DETERMINATION OF MAJOR IONS CONCENTRATIONS IN KELANTAN WELL WATER USING EDXRF

Zaini Hamzah, Wan Noorhayani Wan Rosdi*, Abdul Khalik Wood,

Faculty of Applied Sciences, Universiti Teknologi MARA, 40450 Shah Alam, Malaysia

**Email address of corresponding author: wnoorhayani@yahoo.com*

ABSTRACT

Well water is a renewable natural resources and one of the drinking water sources. The well water may constituted of dissolved essential chemicals such as K^+, Ca^{2+} and Na^+ ; and natural radionuclides such as radioisotopes from uranium-thorium decay series. The geology and mineral composition of the soil will determined the kinds and levels of chemical contents in the groundwater resources. The water flows through the geological formation and dissolved the chemicals before reaching the aquifers. To evaluate how much chemicals and natural radioactive in the water resources, a study has been carried out. Well water samples in this study were taken from 3 districts in Kelantan, which is Bachok, Machang and Kuala Krai. Similarly, in situ water quality parameters were measured using YSI portable water quality parameter include pH, salinity, dissolve oxygen(DO), conductivity, turbidity and total dissolved solids(TDS). The concentrations of K^+, Ca^{2+} and Na^+ were determined using Energy Dispersive X-ray Fluorescence (EDXRF). Five ml of filtered sample was pipette into the sample cup and, irradiated and measured for 100 seconds counting times. The type of filter used for measuring K^+ and Ca^{2+} was Al-thin and default for Na^+. The ranged of concentration of K^+, Ca^{2+} and Na^+ is 23.04-251.89, 3.12-45.41, and 3.71-125.75 ppm, respectively.

ABSTRAK

Air telaga adalah sumber alam yang dapat diperbaharui dan salah satu daripada sumber air minuman. Ia boleh tercemar dengan mudah oleh pelbagai faktor. Geologi dan komposisi mineral tanah akan mempengaruhi jenis dan darjah pencemaran kimia dalam air bawah tanah melalui pengaliran air sebelum sampai ke akuifer. Di dalam kajian ini, sampel air diambil dari 3 daerah di Kelantan, iaitu Bachok, Machang dan Kuala Krai. Di-situ parameter kualiti air telah diukur dengan menggunakan parameter kualiti air YSI mudah alih. Kepekatan K^+, Ca^{2+} dan Na^+ telah ditentukan menggunakan Pendaflur Serakan Tenaga Sinar X. 5 ml sampel yang bertapis telah dipipet ke dalam cawan sampel dan diukur selama 100 saat. Jenis penuras yang digunakan untuk mengukur K^+ dan Ca^{2+} adalah Al-thin dan tiada penuras untuk Na^+. Kepekatan untuk K^+, Ca^{2+}, dan Na^+ masing-masing adalah dalam lingkungan 23.04-251.89, 3.12-45.41, dan 3.71-125.75 ppm.

Keywords: well water, cations, EDXRF, water column.

INTRODUCTION

Well water is renewable natural resources and is vital to human as it is used for domestic application as well as drinking purpose. Well water generally originated from ground water depending on the depth of the well and normally shallow well has its source from the surface water. Groundwater is a suitable source for drinking water because in general groundwater is less polluted compared to surface water (Soltan, 1997). Consequently, groundwater is highly valued throughout the world because people worldwide still depend on groundwater as their source of drinking water and domestic purposes. The quality of groundwater has become a great concern today because there are many factors that can deteriorate its quality. Some of the factors are rapid growth of urban areas which can results in over exploitation of the resources as well as improper agricultural and waste disposal practices (Rajankar *et al.*, 2009).

Major ions such as Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, HCO_3^-, and SO_4^{2-} are very important in classifying and assessing groundwater quality (Khodapanah *et al.*, 2009). It plays a significant part of the total dissolved solids present in groundwater (Nwankwoala and Udom, 2011). It is important to note that Na^+, K^+, Ca^{2+}, are essential elements that are needed by man for a healthy life. However, excessive intakes cause detrimental effect to human. These 3 ions are electrolyte and vital to our body in order to be functioned well. Electrolytes regulate our nerve and muscle function, our body's hydration, blood pH, blood pressure, the rebuilding of damaged tissue. These ions are also important for muscle construction in human's body.

In this study Kelantan is chosen as a study area for its dependency on well water as a source of drinking and domestic use of water. Kelantan has both types of well i.e. dug well (shallow well) and bore hole (deep well). In this paper, the focus is on the determination of the concentration of major ions; which is Na^+, K^+, Ca^{2+} in well water collected from Bachok, Machang and Kuala Krai, Kelantan which is known to be a major source of drinking water for people in that area. This analysis has been done using Energy Dispersive X-ray Fluorescence, EDXRF using 14.0 kV X-ray machine as excitation source and detection using High-resolution Si-Li Drift Detector.

EXPERIMENTAL PROCEDURE

Sampling

Samples of well water were taken from 3 districts in Kelantan, which is from Kuala Krai (2 samples), Machang (2 samples) and Bachok (2 samples). It is important to note that most of residents in these study areas use well water for their domestic usage including as source of drinking water. The sampling locations were selected based on the availability of the well at that location. Sampling coordinates and elevation were obtained using GPS. Water sampling was performed by taking the samples at every 0.5 meter interval from water surface for dug wells. The samples were taken using water sampler and transferred to the 10 L polyethylene bottles which were previously washed with nitric acid and thoroughly rinsed with deionized water. However, for boreholes, water samples were taken from the piping system which was previously flushed to remove any stagnant water within the system. In-situ parameters had been measured using YSI portable multi probes water quality equipment like pH, specific conductivity, DO, temperature, salinity, TDS and turbidity. Table 1 shows the sampling points and the depth of the wells. All water samples are taken from dug wells except for KLD which is boreholes

Table 1: The sampling points and the depth of the wells

Location	Location code	Latitude	Longitude	Elevation (m)	Depth (m)
Kg Jelawat A	KJAD	06° 00.813’	102° 14.532’	20	2.45
Kg Jelawat B	KJBD	06° 00.666’	102° 21.999’	17	2.85
KgPanchor,Gunong	KPGD	03° 53.388’	102° 21.327’	32	1.5
GK Kuari	GKKD	05° 58.387’	102° 21.290’	35	1.5
Kg Labok	KLD	05° 43.175’	102° 13.504’	47	Borehole
Kg Keroh	KKED	05° 37.562’	102° 12.202’	52	2.85

Sample preparation

In the laboratory, the water samples were acidified to pH 2 using nitric acid to preserve the water samples. The samples were then filtered using 0.45µm membrane filter prior to analysis. The measurement of Ca^{2+}, Na^{+}, and K were carried out using Minipal4 EDXRF .Five ml sample (filtered) was pipetted into the sample cups fitted with 1.5µ thin mylar film beneath the cups. XRF is a non destructive method and it is suitable for detection of solid, liquid and powdered samples. It has a simple, fast and safe sample preparation and it is based on the emission characteristics 'secondary' or (fluorescent) X ray from a material that has been excited by bombarding with high energy X rays or gamma rays. For calibration, 1000 ppm single element standard solution was diluted in several concentrations and was measured using the instrument and straight line calibration graph was plotted.

RESULTS AND DISCUSSION

Table 2 shows the values of in situ water quality parameters from 6 sampling locations. The results indicate that pH of the wells are slightly alkaline and varies between 7.6 to 8.42. WHO recommended that the suitable pH for drinking purposes ranged between 6.5-8 (WHO, 2004). Conductivity is affected by the presence of dissolved ions in water (Hoko, 2008). KKED has the highest values for both TDS and conductivity which is 0.268 mg/L and 433 µS/cm, respectively. Conductivity can also be used to measure salinity which generally affects the taste of drinking water (Hoko, 2008). KKED has the highest value for both salinity and conductivity which is 0.2 mg/L and 433 µS/cm, respectively. KLD is the only bore hole well which has very low turbidity and total dissolve solid.

Table 2: Water quality parameters

Location code	DO (mg/L)	Conductivity (µS/cm)	pH	Salinity (mg/L)	TDS (mg/L)	Turbidity (NTU)
KJAD	4.92	271.0	7.81	0.11	0.158	6.5
KJBD	4.63	1.2	8.06	0.05	0.074	3.5
KPGD	5.11	313.0	7.60	0.13	0.186	175.0
GKKD	7.98	128.0	7.70	0.05	0.076	10.3
KLD	5.40	108.0	8.11	0.04	0.063	0.3
KKED	0.52	433.0	8.42	0.20	0.268	21.0

The concentration of Na^{+}, K^{+}, and Ca^{2+} are listed in Table 3. These results are the average of triplicate analysis measurement. The concentration of Na^{+}, K^{+}, and Ca^{2+} are in the range of 29.1 to 114.32 ppm, 23.04 to 251.89 ppm and 3.12 to 45.41 ppm respectively.

The accuracy of the measurement was examined by analyzing known amounts of aliquot, i.e. 40 ppm, and the measured value of 36 ppm, thus the accuracy of the measurements was 90% for K^{+}. The other elements also display about the same accuracy. Precision which is estimated based on RSD of 3 measurements is 6%.

The mean values for all the parameters are below the permissible limits recommended by WHO. For Ca^{2+}, the value recommended is 75 to 200 ppm (Sharma and Sharma, 2011) and for both Na^{+} and K^{+}, the permissible level is 200 ppm. KLD sample has shown very low Ca^{2+} content which could be due to the geological background that could be granite instead of limestone. Kelantan is known for having a large granitic region and this could be one of the reasons for having low Ca^{2+} content.

Since the house owner is depending on well water for their daily water supply, it is a good idea if we could estimate the daily intake of these minerals consumption. Therefore the uptake of Ca, K, and Na determined based on the WHO permissible limit with the average Malaysian water consumption of 2 L per day, is estimated and presented in Table 4.

Table 5 shows the comparisons of the concentration of these three ions with the studies conducted in different countries. The results of Hyderabad and Nalbari, India are comparable with the results of present studies for Na^+ and Ca^{2+}. However, the values for Tehran, Iran are higher than other places for Na^+ and Ca^{2+} which is up to 2759 ppm and 1961 ppm.

Table 6 shows the correlation coefficient between selected water quality parameters and the average concentration of Na^+, K^+, and Ca^{2+}. Correlation coefficient is used to establish the relationship between two variables (Anandakumar *et al.*, 2009). Pairs that have high positive correlations show the dependency of one parameter on the other (Sharma and Sharma, 2011). A good positive correlation is observed between Ca^{2+} and conductivity (R^2= 0.598), Ca^{2+} and TDS (R^2= 0.663) and Ca^{2+} and salinity (R^2= 0.664). Good correlation also observed for Na^+ and TDS (R^2= 0.482), Na^+ and salinity (R^2= 0.493) and also between Na^+ and Ca^{2+} (R^2= 0.601). However such correlation is not observed for K^+. It has weak correlation with other parameters and positive correlation with Ca^{2+} (R^2= 0.388).

Table 3: Concentration of Na^+, K^+, and Ca^{2+}

Location codes	Depth (m)	Concentration of Na^+ (ppm)	Concentration of K^+ (ppm)	Concentration of Ca^{2+} (ppm)
KJAD	0.5	90.5 ± 4.5	54.8 ± 2.7	12.0± 0.6
KJAD	1.0	110.5 ± 5.5	85.2 ± 4.3	8.7 ± 0.4
KJAD	1.5	29.1 ± 0.4	251.9 ± 12.6	8.0 ± 0.4
KJAD	2.0	18.0 ± 0.9	243.6 ± 12.2	9.3 ± 0.5
KJBD	0.5	72.7 ± 3.6	23.0 ± 1.2	10.7 ± 0.5
KJBD	1.0	100.5 ± 5.0	130.6 ± 6.5	8.5 ± 0.4
KJBD	1.5	125.6 ± 6.3	233.7 ± 1.7	12.0 ± 0.6
KJBD	2.0	65.3 ± 3.4	182.9 ± 9.2	7.5 ± 0.4
KPGD	0.5	77.1 ± 3.9	75.3± 3.8	35.7 ± 1.8
KPGD	1.0	70.6±3.7	83.4±4.5	38.5±1.9
GKKD	0.5	61.6 ± 3 .1	40.1 ± 2.0	21.6 ± 1.1
KLD	>10	62.8 ± 3.3	96.2 ± 4.8	3.1 ± 0.2
KKED	0.5	97.4 ± 4.9	24.0± 1.2	38.8± 2.0
KKED	1.0	94.3 ± 4.7	40.6± 2.0	39.6 ± 2.0
KKED	1.5	102.6 ± 5.1	46.4 ± 2.3	45.4 ± 2.3
KKED	2.0	114.3 ± 5.7	77.8 ± 3.9	42.1 ± 2.1

Table 4: Mineral daily intake for Na^{+}, K^{+}, and Ca^{2+}

Location codes	Depth (m)	Na(mg/day)	K(mg/day)	Ca(mg/day)
KJAD	0.5	180	108	22
KJAD	1.0	220	170	16
KJAD	1.5	58	502	14
KJAD	2.0	36	486	18
KJBD	0.5	144	46	20
KJBD	1.0	200	260	16
KJBD	1.5	250	466	24
KJBD	2.0	16	364	14
KPGD	0.5	154	150	70
KPGD	1.0			
GKKD	0.5	122	80	42
KLD	>10	125		6
			192	
KKED	0.5	194	46	76
KKED	1.0	188	80	78
KKED	1.5	204	92	90
KKED	2.0	228	154	84
Permissible limit		400	400	175-400

Table 5: Comparison of the concentrations of Na^{+}, K^{+}, and Ca^{2+} in well water with other literature

Location	Types of wells	Concentration of Na^{+} (ppm)	Concentration of K^{+} (ppm)	Concentration of Ca^{2+} (ppm)	References
Kelantan, Malaysia	Dug wells, boreholes	3.71- 125.6	23.04 - 251.9	3.12 - 45.41	Present study
Hyderabad, India	Dug wells	47 - 128	1 - 8	47 - 57	Satyanarayanan *et. al.*, (2005).
Tehran, Iran	Shallow wells, boreholes, qanats	23.68 - 2759	0 – 44.96	28.86 - 1961	Khodapanah *et. al.*, (2009).
Nalbari district, India	Boreholes	-	-	25 - 52	Sharma et. al., (2011).

Table 6: Pearson correlation coefficient, between water quality parameters and concentration of Na^+, K^+, and Ca^{2+}

	pH	DO	Conductivity	Turbidity	TDS	Salinity	Ca^{2+}	K^+	Na^+
pH	1								
DO	0.608	1							
Conductivity	0.029	0.4	1						
Turbidity	0.273	0	0.161	1					
TDS	0.093	0.618	0.906	0.141	1				
Salinity	0.116	0.647	0.892	0.12	0.998	1			
Ca^{2+}	0.006	0.239	0.598	0.331	0.663	0.664	1		
K^+	0.027	0.003	0.013	0.028	0.019	0.025	0.388	1	
Na^+	0.017	0.269	0.258	0.085	0.482	0.493	0.601	0.133	1

It is agreed that Na^+ is an essential element for a healthy body because of its ability to give a normal heart contraction. However, high amount of this ion can cause hypertension, kidney disease and circulatory illness. Ca^{2+} plays significant roles in bones structure, muscle contraction, nerve impulses transmission, and blood clotting. It is also important in the formation of bone structure and teeth. Deficiency of K^+ can weaken skeletal muscles and make smooth muscle become tired (Bacha *et al.*, 2010).

CONCLUSION

The applicability of EDXRF for determination of $Ca^{2+,}$ Na^+, K^+ in water were examined comprehensively especially in term of the accuracy and precision of the measurement by the analytical technique. From this study, the concentrations of three ions measured in well water of selected sampling sites in 3 districts in Kelantan State i.e. Bachok, Machang and Kuala Krai are found to be below the WHO permissible limits and thus safe for consumption in respect of the measured three cations. Pearson correlation coefficient shows Ca^{2+} has good positive correlation between conductivity, TDS and salinity. Mineral daily intakes for all parameters are below the permissible limit, i.e. 400 mg/day.

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REFERENCES

Anandakumar, S., Subramani, T., and Elango, L., (2009). Major ion groundwater chemistry of Lower Bhavani River Basin, Tamil Nadu, India. Journal of Applied Geochemistry, 11,1,92-101.

Bacha, A.A., Durrani, M.I., and Paracha, P.I., (2010). Chemical characteristics of drinking water of Peshawar. Pakistan Journal of Nutrition, 10, 1017-1027.

Hamzah, Z., Saat, A., and Kassim, M., (2011). Determination of radon activity concentration in hot spring and surface water using gamma spectrometry technique. The Malaysian Journal of Analytical Sciences, 15,2,288-294.

Hoko, Z., (2008). An assessment of quality of water from boreholes in Bindura District, Zimbabwe. Physics and Chemistry of the Earth, 33, 824-828.

Khodapanah, L., Sulaiman, W.N.A., and Khodapanah, N., (2009). Groundwater quality assessment for different purposes in Eshtehard District, Tehran, Iran. European Journal of Scientific Research, 36, 4, 543-553.

Nwankwoala, H. O., and Udom, G. J., (2011). Studies on major ion chemistry and hydrogeochemical process of groundwater in Port Harcourt City, Southern Nigeria. Journal on Spatial Hydrology, 11,1.

Rajankar, P. N., Gulhane, S. R., Tambekar, D. H., Ramteke, D. S., and Wate, S. R., (2009). Water quality assessment of qroundwater resources in Nagpur Region (India) based on WQI. E-Journal of Chemistry.6,3.

Satyanarayanan, M., Balaram, V., Al-Hussin, M. S., Al-Jemaili, M. A. R., Roa, T. G., Mathur, R., Dasaram, B., and Ramesh, S. L., (2005). Assessment of groundwater quality in a structurally deformed granitic terrain in Hyderabad, India. Springer Science.

Sharma, P., and Sharma, H. P., (2011). Groundwater quality assessment of Pachim Nalbari block of Nalbari district Assam based on major ion chemistry. International Journal of ChemTech Research, 3,4, 1914-1917.

Soltan, M. E., (1997). Evaluation of groundwater quality in Dakhla Oasis (Egyptian Western Desert). Department of Chemistry, Faculty of Science, Aswan, Egypt.

World Health Organization (WHO), 2004. “Guidelines for Drinking Water Quality”, Vol. 1 Recommendations (3rd edn). WHO, Geneva.