GROUNDWATER QUALITY IN SOME VILLAGES NORTHEAST OF JEDDAH CITY, SAUDI ARABIA

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ABSTRACT

The groundwater quality is determined in three villages that lie in the northeast of Jeddah city, Saudi Arabia, and they are the only source of drinking water in this area. Fifteen groundwater samples are selected from each village and various quality parameters are measured including pH, electrical conductivity, total dissolved solids, total hardness as well as calcium, magnesium, sodium, potassium, chloride, bicarbonate and sulfate concentrations.

A systematic calculation of correlation coefficient is performed among these parameters. The chemical analyses of groundwater samples show considerable variations, and also most of the samples do not comply with WHO standards for the parameters measured.

Overall the water quality is found to be not suitable for drinking purposes without any prior treatment except at nine locations out of forty four samples.

Keywords: Groundwater, quality, correlation coefficient, Saudi Arabia

INTRODUCTION

Water is essential for life and the human beings try to conserve for future uses in a balanced manners. This source is very important especially in the aid areas such as Saudi Arabia where there are no rivers and the rainfall is very scarce unpredictable, irregular in occurrence which may be very extensive during local storms.

Hence the most important source which the for water supply in the country is groundwater storage especially in the villages., where the people depend on this source to get their daily needs from wells for domestic and household uses in addition to agricultural purposes.

This study presents groundwater quality assessment in three villages in Makkah district.

METHODS AND MATERIAL

1. Study Area

The area under study lies in Makkah district and it is located between longitudes 39° 40‘ E and 39° 46‘ E and latitudes 21° 25‘ N and 22° 00‘N (Fig. 1). It is located in the western part of Saudi Arabia along the Red Sea coast in the west.

The study was undertaken in three villages of Makkah district, namely, Hadat Ash Sham, Madrakah and Brazah. These villages are occupied by people who work mainly in agricultural and some governmental jobs in the nearest cities. The total population of these villages is not known exactly.

The groundwater is considered as the only source of drinking water, in addition to agricultural and home uses where there is no surface water at all. The water is extracted from hand dug wells and transported by private water tankers throughout the district to these villages. The precipitation, which is the sole sources of groundwater recharge in the study area, is very low where the average monthly rainfall is nearly 16mm. The water table in the study area is found to vary from 4.4 m to 56.50 m, and the aquifer is unconfined.

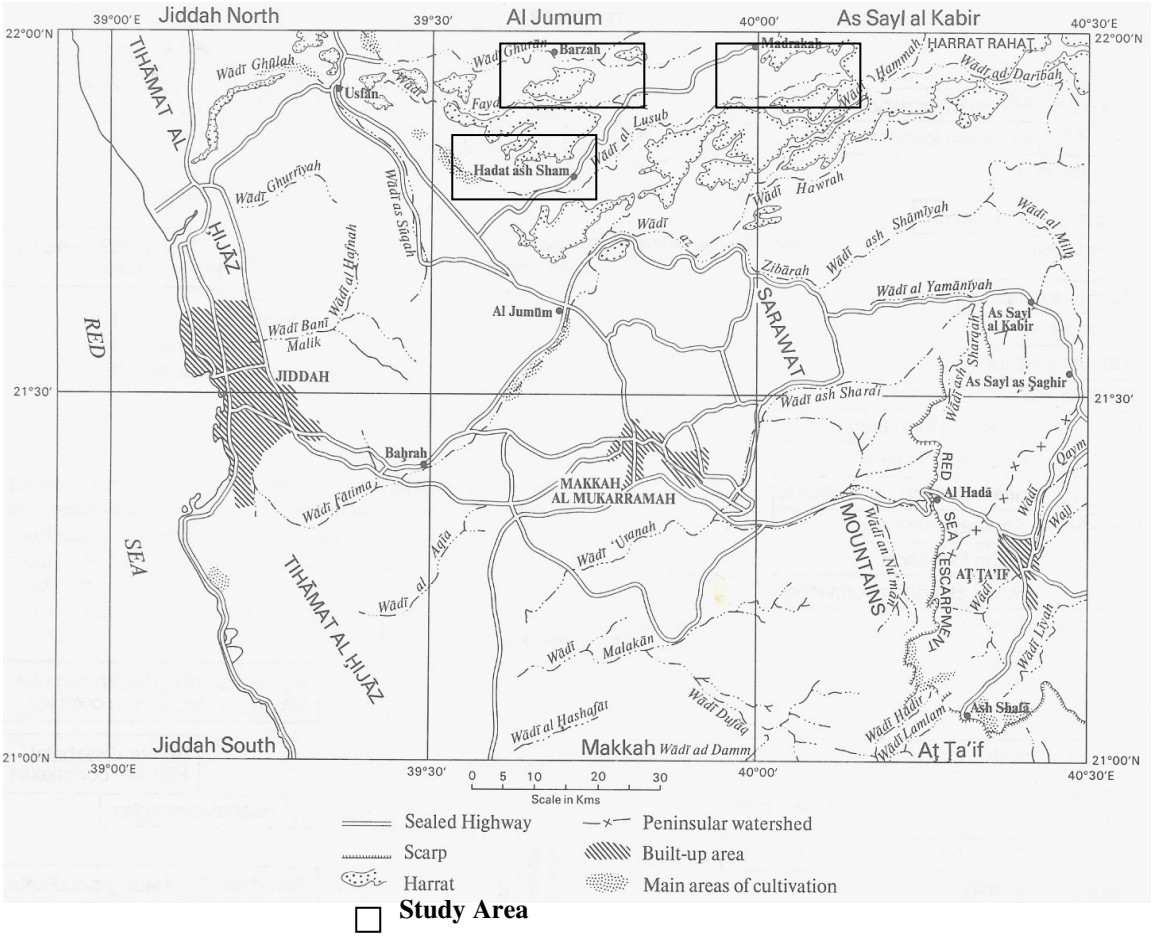

Fig .1. Location Map of the Study Area

Geologically the area under investigation is part of Makkah Quadrangle, which is located on the rifted western margin of the Arabian Shield [1]. The wells are drilled in alluvial which mainly consists of unconsolidated, moderately to poorly sorted sand and gravel.

2. Water Sampling

A total of fifteen groundwater samples are collected from manually operated wells in each village. The samples are collected in clean polyethylene bottles and prior to collection, the samples bottles are rinsed thoroughly with the sample water. The samples are analyzed for calcium, magnesium, sodium, potassium, bicarbonate, chloride and sulfate. The water samples are taken through pumping so the sample will be a representative and in order to avoid any contamination from the surface.

3. Methodology

The pH and electrical conductivity (EC) are measured for each sample at wellhead during field study to these areas. So the pH is measured using pH – meter model E588 while EC is determined using EC – meter model LF91. The chemical analyses of the groundwater samples are carried out at the Faculty of Earth Sciences, King Abdulaziz University where the sodium and potassium are analyzed using a flame photometer; the calcium and magnesium are determined with EDTA; while the titration with mercury nitrated are used to determine chloride. For bicarbonate, a titration with 0.01n sulfuric acid is used. Finally, a turbidity method is employed for the sulfate analyses. Some statistical analysis are done using excel program.

RESULTS AND DISCUSSIONS

The groundwater from the study areas had no color, odor and turbidity. Taste of the water showed some brackish water at some locations. The results of the chemical analysis of groundwater from these villages are presented in Tables 1-3. So, it is necessary to make a comparison of groundwater quality of the study areas with drinking water standards (WHO) and these are presented in Table 4.

The data of the chemical results show a consider variation which reflects their chemical composition.

The pH of groundwater in this area ranges from 6.2 to 7.8 with an average of 7.1. Inspection of these values (Tables 1, 2, 3,) reveals that all samples lie within the permissible range of 6.5 – 8.5. (WHO, 1993) [2].

The EC of the water samples shows a wide variation even in the sample, which is collected from the same village, and the range is between 800 and 7000 μ S/cm. Also it is clear from Table 4 that calcium and sodium are below the WHO acceptable limits except at five and eight locations, respectively. The concentration of chloride in the water samples in the study area is higher than acceptable limit except at ten locations.

Sulfate concentrations vary from 33.70 to 1920.00 mg/l and they are within the acceptable limits except at twenty nine locations.

The total dissolved solid (TDS) concentrations are found to be higher than WHO acceptable limits in most of the samples except at eight locations. It is clear from Table 1 that TDS of all water samples in the Barzah village are higher than WHO values. According to a salinity classification by Rabinove et al. [3], groundwater quality is found to be as fallows: non-saline at eight locations; slightly saline at 30 locations and moderately saline at 7 locations (Table 5). On the other, hand and according to classification of total hardness (TH), the water is hard at four locations and at forty one locations TH is very hard according to Table 6.

The results of the statistical analysis which are shown in Table 7 gave an indication that EC has a positive and signification correlation with TDS, Cl^-, Ca^{2+}, TH, Na^+, SO_4^{2-} and Mg^{2+}. Also, TH has positive and significant correlation with Mg^{2+}, Ca^{2+}, Cl^-, So_4^{2-} and Na^+. Also TDS is significantly correlated with Cl^-, Ca^{2+}, Na^+, TH, So_4^{2-} and Mg^{2+}.

The high correlation between So_4^{2-} and EC indicates that sulfates tend to increase in concentration as the water salinity is increased due to evaporation of recharge water and also due to interaction between the groundwater and the rocks.

The regression equations among the significantly correlated parameters are given in Table 8.

CONCLUSION AND RECOMMENDATIONS

This study shows that groundwater is the only source for people in the study area, and the results of the chemical analyses of groundwater indicate considerable variation. Most of the water samples do not comply with WHO standards for drinking purposes.

The water quality in the investigated area is found to be suitable for drinking only on nine locations, while about forty four locations are not suitable without prior treatments. It must be noted that a regular chemical analysis must be done to insure that the quality of the water in this area is not contaminated, in addition to search for new wells in the area in order to get additional water for the resident people.

Table 1. Physico-chemical properties of groundwater at village Barzah [a]

Sample no.	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	Hco_3^{-}	So_4^{2-}	TDS	pH	EC	TH
1	399.66	533.20	63	9	965.07	505.08	814.73	2250	7.0	3200	3185.27
2	148.61	37.65	124	10	289.15	191.16	116.35	1260	7.1	1750	525.89
3	124.03	60.54	80	3	277.50	197.64	132.26	1350	6.7	1210	558.29
4	275.60	89.30	125	2	537.87	285.50	296.98	1560	7.1	2300	1055.13
5	159.09	126.95	137	2	363.72	395.28	259.31	1260	7.0	1550	918.22
6	137.07	51.65	116	5	306.55	193.32	153.40	1170	7.2	1375	554.44
7	165.93	249.53	41	2	453.05	284.00	461.16	1440	7.6	1210	1437.90
8	168.81	72.67	159	10	335.85	213.12	248.62	1530	6.8	1820	719.97
9	164.26	232.01	160	4	427.53	417.24	666.79	1890	7.3	2360	1361.89
10	142.84	60.41	115	4	312.26	211.50	259.31	1260	6.8	1550	604.78
11	160.17	211.12	100	11	845.51	373.32	444.53	2160	6.9	2270	615.65
12	145.73	232.88	76	4	433.91	417.24	263.77	2700	7.0	2650	1319.13
13	131.30	52.53	112	4	288.33	181.44	148.18	1260	7.1	1490	543.62
14	164.48	58.66	125	4	341.91	193.32	243.40	1170	7.5	1575	651.71
15	144.29	187.36	129	7	421.15	439.20	407.48	2160	7.0	2200	1128.90

[a] All the values are in mg/l, except pH and EC. Units of EC are µmho/cm

Table 2. Physico-chemical properties of groundwater at village Madrakah [a]

Sample no.	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	Hco_3^{-}	So_4^{2-}	TDS	pH	EC	TH
1	79.36	54.72	110.00	2	183.45	274.50	111.13	720	6.6	1206	422.75
2	54.11	41.58	106.20	2	119.64	220.05	185.22	450	7.1	891	305.75
3	52.31	37.21	114.30	2	135.59	225.00	111.13	450	7.8	922	283.34
4	54.11	59.58	15.50	6	207.48	109.80	148.18	720	7.3	1320	379.55
5	79.36	56.61	7.10	1	326.70	247.05	222.26	1260	6.2	2250	430.50
6	124.08	59.54	81.00	3	277.50	197.64	132.26	1890	6.7	877	554.31
7	54.12	41.04	107.00	2	51.92	20.34	185.22	1350	7.1	844	303.56
8	211.00	160.16	99.00	12	845.51	373.32	444.53	2430	7.1	2270	1184.16
9	287.46	101.88	473.40	5	955.80	383.76	483.84	2970	7.8	4203	1136.36
10	295.74	122.58	396.00	4	957.6	274.5	531.46	2700	7.7	3900	1241.93
11	51.39	41.58	148.50	2	270.00	219.60	225.00	2070	6.9	2700	298.95
12	135.00	117.00	162.00	2	319.05	197.73	33.70	3510	6.4	3710	817.20
13	54.13	41.04	99.00	14	236.10	153.80	37.04	1350	6.4	2520	303.59
14	287.46	101.97	167	3	567.00	285.48	333.40	2790	7.7	5598	1136.73
15	124.08	59.54	140.00	16	242.48	175.68	243.40	1530	7.0	2800	554.31

[a] All the values are in mg/l, except pH and EC. Units of EC are µmho/cm.

Table 3. Physico-chemical properties of groundwater at village Hadat Ash Sham [a].

Sample no.	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	Hco_3^{-}	So_4^{2-}	TDS	pH	EC	TH
1	621.54	431.19	720.00	13	2424.69	169.02	1264.68	4140	7.1	5230	3321.73
2	212.76	59.04	148.00	4	440.19	164.7	407.43	1080	7.6	1360	773.96
3	266.94	84.92	110.00	4	470.70	219.60	554.85	2520	7.5	2900	1015.52
4	536.34	379.98	571.50	16	1861.56	178.74	1294.29	3960	7.3	4410	2989.92
5	695.34	468.36	1062.00	10	2637.18	135.27	1920.00	5760	7.6	7000	3658.63
6	252.50	216.69	918.00	9	1530.52	195.62	1111.32	4262	7.2	4200	1519.68
7	212.76	59.04	149.00	4	440.16	164.7	407.43	1080	7.0	1370	773.96
8	202.00	53.19	508.50	8	597.25	147.32	792.74	2335	7.4	2430	723.08
9	509.39	380.85	571.50	16	1861.54	178.71	1294.32	4870	7.1	4510	2834.96
10	708.81	400.55	774.00	14	2706.99	214.94	1059.46	5890	7.3	6280	3414.28
11	261.54	41.59	135.00	3	536.09	192.15	407.43	1440	7.0	1740	824.37
12	142.47	17.51	135.00	7	279.90	274.50	259.20	750	7.0	1440	427.97
13	61.29	33,93	74.00	5	101.70	220.05	73.80	650	6.4	1400	292.34
14	63.13	27.00	126.00	2	146.70	219,60	222.21	900	7.4	950	268.53
15	48.70	26.46	76.50	2	89.28	192.15	221.40	750	6.7	1440	230.34

[a] All the values are in mg/l, except pH and EC. Units of EC are µmho/cm

Table 4. Comparison of groundwater quality at the study areas with drinking water standards (WHO.1993) [a]

Parameters	Values from collected samples			WHO
	Minimum	Maximum	Mean	
Ca^{2+}	48.7	708.81	208.25	500 as $caco_3$
Mg^{2+}	17.51	533.20	136.34	
Na^{+}	7.1	1062.00	222.49	200
K^{+}	1.00	16.00	6.09	
Cl^{-}	51.92	2706.99	631.55	250
Hco_3^{-}	20.34	505.08	238.73	
So_4^{2-}	33.70	1920.00	436.32	400
TDS	450.00	5890.00	2022.16	1000
pH	6.2	7.8	7.1	6.5 – 8.5
EC	844.00	7000.00	2470.69	1400
TH	230.34	3658.63	1057.85	

[a] All the values are in mg/l , except pH and EC. Units of EC are µs/cm.

Table 5. Classification of the water samples in the study area on the basis of TDS

Sample no.	Classification of groundwater	Total dissolved solid (mg/l)	No. of samples
1	Non-saline	< 1000	8
2	Slightly saline	1000 – 3000	30
3	Moderately saline	3000 – 10000	7
4	Very saline	> 10000	-

Table 6. Classification of the water samples in the study area on the basis of TH.(Todd,1980) [4]

Sample no.	Description	Hardness(mg/l)	No. of samples
1	Soft	0 – 75	-
2	Moderately hard	75 – 150	-
3	Hard	150 – 300	4
4	Very hard	Over 300	41

Table 7. Correlation matrix for different water quality parameters

	pH	**EC**	**TDS**	**TH**	**Ca^{2+}**	**Mg^{2+}**	**Na^{+}**	**K^{+}**	**Hco_3^{-}**	**Cl^{-}**	**So_4^{2-}**
pH	1.0	0.2819	0.2368	0.2873	0.3556	0.1771	0.3484	0.0119	0.0378	0.2938	0.3730
EC		1.0	0.9175	0.7989	0.8402	0.7033	0.7986	0.5224	0.0415	0.8542	0.7738
TDS			1.0	0.8425	0.8583	0.7696	0.8479	0.5532	0.0018	0.9065	0.8345
TH				1.0	0.9455	0.9553	0.7320	0.5641	0.1455	0.9187	0.8939
Ca^{2+}					1.0	0.8248	0.7971	0.8402	-0.0033	0.9522	0.8883
Mg^{2+}						1.0	0.6123	0.5463	0.2877	0.8327	0.8299
Na^{+}							1.0	0.5102	-0.2121	0.8876	0.8753
K^{+}								1.0	-0.0778	0.6231	0.5612
Hco_3^{-}									1.0	-0.0377	-0.0317
Cl^{-}										1.0	0.9174
So_4^{2-}											1.0

Table 8. Least square of the relation (y = ax + b) among significantly correlated parameters

y (dependent)	x (independent)	Correlation	b	a
EC	TH	0.7988	1099.44	1.2963
EC	Ca^{2+}	0.8402	889.42	7.5932
EC	Na^{+}	0.7986	1379.16	4.9281
EC	Cl^{-}	0.8542	1249.72	1.9333
EC	Mg^{2+}	0.7033	1412.25	7.9418
EC	SO_4^{2-}	0.7738	1214.52	2.8790
EC	TDS	0.9175	370.36	1.0387
TDS	Ca^{2+}	0.8583	595.25	0.1075
TDS	Mg^{2+}	0.7606	1013.56	7.6264
TDS	Na^{+}	0.8479	998.48	4.6213
TDS	Cl^{-}	0.9065	877.52	1.8124
TDS	SO_4^{2-}	0.8345	825.53	2.7425
TH	Ca^{2+}	0.9454	-38.72	0.1698
TH	Mg^{2+}	0.9553	170.71	6.6345
TH	Na^{+}	0.7320	441.25	2.7838
TH	Cl^{-}	0.9187	248.54	1.2815
TH	SO_4^{2-}	0.8939	163.68	2.0493
TH	TDS	0.8425	-130.76	0.5878
Ca^{2+}	Mg^{2+}	0.8248	71.53	1.0272
Ca^{2+}	Na^{+}	0.7471	87.70	0.5443
Ca^{2+}	K^{+}	0.8402	79.12	21.2072
Ca^{2+}	Cl^{-}	0.9522	57.64	0.2385
Ca^{2+}	SO_4^{2-}	0.8883	48.69	0.3657
Mg^{2+}	Cl^{-}	0.8327	28.75	0.1672
Mg^{2+}	SO_4	0.8299	14.35	0.2744
Na^{+}	Cl	0.8876	15.88	0.3256
Na^{+}	SO_4^{2-}	0.8753	-8.78	0.5278
Cl^{-}	SO_4^{2-}	0.9174	-26.44	1.5080

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