Evaluating the suitability of shallow aquifer for irrigational purposes in some parts of Kelantan, Malaysia

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Abstract: Groundwater is a precious natural resource for the people of Kelantan, Malaysia, as it constitutes the main source of water supply. It serves as the most reliable source of water for their domestic and agricultural activities. This study was aimed at assessing the suitability of groundwater for irrigational purposes in some selected communities of Kelantan where farming activities are very intensive. Thirty-two (29 groundwater and 3 surface water) samples were collected and analysed for major anions and cations. Physicochemical parameters such as electrical conductivity (EC) and total dissolved solids (TDS) were also measured. From the results of the analyses and measurements, the suitability of the groundwater for irrigation were evaluated based on the TDS, EC, percentage sodium (%Na), sodium adsorption ratio (SAR), residual sodium carbonate (RSC), Boron classification, fluoride and Nitrate. US salinity laboratory (USSL) diagram and distribution maps of different parameters were also applied in the present investigation. SAR plot indicates that the groundwater falls within the excellent class for irrigation. In terms of sodium percentage, most of the samples fall within the doubtful class with few samples in permissible class. With respect to residual sodium carbonate, majority of the samples exhibit doubtful class with only few samples in permissible limit. Other samples recorded are not suitable for irrigation. Based on the boron classification, the samples fall within the excellent water class. The groundwater in the study area is generally good for irrigation purposes. However, there are few instances which are problematic and would require special irrigation methods.

Keywords: Groundwater, agriculture, sodium adsorption ratio (SAR)

INTRODUCTION

Groundwater is one of the main sources of freshwater widely used in the field irrigation, agriculture and other domestic purposes (Sarkar *et al*., 2002). Groundwater resources are often understood to be protected in nature as it originates from the deeper setting in the subsurface (Sadashivaiah *et al*., 2008). Hence, the treatments of groundwater in particular areas are seldom conducted. In Kelantan, most of the population relies on groundwater especially in rural regions as access to clean supply of water is often impeded. Increasing urbanization, population growth and industrial activities are often attributed with the decline of groundwater quality (Khan & Frankland, 1983). Apart from that, unscientific agricultural practices might also contribute to groundwater deterioration as uncontrolled use of chemical fertilizers, pesticides and other harmful substances may infiltrate the shallow aquifers thus polluting the vadose zone as well as the saturated zone (Latha *et al*., 2002). Besides, outdated metal pipe system used for water supply in the residential area correspondingly poses serious threat in terms of trace elements dissemination such as boron in water supply (Hunt *et al*., 2008).

In most part of the Kelantan state, the community particularly living in the rural region often depend on the groundwater resources for all of its water requirements such as for domestic use and irrigation purpose for crops and plantation. In earlier days, the people in the state utilized groundwater for drinking. However, due to financial constraints and limited availability of public water supply which is only focused in the urban areas, many people living in the rural part of the Kelantan state often rely on groundwater supply. The groundwater supply in Kelantan is notably high and isreadily recharged, especially the rich alluvial basin in the northern parts of Kelantan. In Kelantan state, majority of the economic activities are driven by agricultural involving paddy, rubber and other plantation. Apart from this, the Kelantan River is a major source of fresh water supply which continuously recharges the nearby aquifer located in the alluvial basin. Therefore, groundwater supply for the drainage of agricultural uses are becoming more important and expanding rapidly throughout the state.

Groundwater system in particular region has its own signatures as a result of chemical alteration of precipitates infiltrating into the subsurface and into the aquifer (Muthulakshmi *et al*., 2012). The chemical alteration are influenced by several aspects such as interaction with soil system, residence time in the aquifer, mixing with mineral and others (Subba Rao, 2001). In Kelantan, groundwater is utilized for various purposes. Since groundwater is protected by the overlying strata, which filters outconsiderable amount of pollutants before reaching the aquifer, it is often regarded as safe for drinking and irrigation purposes (Islam *et al*., 2003). Therefore, groundwater are used for these purposes should be clean and free from any harmful substances. Substances including chemicals, effluents from industrial discharge, toxic elements as well as elevated concentrations of ion and trace minerals may be dangerous if consumed in a prolonged time (Martinez & Motto, 2000). In groundwater system, potential contamination of groundwater resources are simply complex due to various chemical alteration triggered via anthropogenic influences (Umar & Absar, 2003). Thus, groundwater quality assessment including major ions investigation is essential to demarcate the suitability of these resources for drinking and irrigation purposes.

Water quality for irrigation purposes is one of the key aspects that influence the crop growth and underlying soil structure beneath it (Sadashivaiah *et al*., 2008). Problems related to infiltration of water can be linked with relatively high sodium absorption ratios or SAR (Muthulakshmi *et al*., 2012). Besides, calcium concentration may also impact the irrigation process in certain area as high calcium concentration in soils increases the soil characteristics for infiltration which in these cases are useful for irrigation purpose (Kendaragama, 2000; Latha *et al*., 2002). Since farmers mainly depends on the groundwater resources in season of drought, a collaborative management of groundwater resources together with surface water is vital for sustainability of these resources as well as optimising availability of groundwater for irrigated agriculture.

STUDY AREA

The present analysis is conducted in the northern part of Kelantan covering four major district of Tumpat, Pasir Mas, Kota Bharu and Bachok. The study area falls between 5º 55” to6º 15”N and 102º 4” to102º 25” E, covering an area of approximately 1400 km^2. The sample locations have been shown in Figure 1 below. The area is underlain by alluvial deposits of Quaternary age. New alluviums are produced during the end of monsoon (Zamri, 2009). The study area has wet and dry climate with maximum temperature of 32º C during dry seasons. It also encounters annual rainfall throughout the year but higher at the end of year which is contributed by north-east monsoons from October to January. The monsoons occurring till end of year are often attributed to heavy rains which results in flooding (Mohamad Roslan *et al*., 2007).

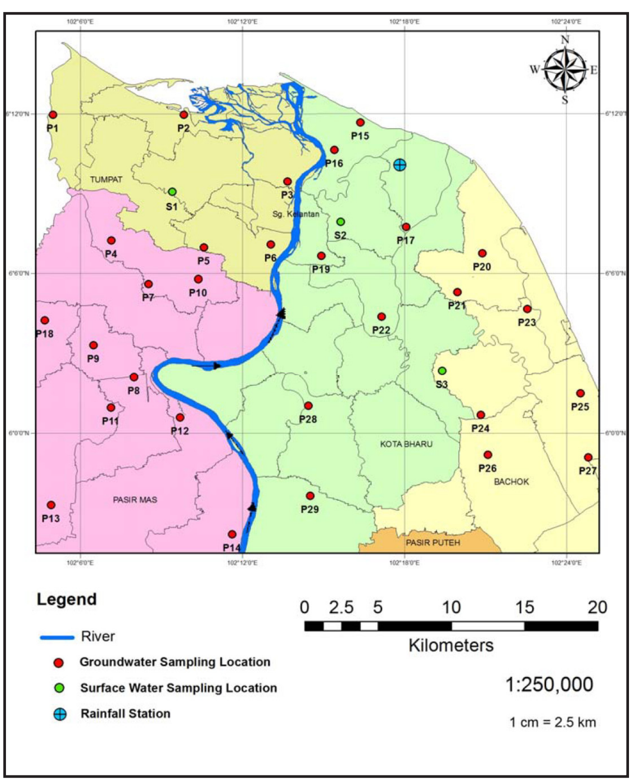

Figure 1: Groundwater sampling location in parts of Kelantan state.

MATERIALS AND METHODS

Water samples were collected using 1 liter nitric acid cleaned polyethylene containers from various wells. For major ion sampling, the sample bottles were soaked with nitric acid prior to sampling activities and rinsed with groundwater samples at sampling location. In-situ parameter measurement including pH, hardness, temperature, total dissolved solids (TDS), and electrical conductivity were observed and recorded on the site with the help of potable water analysis kit. For laboratory analysis, Atomic Absorption Spectrophotometer (AAS) was used to determine the concentration of the major cations including calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}) and potassium (K^{+}). For anion concentration, sulphate concentration was determined using gravimetric method, chloride and bicarbonate concentration by using titration method and finally, nitrate values by using colorimetric method. The major ion concentration of sodium and magnesium is evaluated for the purpose of suitability for agricultural and irrigation assessment. Meanwhile boron (B) was analysed in Malaysian Nuclear Agency using Inductively Coupled Plasma Mass Spectrometer (ICPMS).

RESULTS AND DISCUSSIONS

This study is based on sodium percentage, sodium absorption ratio (SAR), residual sodium carbonate (RSC) and boron elements to assess the suitability of groundwater for irrigation purposes. The in-situ parameters and major ion concentrations obtained are tabulated in the following tables (Tables 1, 2, 3 and 4).

In most part of the study area, groundwater resources are generally appraised for irrigation purposes. These purposes are applied in the agricultural sector to supply drainage for the better growth of crops and plantation such as paddy. Hence, the groundwater abstracted for these purposes should have a proper quality as so that growth of the crops are not adversely affected. A proper supply of groundwater scheme should comply with adequate contents of specific conductance, sodium content, and trace metals such as boron.

Sodium percent (Na %):

The concentration of sodium in groundwater is vital in characterising the suitability of groundwater to be used for the purpose of irrigation. This is due to facts that sodium ion tend to reacts with the soil structures. As a result these reactions will cause the underlying soil to have reduced

Table 1: Physical parameters of groundwater samples in parts of Kelantan.

No.	Latitude	Longitude	Temperature (°C)	pH	Electrical Conductivity (µS cm^{-1})	TDS (mg/l)
P1	N 6°11’58.164”	E 102°4’58.872”	28.4	6.38	139.83	75.86
P2	N 6°11’58.128”	E 102°9’49.428”	27.6	6.34	149.57	87.35
P3	N 6°9’27.576”	E 102°13’40.296”	32.1	6.79	94.43	123.60
P4	N 6°7’14.592”	E 102°7’8.832”	29.1	6.93	174.69	275.98
P5	N 6°6’59.22”	E 102°10’34.212”	25.3	7.39	95.48	265.63
P6	N 6°7’5.16”	E 102°13’3.288”	29.7	7.32	79.29	196.45
P7	N 6°5’37.032”	E 102°8’30.984”	27.6	6.46	98.29	274.59
P8	N 6°2’7.332”	E 102°7’58.872”	28.9	6.23	92.70	280.43
P9	N 6°3’19.152”	E 102°6’29.016”	30.9	6.45	149.59	168.86
P10	N 6°5’47.724”	E 102°10’22.116”	26.9	6.02	194.59	163.57
P11	N 6°0’58.608”	E 102°7’7.68”	32.7	6.32	138.38	146.97
P12	N 6°0’35.784”	E 102°9’41.688”	29.5	7.29	157.58	186.65
P13	N 5°57’19.1844”	E 102°4’55.38”	29.9	7.10	134.56	257.85
P14	N 5°56’13.0884”	E 102°11’36.834”	30.7	5.93	147.46	157.97
P15	N 6°11’41.172”	E 102°16’22.656”	31.8	5.95	175.57	156.76
P16	N 102°15’24.084”	E 6°10’39.036”	32.2	5.91	134.78	143.76
P17	N 6°7’44.976”	E 102°18’3.852”	30.1	6.57	186.43	297.86
P18	N 6°4’14.988”	E 102°4’41.016”	31.2	6.98	249.38	304.35
P19	N 6°6’39.996”	E 102°14’55.608”	29.6	6.03	175.76	296.54
P20	N 6°6’45.37”	E 102°20’53.58”	30.9	5.83	116.60	73.34
P21	N 6°5’18.788”	E 102°19’57.635”	29.0	6.64	138.80	284.37
P22	N 6°4’23.1”	E 102°17’8.94”	26.9	5.69	198.50	143.49
P23	N 6°4’40.486”	E 102°22’32.91”	27.5	6.38	153.79	99.38
P24	N 6°0’42”	E 102°20’49.6”	31.2	6.63	86.97	197.75
P25	N 6°1’30.5”	E 102°24’31.4”	30.2	6.92	96.54	193.45
P26	N 5°59’11.6”	E 102°21’5.5”	31.8	6.75	85.46	214.45
P27	N 5°59’5.6”	E 102°24’48.2”	32.0	6.37	135.45	267.45
P28	N 6°1’2.38”	E 102°14’26.72”	28.9	6.28	157.87	187.87
P29	N 5°57’39.65”	E 102°14’30.99”	29.7	6.29	255.86	96.56

Table 2: Physical parameters of surface water samples in parts of Kelantan.

No.	Latitude	Longitude	Temperature (°C)	pH	Electrical Conductivity (µS cm^{-1})	TDS (mg/l)
S1	N 6°9’1.3392”	E 102°9’24.192”	31.5	6.42	294.57	74.74
S2	N 6°7’56.676”	E 102°15’38.772”	31.3	6.68	197.57	178.76
S3	N 6°2’20.6”	E 102°19’23.7”	27.8	4.61	85.59	50.39

permeability. Soils under such conditions exhibit reduced transitivity thus are not suitable for agricultural use as it may inhibit flow of water and other constituents such as compost, fertilizer and other materials into the root system of the crop. Soils containing large proportions of sodium ion with carbonate as the major anion are termed as alkaline soils while those with chloride and sulphate as the major anion are termed as saline soils (Bartarya, 1993). Typically, both alkaline soils and saline soils exhibit characteristic reduced permeability properties which will inhibit crop growth thus are not appropriate for irrigation purposes. The sodium content is generally denoted in percentage expressed as follow:

$$\% Na = (Na + K) 100/ (Ca + Mg + Na + K)$$

The sodium percentage values are tabulated in Tables 5 and 6. The values are then compared with the quality classification of the water for irrigation purposes in Table 7. Based on the interpretation, it can be recognised that majority of the samples exhibit permissible to doubtful characteristics. The lowest sodium percentage reading is

Table 3: Chemical parameters of groundwater samples in parts of Kelantan.

No.	Na^+ (mg/l)	K^+ (mg/l)	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	HCO_3^- (mg/l)	Cl^- (mg/l)	SO_4^{2-} (mg/l)	NO_3^- (mg/l)	F^- (mg/l)	B (mg/l)
P1	2.260	1.610	0.761	0.738	89.60	47.04	10.20	4.60	0.26	0.004
P2	1.410	1.177	0.239	0.406	121.00	41.20	16.50	3.90	0.23	0.005
P3	2.519	1.624	0.576	0.348	97.00	42.27	7.40	6.40	0.38	0.006
P4	2.888	1.846	0.695	0.422	146.20	45.33	14.40	9.60	0.37	0.005
P5	2.782	1.357	0.277	0.162	87.60	31.24	15.90	3.90	0.29	0.006
P6	1.966	0.923	0.291	0.298	93.00	21.30	11.00	3.40	0.30	0.010
P7	2.170	1.316	0.330	0.233	128.30	28.40	9.30	4.20	0.21	0.005
P8	5.808	2.761	0.633	0.304	156.80	53.72	19.00	2.30	0.39	0.005
P9	2.107	2.486	1.695	0.508	86.70	61.84	12.00	1.20	0.20	0.009
P10	0.515	0.781	0.395	0.120	132.80	45.04	6.10	3.20	0.30	0.004
P11	2.240	1.691	0.532	0.671	97.00	36.38	11.30	2.30	0.20	0.005
P12	0.547	0.817	0.399	0.124	63.40	31.01	20.70	4.20	0.20	0.004
P13	1.429	1.942	0.356	0.299	72.20	42.76	17.00	3.40	0.29	0.004
P14	3.470	2.731	1.327	0.843	118.00	24.52	24.90	5.30	0.24	0.004
P15	2.298	1.829	0.801	0.636	86.75	24.63	25.00	3.10	0.23	0.005
P16	2.094	1.729	0.667	0.621	93.40	18.40	5.20	5.20	0.31	0.005
P17	1.730	0.748	0.230	0.279	71.38	23.00	9.50	3.90	0.26	0.015
P18	1.536	1.881	0.801	0.831	83.40	42.56	13.80	4.70	0.24	0.005
P19	1.656	1.542	0.401	0.513	73.00	50.05	16.80	5.10	0.39	0.004
P20	1.567	1.448	0.295	0.491	79.20	43.14	12.30	4.80	0.25	0.004
P21	1.858	0.806	0.251	0.303	125.60	32.59	7.60	4.40	0.31	0.016
P22	2.158	1.717	0.637	0.559	94.00	39.45	19.00	3.50	0.30	0.004
P23	1.658	1.328	0.548	0.531	84.20	38.34	13.30	5.70	0.21	0.004
P24	1.458	1.440	0.672	0.414	62.40	20.27	18.00	3.40	0.23	0.005
P25	1.816	1.515	0.544	0.570	61.30	52.54	4.00	1.40	0.29	0.004
P26	4.468	2.906	1.968	0.939	81.00	42.60	16.10	3.50	0.24	0.004
P27	1.547	0.566	0.132	0.245	68.00	32.57	8.00	5.30	0.36	0.016
P28	2.296	1.925	0.995	0.547	76.00	29.46	12.60	2.70	0.38	0.005
P29	1.396	1.391	0.555	0.404	63.00	27.95	18.30	6.61	0.33	0.005

Table 4: Chemical parameters of surface water samples in parts of Kelantan.

No.	Na^+ (mg/l)	K^+ (mg/l)	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	HCO_3^- (mg/l)	Cl^- (mg/l)	SO_4^{2-} (mg/l)	NO_3^- (mg/l)	F^- (mg/l)	B (mg/l)
S1	5.139	1.428	0.436	0.329	78.00	32.62	13.80	5.80	0.25	0.005
S2	1.592	1.485	0.328	0.514	92.00	31.10	15.70	4.20	0.33	0.004
S3	2.030	1.531	0.674	0.588	93.00	26.04	6.10	5.20	0.23	0.004

51.49 % while the highest value calculated is 85.10%. The moderate to high values of sodium percentage in the groundwater samples indicates that the soil structure in the study area has reduced permeability.

Electrical conductivity (EC):

Electrical conductivity is a measure of water capacity to convey electric current. The most desirable limit of EC in drinking water is prescribed as 1,500 µS cm^{-1} (WHO, 2004). The EC of the groundwater is varying from 79.29 and 255.86 µS cm^{-1} with an average value of 146.10 µS cm^{-1} (Figure 2). Higher EC in the study area indicates the enrichment of salts in the groundwater. The value of electrical conductivity may be an approximate index of the total content of dissolved substance in water. It depends upon temperature, concentration and types of ions present (Hem, 1985). The EC can be classified as type I, if the enrichments of salts are low (EC < 1,500 µS cm^{-1}); type II, if the enrichment of salts are medium (EC 1,500 and 3,000 µS cm^{-1}); and type III, if the enrichments of salts are high (EC > 3,000 µS cm^{-1}). According to the above classification of EC, all of the samples (both groundwater and surface water samples) come under the type I (low enrichment of salts). The repeated recharge through rainfall and shallow nature of the aquifer may be the reason for low enrichment of EC in the study area.

Total dissolved solids (TDS):

According to WHO specification TDS up to 500 mg/l is the highest desirable and up to 1,500 mg/l is maximum permissible. In the study area the TDS value varies between a minimum of 73.34 mg/l and a maximum of 304.35 mg/l (Figure 3), indicating that all the groundwater and surface water samples lie within desirable limit of < 500 mg/l. According to the Davis & De Wiest (1966) (Table 8) classification of groundwater based on TDS, all groundwater samples are desirable for drinking (TDS < 500 mg/l). Low concentration of TDS in the groundwater sample is due to repeated dilution through rainfall and influent nature of surface water bodies.

Table 5: Sodium percentage (%Na), SAR and RSC values in groundwater samples in parts of Kelantan.
Blue=permissible; yellow=doubtful; orange=unsuitable

No.	%Na	SAR	RSC
P1	58.56	0.44	1.37
P2	66.86	0.41	1.94
P3	72.48	0.65	1.53
P4	71.35	0.67	2.33
P5	85.15	1.04	1.41
P6	73.65	0.61	1.49
P7	78.23	0.71	2.07
P8	85.10	1.50	2.51
P9	55.12	0.36	1.29
P10	58.89	0.18	2.15
P11	63.25	0.48	1.51
P12	59.74	0.19	1.01
P13	72.53	0.43	1.14
P14	61.96	0.58	1.80
P15	61.39	0.47	1.33
P16	61.59	0.44	1.45
P17	73.27	0.57	1.14
P18	51.47	0.29	1.26
P19	64.18	0.41	1.13
P20	65.62	0.41	1.24
P21	73.03	0.59	2.02
P22	63.92	0.48	1.46
P23	59.90	0.38	1.31
P24	59.73	0.35	0.96
P25	61.39	0.41	0.93
P26	60.50	0.66	1.15
P27	75.36	0.58	1.09
P28	61.17	0.46	1.15
P29	61.25	0.35	0.97

Sodium absorption ratio (SAR):

From the calculated values of Sodium Absorption Rates, the SAR values are recorded form of 0.184 to 1.502 in the study area. For the irrigation purposes the Sodium Absorption Ratio (SAR) is calculated using the standard equations outlined as follow:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}}$$

Table 6: Sodium percentage (%Na), SAR and RSC values in surface water samples in parts of Kelantan.
Blue=permissible; yellow=doubtful; orange=unsuitable

No.	%Na	SAR	RSC
S1	84.20	1.43	1.23
S2	64.64	0.40	1.45
S3	60.85	0.44	1.44

Table 7: Quality classification of sodium percent for irrigation.

Water Class	Percent Sodium(%)
Excellent	<20
Good	20-40
Permissible	40-60 (24%)
Doubtful	60-80 (69%)
Unsuitable	>80 (7%)

Table 8: Classification of groundwater based on TDS (Davis & De Wiest, 1966).

TDS (mg/l)	Water type	% of Samples
< 500	Desirable for drinking	All 29 samples including surface water samples
5000 - 10000	Permissible for drinking	
< 3000	Useful for irrigation	
> 3000	Unfit for drinking and irrigation	

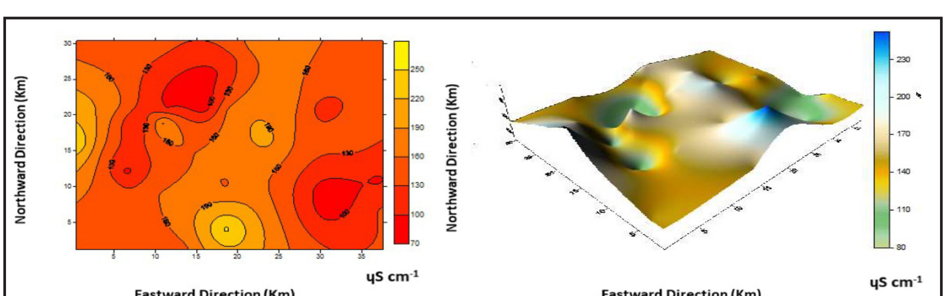

Figure 2: Distribution of EC in groundwater samples in parts of Kelantan.

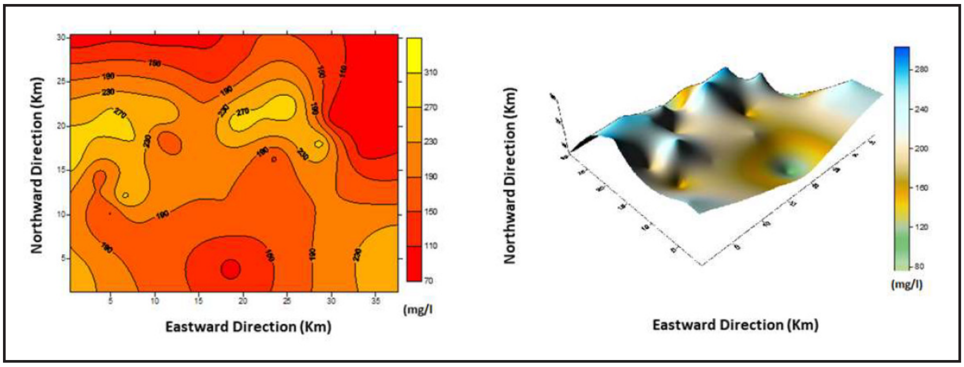

Figure 3: Distribution of TDS in groundwater samples in parts of Kelantan.

Table 9: Quality classification of SAR for irrigation.

Water Class	SAR Values (meq/l)	Groundwater category in Study Area
Excellent	<250	29 (100%)
Good	250 - 750	
Moderate	750 - 2250	
Poor	>2250	

High levels of sodium ion in groundwater with relative low levels of calcium ion are known to affect the subsurface structure and degree of water infiltrating the strata (Sadashivaiah *et al*., 2008). High SAR values are understood to reduce the soil permeability thus making the soil structure to be difficult for irrigation purposes (Muthulakshmi *et al*., 2012). Decreasing content of ion such as magnesium and calcium are often attributed with increase in sodium which may result in high SAR values. As a result, these events may alter the soil structure which will cause drainage process (Kendaragama, 2000). Based on the recorded ranges of SAR (Tables 5 and 6), thus it can be agreed that no sodium hazard exist in the area. The samples are plotted in S_1 category as depicted in Figure 4 (Anita *et al*., 2010). For that reason, the groundwater in the preferred study area is suitable for irrigation purposes including agricultural and other domestic activities as shown in Table 9.

Residual sodium carbonate (RSC):

Excess sum of carbonate and bicarbonate in groundwater over the sum of calcium and magnesium also influences the suitability of groundwater for irrigation. This is denoted as residual sodium carbonate (RSC) calculated as follows. The RSC results and quality classification of RSC for irrigation are given in Tables 5, 6, 10.

$$RSC = (HCO_3^- + CO_3^{2-}) - (Ca^{2+} + Mg^{2+})$$

Boron (B):

Trace elements such as boron are essential in minute quantities for the normal growth of crops and other plantation. However, excessive concentration of boron in the soil strata may not be suitable as it may intoxicate the soil system (Varalakshmi & Ganeshamurthy, 2010). Hence, plant growing in these soils may absorb elevated concentrations of boron via the root structure. Form the analysis of boron concentration in the study area, the boron values are assessed to be in the range of 0.004 mg/l to 0.016 mg/l (Table 3). Based on the quality classification in Table 11, almost all of the boron concentration shows excellent water class in the study area.

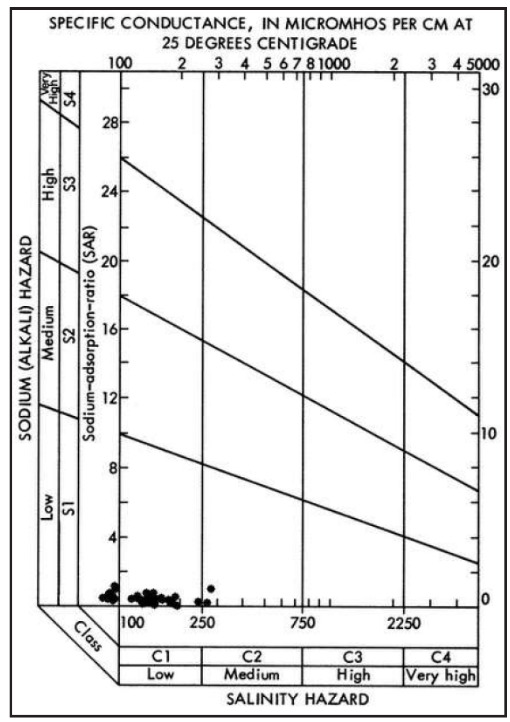

Figure 4: The SAR plots of groundwater samples in the Study Area.

Nitrate (NO_3^-):

The nitrate concentrations in the study area is between 3.10 mg/l to 9.30 mg/l. Nitrate ion is generally present due to the presence of fertilizers and nutrients that are commonly used for agricultural practises (Dai *et al*., 2004). The nitrate concentration in the study area are typically low to moderate compared to maximum permissible limit of 10 mg/l (MOH, 2008). The nitrate distributions in the study area are presented in Figure 5. Based on the figure, it can be recognised that high nitrate concentrations are observed in the west part compared to east part of the study area. Using high nitrate groundwater for irrigation can minimize the requirement for inorganic fertilizers and reduce the cost of cultivation and nitrate contamination.

Table 10: Quality classification of RSC for irrigation.

RSC (meq/l)	Remark on quality	Representing Samples (%)
<1.25	Good	11 (38%)
1.25-2.5	Doubtful	17 (59%)
>2.5	Unsuitable	1 (3%)

Table 11: Quality classification of boron for irrigation.

Water Class	Boron, mg/l		
	Sensitive Crops	Semi tolerant Crops	Tolerant Crops
Excellent	<0.33 (100%)	<0.67 (100%)	<1.00 (100%)
Good	0.33-0.67	0.67-1.33	1.00-2.00
Permissible	0.67-1.00	1.33-2.00	2.00-3.00
Doubtful	1.00-1.25	2.00-2.50	3.00-3.75
Unsuitable	>1.25	>2.50	>3.75

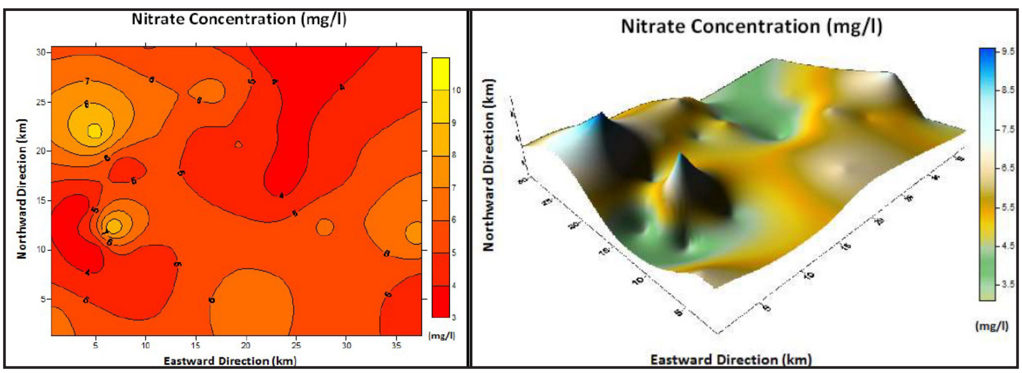

Figure 5: Distribution of Nitrate in parts of Kelantan.

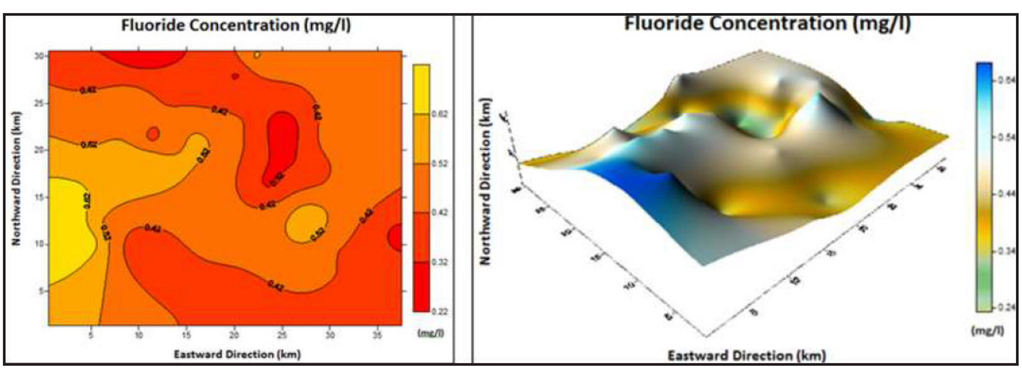

Figure 6: Distribution of Fluoride in parts of Kelantan.

Fluoride (F):

The concentration of fluoride ion in the study area ranges from 0.23 mg/l to 0.67 mg/l (Figure 6). Fluoride concentration in groundwater occur from dissolution of fluoride-rich mineral deposits of the bedrock. The limits of fluoride ion concentration in the groundwater are 1.5 mg/l. The fluoride concentrations are low compared to the permissible limit. Groundwater in the preferred study area is not contaminated from fluoride. The fluoride transports from agricultural soil and irrigation water to plants, the consumption of grains containing fluoride by humans, and the accumulation of fluoride in humans lead to the development of dental and skeletal fluorosis. Keeping this movement of fluoride from water and soil into human bodies in view, it's vital to assess its concentration in the water being used for irrigation purposes.

CONCLUSIONS

Groundwater is an important source of drinking water for many people around the world. Contamination of groundwater generally results in poor drinking water quality, loss of water supply, high cleanup costs, high-cost alternative water supplies and potential health problem. A study was carried out in parts of Kelantan to evaluate the current status of groundwater and its suitability for various uses such as for drinking and irrigation purposes. Based on the EC and TDS values, all samples from the study area are found to be safe and suitable for drinking purposes. The majority of groundwater samples belong to C_1S_1 indicating low salinity, and very few samples fall in C_2S_1 indicating medium salinity, which can be used for irrigation on all types of soil without danger of exchangeable sodium. In terms of sodium percentage, most of the samples are plotted in doubtful class with few samples in permissible class. Hence, majority of the samples have high sodium percent indicating low soil permeability. The low agricultural yields in lands irrigated with water belonging to doubtful is probably due to the presence of sodium salts, which causes osmotic effects in soil plant system. In terms of sodium absorption ratio, all samples are plotted in the excellent class suggesting good irrigation characteristics. But only based on residual sodium carbonate technique, majority of the samples exhibit doubtful class with only few samples in permissible limit.Continuous usage of water with high RSC will result in burning of leaves of plants, affects crop yield. Other samples recorded are not suitable for irrigation. Based on the boron classification, almost all of the boron concentration suggests excellent water class in the study area. Both nitrate and fluoride values are well below the desirable limit, and hence marks its safe utility for agricultural activities. Groundwater is immensely important to meet the human needs in this part of Kelantan. Overall, the water is suitable for various purposes, but still some concrete efforts should be made to systematically assess the quantity and quality of this natural resource.

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