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GROUNDWATER ASSESSMENT IN AGRICULTURAL AREA, CASE STUDY FROM MACHANG - MALAYSIA

(Penilaian Air Tanah di Daerah Pertanian, Studi Kasus di Machang Malaysia)

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Abstract

The study area is located in Machang, North Kelantan - Malaysia. The North Kelantan plain is covered with Quaternary sediments overlying granite bedrock. The drainage system is dendritic with the main river flowing into the South China Sea. Hydrogeochemical method was used to study groundwater of shallow aquifer characters within the area. Based on water samples analysis collected from the study area, it can be deduced that the cations and anions concentration are good for domestic use except in the southern region which the nitrate concentration is higher (more than 20 mg/l) compared to the northern region (relatively zero). The areas that possibly possess nitrate-contaminated groundwater have been mapped along with groundwater flow patterns. The southern and middle part of the study area has an east to west groundwater flow pattern, making it impossible for contaminated water from the southern region to enter the northern area, despite in the northern area has lower elevation.

Keywords: Groundwater, Nitrate.

Abstrak

Lokasi area studi adalah berada di Machang, Kelantan Utara – Malaysia. Dataran tanah wilayah Kelantan Utara dilapisi oleh batuan Sedimen Kuarter yang mana batuan granit sebagai batuan dasar. Sistem pengairan adalah berbentuk jaringan dendritik dengan sungai utama mengalir ke Laut Cina Selatan. Metoda hydrogeochemical digunakan untuk mempelajari karakter air tanah dari akuifer dangkal untuk keseluruhan area studi. Berdasarkan pada analisa air yang diperoleh dari area studi, dapat disimpulkan bahwa konsentrasi kation dan anion baik digunakan untuk kehidupan sehari hari kecuali air tanah di area sebelah selatan yang mana kandungan nitratnya tinggi (lebih dari 20 mg/l) dibandingkan di area sebelah utara (hampir tidak ada kandungan nitrat). Area yang memungkinkan memiliki konsentrasi nitrat pada air tanah dipetakan dengan kombinasi pola aliran air tanah. Pola aliran air tanah di area belahan selatan dan bagian tengah adalah dari timur ke barat yang mana tidak memungkinkannya air tanah yang terkontaminasi oleh nitrat di belahan selatan untuk masuk ke area belahan utara walaupun di belahan utara adalah dataran rendah.

Kata kunci: Airtanah, Nitrat.

INTRODUCTION

Groundwater is among the North Kelantan's most important natural resources. It provides drinking water to urban and rural communities, supports irrigation and industry, sustains the flow of streams and rivers, and maintains riparian and wetland ecosystems. The importance of groundwater for the existence of human society cannot be overemphasized.

Like other places, in the study area, chemical fertilizers are rigorously used to enhance the agricultural establishment (Yang, et al., 2006) of crude palm oil. Fertilization is conducted every two months using fertilizers of different chemical content. For example, at the beginning of the year, 400 kilograms of Urea with 60% nitrogen is used for a two hectare palm plantation. Two months later, another fertilizer with 15% Nitrogen, 30% Phosphorus, and 55% Potassium (NPK) is applied to further improve the production of palm. This process is repeated in the middle of the same year and continues till the end of the year. All in all, at least 800 kilograms of urea is employed for the fertilization of palm trees in a two hectare area per year.

Other agricultural activities within study area include the cultivation of paddy fields and rubber trees. However, in comparing the intensity of the fertilization process for paddy and rubber trees with that of palm oil, it is much less than that of palm oil. The farmers in study area plant paddy only once a year on average, although some plant paddy up to twice a year over several areas. Paddy fields consume a mere 100 kilograms of urea per two hectare a year. For rubber trees, 200 kilograms of urea is utilized for every two hectare per year.

Contaminant leaching (especially nitrate) from agricultural soils has been widely studied (Almasri and Kaluarachchi, 2004; Saadi and Maslouhi 2003). In this study attention has been focused mainly on assessment of groundwater within sandy soils in the shallow aquifer. Clay soils are usually not considered to have a high nitrate leaching potential.

Review of Geology Study Area

The total extent of study area covers approximately 98 square kilometers (km^2). The southern part of the area is defined by Kampung Tok Bok and is bounded in the north by Kampung Ketereh. The study area is covered with Quaternary sediments overlying granite bedrock. It is drained mainly by short rivers and streams which flow into the South China Sea. The thickness of the Quaternary deposits varies from 20 m inland to about 200 m near the coast. The loose quaternary sediments consist of alternating layers of coarse gravels to silts or mixtures of the two (Saim, 1999). It can be clearly seen that the study area is bounded by Kelantan River at the west side and the high hill at the east side (Figure 1). The hill is a part of the Boundary Range Composite Batholith. It consists of two major components, the Machang Batholith which is 100 x 20 km, and the smaller Kerai Batholith situated on the western flank (Cobbing, and Pitfield, 1992). Around the hill, a lot of exposed granite can be found especially at Sungai Buluh Quarry. Other exposed granite can also be found in Kampung Pulai Condong around 4 km to the west of Machang Batholith Boundary Range. Figure 1 shows the location map of the research area. The RSO West Malaysia and Kertau 1946 are used as the coordinate system and datum in the map.

METHODOLOGY

A hydrogeochemical method was used to study the groundwater characters in this area. In the study, special emphasis was given to the first aquifer (shallow aquifer) because it is the main source of the water supply for domestic uses. Samples of groundwater were collected from the existing wells, and in-situ parameters such as well depth, water level, total dissolved solid, pH, conductivity, salinity and temperature were measured. Water samples of 500ml were kept in plastic bottles and maintained at a temperature of 4^0C. This was done for determining their major ion contents analysis with IC and ICP in the hydrogeology lab. Physical information about water samples were retrieved directly from existing wells or piezometers whereas the physical information about these well, like well location, well depth, depth to water were obtained from the well owner.

The hydrogeochemical data obtained from this study were used in the interpretation of the overall data. Major ion concentration, electrical conductivity, and total dissolved solids were among the hydrogeochemical parameters used in the characterization of the groundwater.

RESULTS AND DISCUSSION

The amounts of different elements including in-situ water, physical well parameters and hydrogeochemical content have been presented in milligrams per litre (mg/l) for the tested water samples, these figures are tabulated in Table 1.

Ninety five percent of the groundwater in the shallow aquifer possesses a hydrogen ion concentration (pH) that is moderately acidic (4

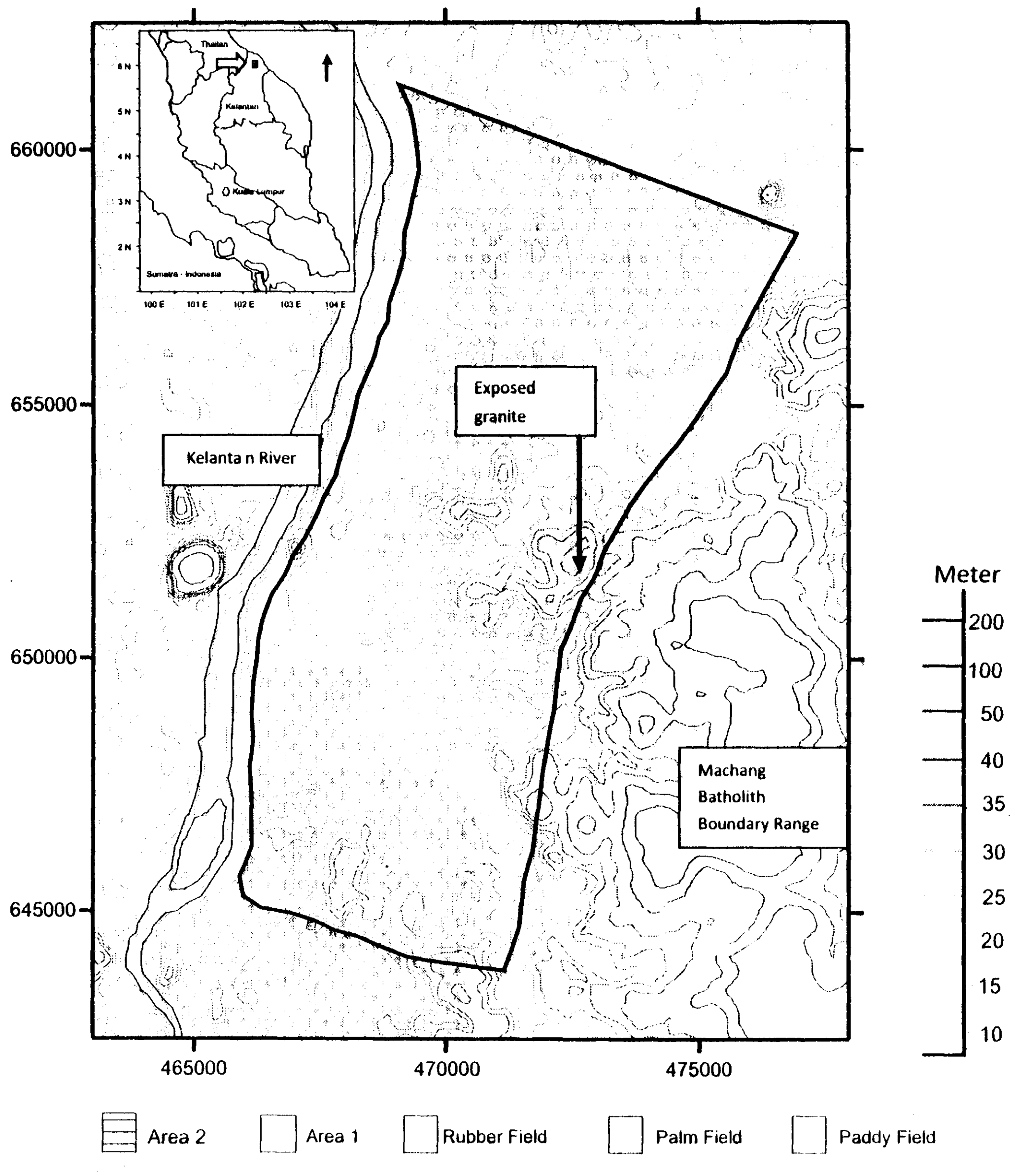

Figure 1. Location of study area.

- 6.5) whereas the remaining 5% is indicative of a more neutral pH condition (6.5-7.8). Thus it is generally good for some other domestic uses. Thirty percent of the water sample is less than 5 on the pH scale and is considered not good for human consumption if untreated. The fact that the hydrogen ion concentration is more or less neutral affects the aggressiveness of the solution.

Magnesium ion (Mg2+) concentration is generally low. The availability of magnesium ion in the groundwater of the area can be explained by the occurrence of magnesium with calcium carbonate cement in sedimentary formation. The low values of magnesium ion concentration may be a result of deficiency of minerals capable of yielding magnesium ion in water. This implies, however, that the magnesium content of groundwater in the area renders it suitable for human use.

There are notably low values of sodium (Na) and potassium (K) in the water samples of the mapped area. The possibility of contributory factor is an impurity in the cementing material where sodium ions permeate the carbonate lattice. Other natural sources include the weathering of feldspars and leaching of clay minerals (Egbunike, 2007, Hounslow, 1995). Potassium, an important fertilizer, is strongly held by clay particles in soil. Therefore, leaching of potassium through the soil profile and into ground water is important only on coarse-textured soils. Potassium is common in many rocks. Many of these rocks are relatively soluble and potassium concentrations in ground water increase with time. Important sources of sodium include fertilizing activities and animal wastes. Sodium is more mobile in soil than potassium and so it is used often as an indicator of human impacts to shallow ground water. Sodium is also a common chemical in minerals. Like potassium, sodium is gradually released from rocks. Concentrations therefore increase with time.

The chloride concentration of the groundwater was reported to be relatively low because of the fact that chloride does not show any correlation with the components of pore water derived from mineral breakdown. Also, in sedimentary rocks, the major source of chloride in groundwater is due to evaporate. The concentration of rain water by evapotranspiration may be an important source of chloride in the area (Egbunike, 2007). Another common source of chloride in groundwater is the leaching of chloride fertilizing over long periods time. The influence of the fertilizing factor in the chloride content of the groundwater around the southern part of the study area can be found in water sample from the borehole at A006 with chloride concentration of 12.10 mg/l. The chloride concentration in the water samples are within the accepted limits for human consumption.

The concentration of nitrate in the mapped area is generally good and falls within the accepted limit except in the palm oil field area around surface water termination (A002, A003, A004, S001 and S002). However, out of the exceptional area, the nitrate safe drinking water concentration of 10 mg/l (WHO, 1984). The potential source of nitrate in the area may include fertilizing activities, animal excrement, and probably the atmosphere.

Aluminium ion (Al^{3+}) content in the study area varies from 0.00 – 1.505 mg/l and is within the accepted limit. There are only two groundwater samples (LR016A and S001) in which bicarbonate are absent. The presence of bicarbonates in the shallow aquifer within study area is predicted to be as a result of agricultural activities that utilize dolomite for various purposes. Sulphate (SO_4) concentration ranges from 0 - 12.339 mg/l which is considered low and lies within the accepted limit.

Overall, correlation between conductivity and other water chemical content can be calculated statistically using the Pearson product-moment correlation (Till, 1974). Based on the data in Table 1, the correlation coefficient between conductivity and TDS is 0.9899, conductivity and chloride is 0.2532, conductivity and nitrate is 0.8024, and conductivity and sulphate is 0.0432. Based on this fact, it is concluded that the amount of nitrate in the groundwater will influence total conductivity readings.

Table 1. In-situ parameters and chemical results of groundwater samples within study area. In the bottom row of the table, limit concentration for domestic use by WHO 1992 is displayed.

No	Sample ID	Location X (m)	Location Y (m)	Well Depth (m)	Ground Level (m)	Depth to Water (m)	Water Level (a.m.s.l) (m)	TDS mg/l	Conductivity µS/cm	Salinity 0/00	T °C	pH
1	A001	471343	646277	<7	28	2.56	25.44	76	159	0	27.8	4.77
2	A002	470511	646770	<7	24	2.1	21.9	323	654	0.1	30.5	5.98
3	A003	468507	648571	5	22	1.96	20.04	407	830	0	29.4	4.93
4	A004	466884	648964	<7	21	0.86	20.14	76	159	0	29.2	4.63
5	A005	467562	650522	<7	22	0.98	21.02	78	163	0	29.1	5.72
6	A006	470178	649987	<7	18	0.67	17.33	151	313	0	27.4	5.75
7	A007	471890	651687	<15	40	10.62	29.38	57	120	0	28.5	6.14
8	A008	471962	653352	<7	24	1.35	22.65	83	173	0	31.7	4.86
9	A009	468452	650985	<7	20	0.91	19.09	50	104	0	34.4	5.72
10	LR10A	470404	658785	<7	19	1.02	17.98	183	381	0	42.2	5.77
11	LR12A	473733	656574	<7	14	0.23	13.77	84	170	0	31.1	6.4
12	LR14A	470689	656930	5	17	0.65	16.35	89	180	0	25.7	6.42
13	LR15A	473804	654980	6	28	2.11	25.89	64	130	0	28.7	6.22
14	LR16A	470475	654957	<7	17	0.61	16.39	106	217	0	27.2	4.11
15	S001	467159	646187	5	24	1.43	22.57	370	751	0	28.3	6.88
16	S002	467455	645676	5	26	1.92	24.08	247	501	0	28.3	5.98
17	S003	469175	646657	3	28	2.38	25.62	49	98	0	30.5	5.09
18	S004	469982	645778	7	38	2.46	35.54	60	121	0	28.1	4.49
19	S005	470622	646025	5	29	1.22	27.78	35	70	0	28.5	6.19
20	S006	470630	645415	<7	33	2.96	30.04	48	97	0	30.1	6.42
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Table 1. Continued

No	Sample ID	Chloride mg/l	Nitrate mg/l	Sulfate mg/l	Fluoride mg/l	K mg/l	Ca mg/l	Mg mg/l	Na mg/l	Al mg/l	.Fe mg/l	CO3 mg/l	HCO3 mg/l
1	A001	5.86	2.77	5.915	0	1.309	4.782	0.304	7.912	0.045	0.054	0.000	85.320
2	A002	6.66	22.28	1.716	0.058	1.693	24.790	0.588	5.124	0.015	0.006	0.000	47.160
3	A003	7.60	28.79	0.25	0	2.181	19.540	1.887	10.010	0.000	0.220	0.000	52.56
4	A004	6.75	12.90	0.622	0	1.785	3.295	0.447	6.057	0.331	0.023	0.000	62.230
5	A005	4.11	3.84	3.544	0.049	2.505	8.306	0.622	3.581	0.122	0.058	0.000	12.510
6	A006	12.10	4.46	4.154	0	3.228	12.210	0.536	10.550	0.072	0.055	1.760	73.340
7	A007	2.14	0.00	1.213	0	1.329	2.469	0.327	3.059	0.025	0.540	0.000	2.700
8	A008	3.51	2.18	1.443	0	1.172	3.681	0.258	3.078	0.059	0.021	0.000	1.300
9	A009	7.21	12.58	0	0.22	1.487	3.628	0.698	11.240	0.130	0.025	1.600	23.800
10	LR10A	18.16	0.00	7.953	5.643	2.303	2.972	0.326	0.000	0.072	0.000	0.000	195.200
11	LR12A	2.43	0.00	0.263	0.032	4.151	3.048	0.888	3.227	0.130	1.993	0.000	7.000
12	LR14A	4.36	0.00	0.212	0.000	7.581	2.739	1.094	1.715	1.505	0.541	0.000	10.100
13	LR15A	1.83	0.00	0.000	0.073	3.797	3.340	0.915	1.183	0.448	0.164	0.000	13.200
14	LR16A	19.90	0.00	0.663	0.052	5.547	3.309	1.127	3.609	1.338	0.280	0.000	0.000
15	S001	6.28	24.18	0.318	0.000	2.534	6.025	1.558	7.835	0.000	0.032	0.000	0.000
16	S002	8.18	18.93	5.571	0.000	5.044	22.250	2.418	13.190	0.034	0.146	4.800	80.600
17	S003	5.23	6.83	1.605	0.000	1.457	6.211	0.433	8.004	0.304	0.029	0.000	4.200
18	S004	8.15	6.06	12.339	0	4.343	6.238	1.048	10.350	0.266	0.001	0.000	7.300
19	S005	3.65	9.72	1.394	0.000	2.064	3.917	0.666	4.831	0.144	0.004	0.000	4.500
20	S006	2.11	0.34	0.237	0.000	4.616	4.146	0.575	3.949	0.082	0.122	0.000	12.000
		250	10	400	1.5			150	200	0.2	0.3		

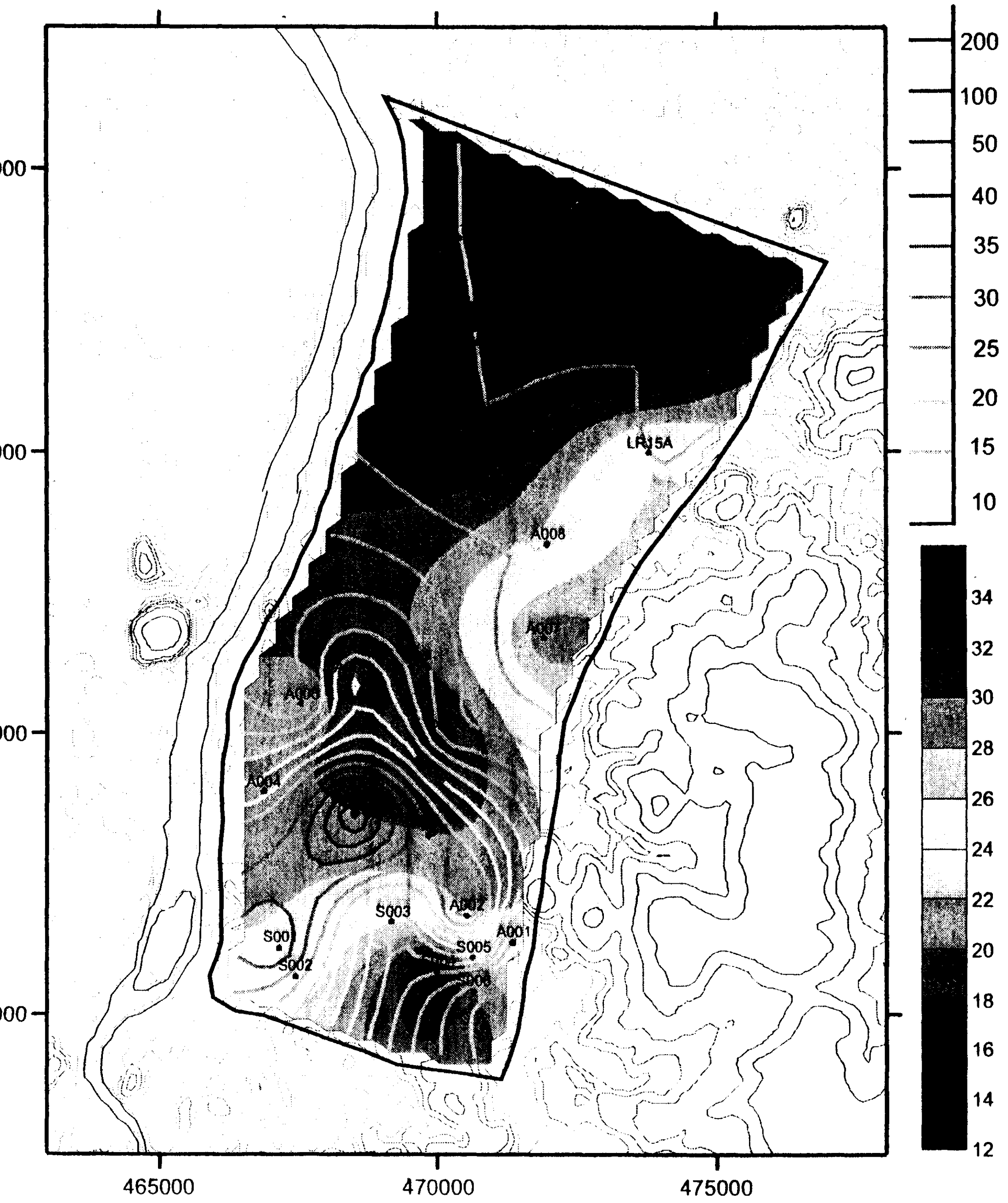

Figure 2. Combination map of three sets of contour data. The solid contour represents water level relative to mean sea level and the line contour above the solid contour is nitrate concentration in shallow aquifer (less than 11 meter deep) with well ID marks. The remaining contour lines reflect surface elevation.

The map shown in Figure 2 exhibits the well position for groundwater sampling. It also shows the contour of nitrate concentration from 20 well samples and water levels relative to mean sea level. Relative high concentration of nitrate can be found in the Palm oil field zone. The remaining rubber tree fields and paddy fields exhibit generally low nitrate concentrations.

In the well with sample ID A002, concentration of nitrate is considered to be high (12.58 mg/l) although no palm oil field is adjacent to the well. Here, there are minor agricultural activities, including corn plantation. For these activities, chemical fertilizer activities are not employed. Only organic fertilizers like cow manure are used.

According to Figure 2, zone 1 is the area between the y-coordinate lines 64500 and 65500 which are parallel to the x-axis. The groundwater in the shallow aquifer in this zone flows northwest from Boundary Range Hill to kampong Tok Bok. Boundary Range Hill is elevated at more than 250 m above mean sea level whereas Kampung Tok Bok is situated at around 35 m above mean sea level.

The groundwater around the wells S001 and S002 at the zone 1 (Figure 2) flows toward the Kelantan River. The direction is consistent to the groundwater flow of the wells near the eastern boundary of zone 1. It is noted that well S004 of eastern zone is located adjacent to the palm oil field in Kampung Tok Bok.

Thus, generally, groundwater movement within zone 1 is from southeast to northwest. Comperatively, in zone 2 (the area between the Y-coordinate lines 65500 and 66500, which are parallel to the X-axis) the groundwater movement occurs in two directions: southeast-northwest and northeast-southwest flow direction is minor and after calculating the vector resultant for groundwater flow of zones 1 and 2. The general direction of flow is from the southeast to the west, toward the Kelantan River.

It can thus be generalized that the direction of groundwater movement and surface runoff is influenced by elevation, moving from high land areas to lowland areas. It is observed that this mentioned factor may also affect the potential nitrate concentration of an area. Groundwater in lower elevation areas with palm oil field at its borders tend to have higher concentrations of nitrate whereas groundwater in higher elevation areas have lower concentration of nitrate.

In the zone between 645400 to 655000 of the Y-axis, the groundwater flow within the shallow aquifer in Kampung Merbau Condong (also known as zone 3 in Figure 2) is also known to originate from the Boundary Range Hill area. The flow is from an elevation of more than 250 meters above mean sea level at the Boundary Range Hill area to about 30 meters above mean sea level at the Kampung Merbau Condong area.

At around the A007 well in the nor eastern region of Zone 2, groundwater flow is deemed to occur in three directions as a nearest of the well being located at the top of a hill. The three directions of flow are northeast-southwest, east-west, and southeast-northwest, as shown in Figure 2. Nonetheless, all groundwater flows toward the Kelantan River which is elevated at 15 meters above mean sea level.

Zone 3 is located between the Y-coordinate lines 65500 and 66000, which are parallel to the X-axis. The southeastern part of this zone possesses the lowest groundwater level in the whole area, positioned at a lower elevation than that of the Kelantan River. Thus, groundwater does not flow toward the Kelantan River in this zone. Instead, the groundwater in this zone flows downward into the next aquifer below the first shallow aquifer.

CONCLUSION

The hydrogeochemical method was successful to study groundwater of shallow aquifer characters within the agricultural area. In the area around palm oil field, nitrate concentration is higher compared to the area with no palm oil field. Application of chemical and natural fertilizer is the reason high of nitrate concentration found in the palm oil field. The groundwater which has high level of nitrate concentration have been mapped along with groundwater flow patterns. The southern and middle part of the study area has an east to west groundwater flow pattern, making it impossible for contaminated water from the southern region to enter the northern area, despite the lower elevation of the area.

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