IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)
e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 6, Issue 3 Ver. III (May. – June. 2018), PP 18-24
www.iosrjournals.org

Assessment of Groundwater Quality around Al Khor and Environs, Qatar

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Abstract: *Assessment of hydrogeochemical properties and quality of the groundwater in Al Khor and environs was done to evaluate the suitability of the groundwater for irrigation, and to characterize the hydrogeochemical facies within the area. 18 groundwater samples were collected from bore wells within the study area and were analysed for various physico-chemical properties. The more significant anions are chloride, sulphate, phosphate and nitrate, with concentrations ranging from 173.699-3004.54 mg/l, 424.4-3494.69 mg/l, 448.62-1364.728 mg/l and 4.8-40.14 mg/l respectively. The major cations were all present in the samples, with calcium and sodium contributing more to the TDS compared to the other cations. The presence of nitrates in most of the samples, and phosphates in a few other samples was attributed to the agricultural activities and fertilizer usage within the study area. Hydrogeochemical ratios were determined and explained. Piper trilinear plots show that the groundwater is dominated by strong acids, alkaline earths and Na + K, with* $Ca\text{-}Mg\text{-}SO_4$ *and Na+K-Cl water types being dominant. Techniques like KR, SAR, SSP, PS, EC and %Na were used to assess the suitability of the water for irrigation. The values obtained from these techniques were compared to some pre-defined standards for comparisons. The results show that a majority of the water is unsuitable for irrigation, while a few others could be utilized but under special considerations and for some high tolerance plants.*
Keywords: *Groundwater quality, hydrogeochemical facies, Al Khor, Piper diagram, water types*

Date of Submission: 05-06-2018 Date of acceptance: 20-06-2018

I. Introduction

Although about 75% of the earth is covered by water, more than 96% of this water occurs in oceans which is too saline for man's immediate use and consumption. The other remaining water occurs as ice caps, groundwater, salt water lakes, fresh lakes, in rivers and as atmospheric water.

The study of quantity of water alone is not sufficient to solve the water management problems because its uses for various purposes depend on its quality. Hence, the hydrogeochemical character of groundwater and groundwater quality in different aquifers over space and time have proven to be important in solving the problems[4,5].

Groundwater chemistry is largely a function of the mineral composition of the aquifer through which it flows. The hydrochemical processes and hydrogeochemistry of the groundwater vary spatially and temporally, depending on the geology and chemical characteristics of the aquifer. Hydrogeochemical processes such as dissolution, precipitation, ion exchange processes and the residence time along the flow path control the chemical composition of groundwater.

Geochemical processes occurring within the groundwater and reactions with aquifer minerals have a profound effect on water quality. Hydrogeochemical composition of groundwater can also be indicative of its origin and history of the passage through underground materials with which water has been in contact with.

Groundwater quality will restrict the type of the crop because the water and nutrients requirements for each crop are different. It may be harmful to some crops and suitable for others. Using of unsuitable water in irrigation will cause reduction in the crop's yield and deteriorate the soil physical properties[9].

Specific water may be suitable for irrigation but may not be suitable for drinking and industrial uses due to presence of some other ions at toxic level[7,11].

The quality of groundwater has been adversely affected by man-induced pollution, over-abstraction of fresh groundwater resource which has led to the fresh water-salt water interface moving further inland in coastal regions. Water scarcity and unavailability stemming from accelerating demand for water over the years in different parts of the world has also been exacerbated by the menace of water pollution, degradation, contamination and the incursion of sea water into aquifers (saline intrusion) as is noticeable within Qatar and most arid peninsulas[2].

This study tries to assess the groundwater quality of the area on the basis on analysis of some physico-chemical parameters. The water was also analysed based on some pre-defined standards to determine its suitability especially as irrigation water, since most parts of the study area practise irrigated farming.

Location of the area: The area studied is within North-east and North central parts of Qatar. It is within Latitudes 25°28'02.44"N-25°46'47.19"N and Longitudes 51°19'41.80"E-51°25'48.33"E.

Geology and hydrogeological setting: Qatar is situated within the stable shelf of the Arabian plate, however there a few local tectonic features. The peninsula is underlain by gently dipping to flat-lying sediments, resting on the basement rocks.

The larger part of Qatar is underlain by remarkably uniform limestone beds. The limestone is overlain in some places by younger strata that form a number of mesa-type hills. The oldest outcropping rocks belong to the Lower Eocene Rus Formation, comprising chiefly dolomite and limestone with some scattered outcrops of Miocene age.

The surface geology of Qatar is covered by two varying lithologies; carbonates and clastics. The Miocene-Pliocene and Pleistocene strata are formed of clastic materials while the rest are formed of carbonate sediments and strata.

The groundwater system of Qatar iscontrolled by that of Eastern Arabia, with the aquifers occurring mainly within the Tertiary strata. Most of the groundwater in Qatar are found in three aquifers. These are the Umm erRadhuma, Rus and Dammam aquifers. The Umm erRadhuma Formation is of Paleocene age, with a thickness ranging between 300-500m. Within its top 30-50m are karstic dolomites. This Formation contains brackish water beneath the whole of Qatar. The Rus Formation of Eocene age comprises anhydrite, marl and thin limestones. It is 10-100m thick. The anhydrites are aquicludes while the carbonate facies are important fresh water reserves. The Dammam Formation is also of Eocene age. Its lower part contains chalky limestone and fossiliferous shales, while the upper part consists of dolomitic limestone. This shale layer has a confining effect on the Rus groundwater.

The water table occurs in either the Dammam or Rus Formations over most of Qatar. Occurrence in the Dammam, however, is generally confined to the lower-lying coastal areas.

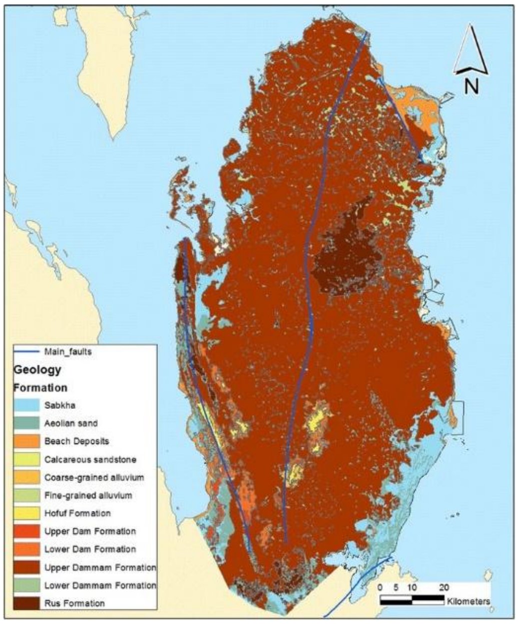

Figure no 1: Surface geology of Qatar (after Baalousha 2016)

II. Materials And Method

Groundwater samples were collected from 18 different wells distributed in four separate locations within Al Khor and environs. These samples were taken in pre-distilled 1.5l polyethene bottles. The wells were pumped for several minutes to maintain static conditions before sample collection. The samples were preserved appropriately for onward delivery to the Central Laboratories Unit of Qatar University. The pH of the water samples was determined in-situ with a pocket pH-102 meter (RoHS). Prior to this, standard buffer solutions were used to calibrate the pH meter. EC was also measured in-situ using the EC DiST-3 meter (HANNA, HI 98303). TDS of the samples was determined using the TDS-3 meter, TDS/TEMP (HM Digital). The geochemical analyses of the collected water samples were carried out based on the methods adopted by the U.S.

Environmental ProtectionAgency (EPA) and the American Society for Testing andMaterials (ASTM). The Metrohm USA IC system (Model #850 Professional IC 850) was utilized for the analyses.

III. Results

The results of the physico-chemical analyses of the groundwater samples are summarized in the table below.

Table no 1: Results of the analyzed hydrogeochemical parameters from collected water samples

S/N	Location	TDS (mg/l)	E.C (µS/cm)	Cl^- (mg/l)	SO_4^{2-} (mg/l)	F^- (mg/l)	Br^- (mg/l)	NO_3^- (mg/l)	PO_4^{3-} (mg/l)	Na^+ (mg/l)	K^+ (mg/l)	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)
1	Ahmed Khaled farm, Al Khor	966.24	1509.75	181.846		1.081		24.816	455.365	107.01	26.037	121.72	48.365
2	Ahmed Khaled farm, Al Khor	1584.29	2475.45	407.868				38.038	1085.916	17.97	1.814	21.236	7.348
3	Ahmed Khaled farm, Al Khor	1961.48	3064.81	494.414		1.06		26.876	1364.728	29.336	3.278	28.138	10.098
4	Ahmed Khaled farm, Al Khor	942.91	1473.29	173.699		1.095		23.858	448.620	104.366	25.952	118.12	47.20
5	Ahmed Khaled farm, Al Khor	1962.85	3066.95	483.352		1.358		14.26	1410.56	22.132	3.022	18.584	6.474
6	Al Jassimya farm, Ash Shafallahiyah	1614.63	2522.86	426.34	623.01			20.25		271.90	29.52	169.41	71
7	Al Jassimya farm, Ash Shafallahiyah	1066.9	1667.03	246.68	442.91			5.25		152.18	24.65	132.71	55.52
8	Al Jassimya farm, Ash Shafallahiyah	793.58	1239.97	240.11	424.40			11.65		148.84	23.30	131.00	53.66
9	Al Jassimya farm, Ash Shafallahiyah	3805.11	5945.48	1104.80	1464.89			26.53		679.24	44.79	330.16	151.30
10	Al Jassimya farm, Ash Shafallahiyah	3360.26	5250.41	987.63	1300.72			24.97		585.01	39.55	290.32	131.00
11	Abo Rashed farm	7933.18	12395.59	2226.33	3256.02			22.33		1532.85	101.52	525.91	267.84
12	Abo Rashed farm	6677.23	10433.17	1811.64	2816.75			30.89		1129.72	83.99	569.82	232.81
13	Abo Rashed farm	8058.77	12591.83	2343.36	3196.48			40.14		1446.42	91.14	664.48	273.25
14	Abo Rashed farm	6328.65	9888.52	1639.93	2793.71			21.51		973.18	80.04	602.75	213.94
15	Abo Rashed farm	4386.92	6854.56	1134.64	1970.74			4.80		762	64.91	332.51	115.99
16	Abo Rashed farm	8458.67	13216.67	2338.55	3494.69			31.58		1590.43	114.24	619.32	267.53
17	Al Khor Camp	7186.49	11228.89	3004.54	1769.52		3.624			1789.44	94.36	367.62	155.38
18	Jerry Smeih farm, Al Khor	4512.58	7050.91	1603.06	1449.86			19.28		934.05	75.64	307.93	121.68

IV. Discussion

The TDS is a rough approximation of the summation of the cations and anions present in any groundwater sample. The higher the concentration of the ions, the higher the TDS. The TDS of the samples range from 793.58-8458.67 mg/l. From the classification of groundwater based on TDS given by Freeze and Cherry (1979), it is seen that 16.67% of the samples are fresh water, while 83.33% are brackish. The TDS is intrinsically related to the electrical conductivity (E.C). The samples with high TDS also showed high E.C values. This in turn is related to the salinity as EC is a good measure of salinity. EC values range from 1239.97-13216.67 µS/cm. Fluoride and Bromide occur in rather minute amounts. The more significant anions are chloride, sulphate, phosphate and nitrate, with concentrations ranging from 173.699-3004.54 mg/l, 424.4-3494.69 mg/l, 448.62-1364.728 mg/l and 4.8-40.14 mg/l respectively. The significant concentrations of phosphate within the groundwater of Ahmed Khaled farm is not unrelated to theintense composting and fertilizer application in the location, which makes the excess phosphorus dissolve through the soil and move downwards to the aquifers.Chloride is a major dissolved constituent of most natural water. Stuyfzand (1989), attempted a classification of groundwater based on its chloride content.

Tableno 2: Groundwater classification based on Cl in mg/l (after Stuyfzand 1989)

Main type	Cl (mg/l)
Very oligohaline	<5
Oligohaline	5-30
Fresh	30-150
Fresh-brackish	150-300
Brackish	$300-10^3$
Brackish-salt	10^3-10^4
Salt	$10^4-2.10^4$
Hyperhaline	$>2.10^4$

From the table, 22.22% of the samples are classified as fresh-brackish, 27.78% as brackish while 50% fall under the brackish-salt class. Nitrates occur in all but one of the samples. These nitrates probably percolated downwards to the aquifers from the chemical fertilizers utilized in agriculture in these locations. The only location without the occurrence of nitrates (Al Khor Camp), is surprisingly not a farm land.

The major cations were all present in the samples, with calcium and sodium contributing more to the TDS.

Table no 3: Hydrogeochemical ratios of the relevant cations and anions.

Sample No	Na^+/Cl^-	SO_4^{2-}/Cl^-	Ca^{2+}/Mg^{2+}
Sample 1	0.87		1.54
Sample 2	0.07		1.76
Sample 3	0.09		1.70
Sample 4	0.92		1.53
Sample 5	0.07		1.75
Sample 6	0.98	1.08	1.46
Sample 7	0.95	1.33	1.46
Sample 8	0.96	1.31	1.49
Sample 9	0.95	0.98	1.33
Sample 10	0.91	0.97	1.35
Sample 11	1.06	1.08	1.20
Sample 12	0.96	1.15	1.49
Sample 13	0.95	1.01	1.48
Sample 14	0.92	1.26	1.72
Sample 15	1.04	1.28	1.75
Sample 16	1.05	1.11	1.41
Sample 17	0.92	0.44	1.44
Sample 18	0.90	0.67	1.54
Average value of Sea water	0.90	0.1	0.2
Average value of River water	1.80	1.6	3.7
Range values of study area	0.07-1.06	0.44-1.33	1.20-1.76
Average value of study area	0.81	0.76	1.52

The average values of sea and river water from Al-Ruwaih and Ben-Essa (2004)

Na^+/Cl^- ratios vary from 0.07-1.06 with a mean value of 0.81. These values are closer to the average value for sea water, indicating a level of saline intrusion into the groundwater aquifers. Ca^{2+}/Mg^{2+} ratios vary from 1.20-1.76, with a mean value of 1.52. The relative abundance of calcium as compared to magnesium signifies limestone alteration through the process of dolomitization.

Chloride has a higher concentration than sulphate, as shown by $SO_4^{2+/}Cl^-$ ratios varying from 0.44-1.33, with a mean value of 0.76. This shortage of sulphate relative to chloride may indicate the absence of evaporites within the study area. Local geology of the area also supports this.

Major ions within the study area were plotted on Piper trilinear diagrams to determine the dominant hydrogeochemical facies and water type. The Piper diagrams are represented in Figures 2, 3 and 4 below.

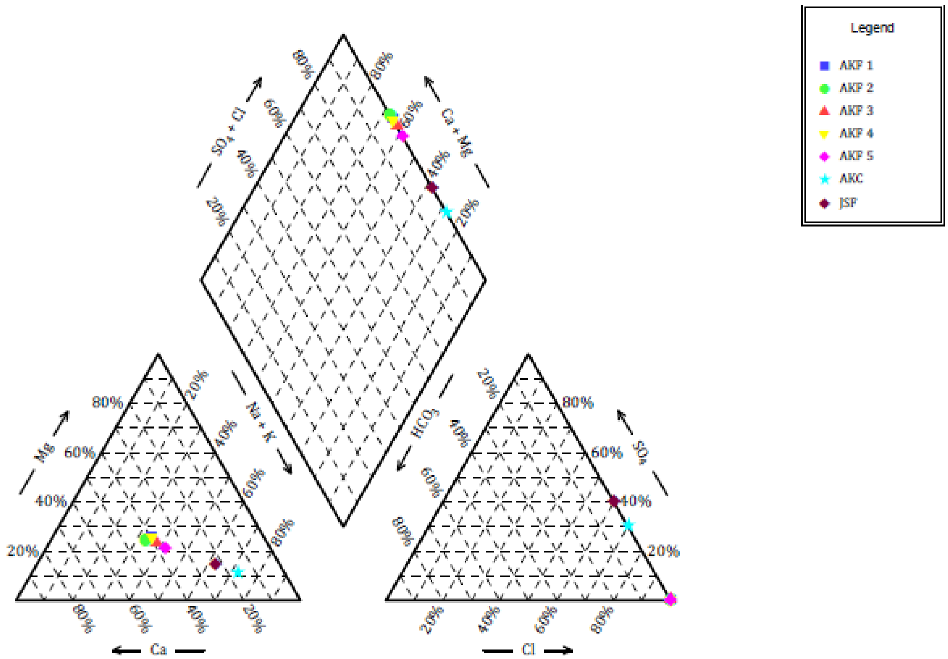

Figure no 2: Piper trilinear diagram for samples within Al Khor

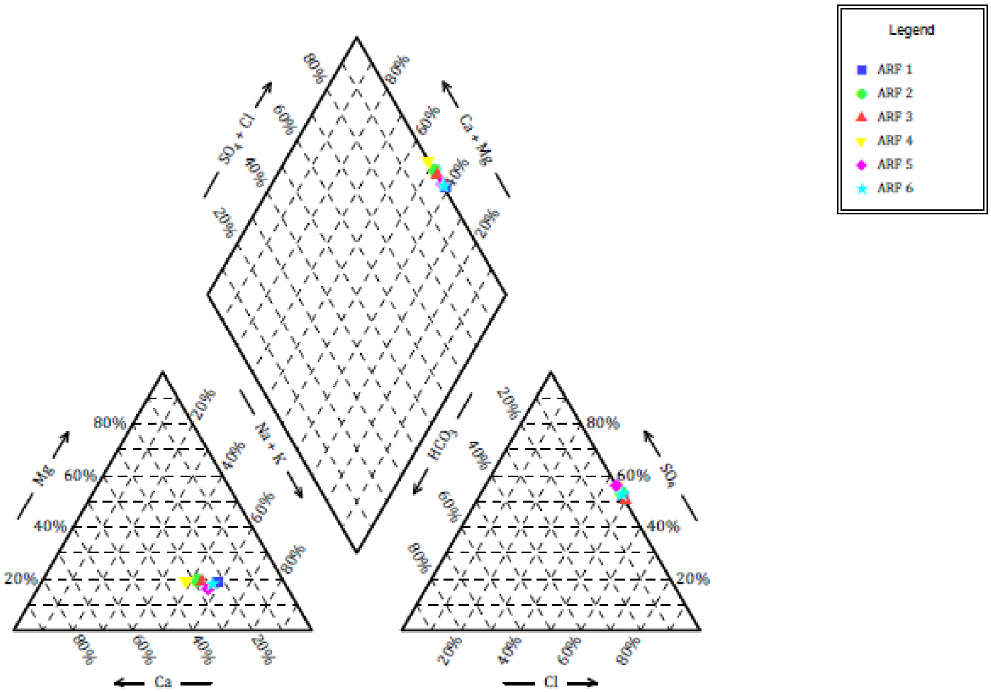

Figure no 3: Piper trilinear diagram for samples within Abo Rashed Farm

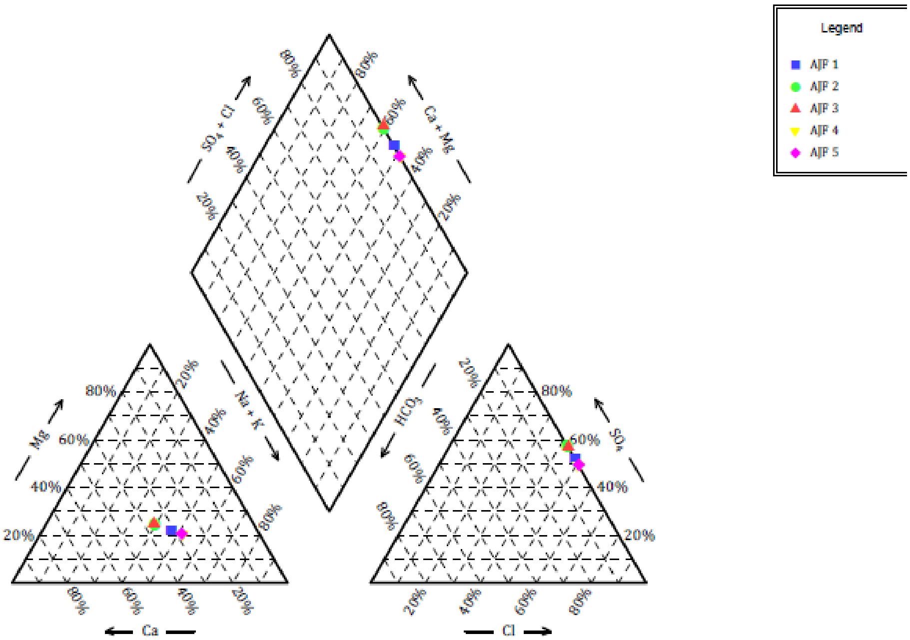

Figure no 4: Piper trilinear diagram for samples within Ash Shafallahiyah

The plots show that the groundwater is dominated by strong acids (Cl + SO_4), alkaline earths (Ca, Mg) and Na + K. Within the study area, two water types dominate as seen from the Piper diagrams. They are Ca-Mg-SO_4 and Na+K-Cl water types. The Na+K-Cl type is normally associated with marine and ancient groundwaters that are usually of high salinity.

Water quality analysis for irrigation purposes: Assessing the water quality in the study area is necessitated by the existence of farm lands that depend on irrigated groundwater sources. Several indices are used to determine the suitability of groundwater for irrigation. The values of these indices are then compared to some standard references and they form the basis of acceptance or otherwise of the water for irrigation.
The summary of the studied parameters is given in the table below.

Table no 4: Analysed parameters for classification of irrigation water

Sample no	Kelly's ratio	Soluble Sodium Percent	Sodium Adsorption Ratio	Sodium Percentage	Potential Soil Salinity
Sample 1	51.87	98.11	21.52	98.11	5.12
Sample 2	4.54	81.93	2.66	81.95	11.49
Sample 3	4.94	83.15	3.55	83.17	13.93
Sample 4	13.04	92.87	10.82	92.88	4.89
Sample 5	2.24	69.07	2.07	69.11	13.62
Sample 6	22.89	95.81	23.27	95.81	18.50
Sample 7	10.98	91.65	12.06	91.66	11.56
Sample 8	9.40	90.37	11.03	90.38	11.18
Sample 9	38.13	97.44	47.45	97.44	46.38
Sample 10	29.55	96.72	38.77	96.73	41.37
Sample 11	70.40	98.60	96.87	98.60	96.63
Sample 12	47.56	97.94	68.35	97.94	80.37
Sample 13	56.21	98.25	84.08	98.25	99.31
Sample 14	35.12	97.23	54.51	97.23	75.30
Sample 15	25.66	96.25	41.24	96.25	52.49
Sample 16	50.22	98.05	83.33	98.05	102.28
Sample 17	53.18	98.15	90.96	98.15	103.07
Sample 18	26.21	96.32	46.14	96.33	60.26

The most influential water quality guideline on crop productivity is the water salinity hazard as measured by electrical conductivity (E.C)[1].Water with E.C less than 250 µS/cm is excellent, 250-750 µS/cm is good, 750-2000 µS/cm is permissible, 2000-3000 µS/cm is doubtful, while above 3000 µS/cm is unsuitable. The E.C values within the study area range from 1239.97-13216.67 µS/cm, with a mean value of 6215.34 µS/cm. 22.22% of the sample fall under the permissible range, 11.11% under the doubtful range, while 66.67% of the samples are outrightly unsuitable on the basis of E.C classification of irrigation water.

The sodium percent ranges from 69.11-98.60%, with a mean value of 93.22%. Under this classification scheme, it is seen that about 5.56% of the samples are under the doubtful range, while the rest 94.44% corresponding to 17 samples are under the unsuitable range for use as irrigation water. High sodium percent in soil reduces the permeability and eventually results in soil with poor internal drainage[6,8].

The soluble sodium percent (SSP) is a sodium hazard indicator. It is defined as the ratio of sodium in epm to the total cation in epm expressed as a percentage. Water with SSP>60% may cause sodium to accumulate to an extent of changing adversely the soil's physical properties. All the samples studied show SSP>60% (69.07-98.60%), with a mean value of 93.22. These values are very similar to the sodium percent and as such both parameters can usually be correlated in defining sodium hazards.

The Kelly's Ratio of the groundwater samples varies from 2.24-70.40, with a mean of 30.67. This ratio measures the level of sodium against calcium and magnesium. Values above 1 are unsuitable for use as irrigation water.

Values of Sodium Adsorption Ratio (SAR) range from 2.07-96.87, with an average of 41.04. 11.11% of the samples fall under the good class for irrigation water (SAR between 0-3), while the rest 88.89% are under the unsuitable class (SAR>6-9). If the SAR value is greater than 6 to 9, the irrigation water will cause permeability problems on shrinking and swelling types of clayey soils[8].

The Potential Soil Salinity (PS) is another useful parameter in classifying irrigation water. Values of PS<5 epm are classified as excellent-good, values between 5-10 epm are classed as good-injurious, while PS>10 epm are injurious-unsatisfactory for usage as irrigation water. The studied samples show PS values ranging from 5.12-103.07 epm, with a mean of 47.10. Of this, 11.11% fall under good-injurious while the rest 88.89% of the samples fall under the injurious-unsatisfactory group.

V. Conclusion

Analysis of the groundwater within the area has shown that a majority of the groundwater studied are either brackish or saline, with a minority falling under the fresh water class based on TDS and chloride classification schemes. This renders the water outrightly unfit for drinking but a minority of the water may suit irrigation of some tolerant plants. The analysis of groundwater quality for irrigation by calculation of KR, SSP, %Na, SAR, PS yielded mostly values exceeding the normal permissible range, with a few of the samples providing values within the limits of acceptance. Piper trilinear plots show that Ca-Mg-SO_4 and Na+K-Cl water types are dominant in the area.

Further studies should navigate other graphical methods like Schoeller diagram, Stiff diagram and Durov diagram to make comparisons with the groundwater types derived from the Piper trilinear plots.

Acknowledgement

Big thanks to Nosiri Obioma for his contribution in the Piper diagrams and Vani for typesetting.

References

[1]. Ahmed SS, Mazumder QH, Jahan CS, Ahmed M, Islam S. Hydrochemistry and classification of groundwater, Rajshahi City Corporation area, Bangladesh. Journal of Geological Society of India. 2002;60:411-418.

[2]. Al-Naimi LS, Mgbeojedo TI. Hydrogeochemical evaluation of groundwater in parts of Shamal, Northern Qatar. Environmental Management and Sustainable Development. 2018;7(2):181-192. doi:10.5296/emsd.v7i2.13046

[3]. Al-Ruwaih FM, Ben-Essa SA. Hydrogeological and hydrogeochemical study of the Al-Shagaya Field-F, Kuwait. Bulletin of Eng Geol Env. 2004;63:57-70.

[4]. Atwia MG, Hassan AA, Ibrahim A. Hydrogeology, log analysis and hydrochemistry of unconsolidated aquifers south of El-Sadat city, Egypt. J.Hydrol. 1997;5:27-38.

[5]. Ballukraya PN, Ravi R. Characterization of groundwater in the unconfined aquifers of Chennai City, India; Part I: Hydrogeochemistry. J. Geol. Soc. India. 1999;54:1-11.

[6]. Collins R, Jenkins A. The impact of agricultural land use on stream chemistry in the middle hills of the Himalayas Napal. J. Hydrol.1996;185:71-86.

[7]. Freeze RA, Cherry JA. 1979. Groundwater. 2nd Edn., Prentice Hall Inc., Englewood, NJ., USA., ISBN-13: 9780133653120.1979:604.

[8]. Saleh A, Al-Ruwaih F, Shehata M. Hydrogeochemical processes operating within the main aquifers of Kuwait. J.Arid. Envir.1999;42:195-209.

[9]. Shahalam A, Abu Zahra BM, Jaradat A. Wastewater irrigation effect on soil, crop and environment: A pilot scale at Irbid. Jordan. Sci. Technol.1998;106:425-455.

[10]. Stuyfzand PJ. A new hydrochemical classification of water types. Proc, IAHS 3 Science Association, Baltimore,U.S.A. 1989:33-42.

[11]. Tanninen J, Kamppinen L, Nystrom M. Pre-treatment and Hybrid Processes: Nanofiltration-Principles and Application. Advanced Technology Publisher, London, ISBN-13: 978-1-85617-405-3. 2005.

[12]. Baalousha HM. Development of a groundwater flow model for the highly parameterized Qatar aquifers. Model. Earth Syst. Environ. 2016:2:67. https://doi.org/10.1007/s40808-016-0124-8.

Tochukwu Innocent Mgbeojedo."Assessment of Groundwater Quality around Al Khor and Environs, Qatar." IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG) 6.3 2018): 18-24.