher in all the wells during rainy season than during dry season. The average COD for the fifteen wells during rainy season was 33.8 mg/L, and improved to 12.3 mg/L in dry season. Although the maximum value of 40.9 mg/L was recorded for water sample from well B1 during rainy season, this value is still below the 50 mg/L limit of Class III standardized in INWQS.

Biochemical Oxygen Demand, BOD

In wet season, average BOD of the fifteen wells is 3.9 mg/L, with a maximum value of 13.0 mg/L at well B5. Well B5 is within the vicinity of a paddy field, and is abandoned. The average BOD increases in dry season to 13.0 mg/L. Results show that the BOD of all the well water samples in dry season exceeded the standard value of 6 mg/L (Class III) of INQWS.

Nitrogen-Ammonia, N-NH_3

On average during wet season the nitrogen-ammonia concentration ranged between 0.02 – 0.67 mg/L. These concentrations are below the INQWS limit (for Class III) of 0.9 mg/L. Except for well B4, identical trend is also observed during dry season. However, for B4 the concentration of 1.23 mg/L is beyond the INQWS limit. Generally, the nitrogen-ammonia concentration of the wells shows reduction in value during wet season.

Total Suspended Solids, TSS

All of the well water studied either during wet or dry season fall into TSS Class I, with wet and dry season average of 8.4 mg/L and 7.2 mg/L respectively. This shows that the well water studied posed no problems in terms of TSS.

Turbidity

As turbidity is closely correlated to TSS, the study found that all the well water (either during wet or dry season) fall into Turbidity Class I. Physical observation also showed that all the water samples were very transparent in nature. In wet season the turbidity range between 0.50 – 1.11 NTU, while in dry season the range is 0.50 – 1.76 NTU.

Water Quality Index, WQI

Based on the WQI values the study found that the majority of the well water samples fall into Class IV or V. The general trend showed that the WQI values decreased during dry season. Only wells B1 and B2 maintained the Class III category during wet as well as dry season. According to the INWQS classification only Class III and below are suitable as water supply, and that needs extensive treatment. From Table 3 and Table 4, it can be seen that the main contributing and affecting parameters on the WQI values are the DO, COD and BOD. The pH values contribute a significant role during dry season in influencing the WQI values.

A comparative analysis for wet and dry season parameters was also carried out. Generally, it was found that the quality of well water studied improved during wet season. This can obviously be seen in Figure 1 where the averages of the respective parameters studied were compared for wet and dry season.

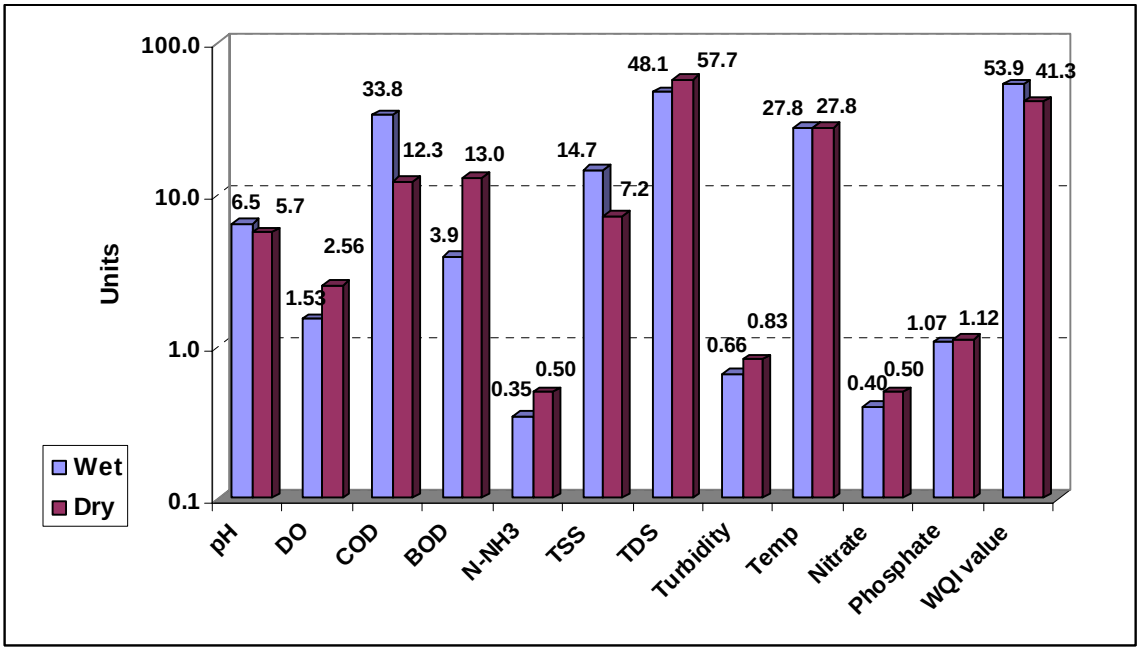

Figure 1. Comparison on the average of the parameters studied during wet and dry season.

Conclusion

The nitrate and phosphate contents of all the samples studied are still below the suggested limit, indicating the effect of fertilizers on the wall water is minimal. In general, the study has shown that only six out of the fifteen wells studied are suitable as water supply based on the INWQS index and classification, and that need further extensive treatment. The low DO level and high COD and BOD are the main contributing factors attributed to the classification of the well water samples to between Class III and Class V. In dry season the water become more acidic, and thus play an important role as well in determining the class. The water quality improved during wet season.

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