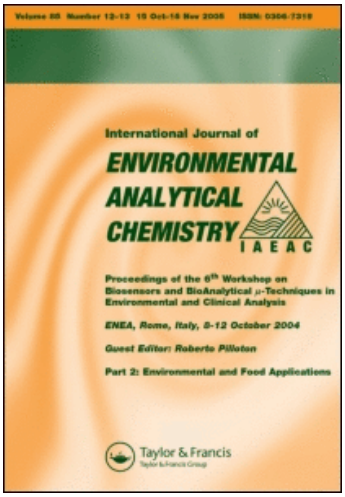

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Geochemical Analysis of Riyadh Ground Water

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This paper presents geochemical study of Riyadh ground water from Minjur and Jubaila aquifers near Riyadh region in Saudi Arabia. The concentration of Fe, Cu, Ni, and the potentially toxic elements such as As, Cd, Pb and Se has been found to be less than 0.01 ppm. These waters contain Ca^{++}, Mg^{++}, Na^{+}, Cl^{-}, and SO_4^{--} in higher concentrations than K^{+} and HCO_3^{-}. The concentration of all the elements detected in these waters is within the maximum permissible limits suggested by various world health organizations. The waters from the Minjur and Jubaila aquifers are of SO_4-Mg and Cl-Ca type, respectively, and are believed to be a mixture of marine and meteoric genesis. These waters are suitable for drinking after some softening and desalination treatment.

KEY WORDS: ground water, water table, neutron activation (NAA), inductively coupled argon plasma (ICAP).

INTRODUCTION

The ground water resources of the Riyadh region mainly consist of deep, shallow and medium-depth aquifers. The ground water supplied to Riyadh (capital of the Kingdom of Saudi Arabia) and its immediate vicinity is from underground rocks of the Minjur, Jubaila and Wasia formations. This study is only about the waters from Minjur and Jubaila formations. The present study has been carried out because the ground water of Minjur and Jubaila aquifers is an

important source of water supply in Riyadh region. The study focuses on the potability and chemical properties of these waters in addition to some of their hydrogeological properties.

Riyadh lies on the edge of the Jubaila limestone outcrops and the Arab formation.[1] The region is underlain by quaternary superficial deposits and Mesozoic sedimentary rocks. There are about twenty groundwater sources in this region. Some of these water sources are nearly depleted due to their extensive use as a result of increased water consumption by the sharp increase in population in the Riyadh region. It has been estimated[1] that the water inflow rate of Jubaila and Minjur aquifers is 8.9 MCM/year and 143.6 MCM/year. At present the water extraction rate is higher than the inflow rate of these aquifers, which results in continuous lowering of the water table in the Riyadh region. Therefore, in order to meet the growing demand for water in Riyadh city, it will be necessary to tap different ground water reserves far from Riyadh city and to look for some other sources of water such as desalinated water. The present water consumption rate for Riyadh city and its immediate vicinity is about 0.65 MCM/day, and approx. 60% of this is desalinated water from the Jubail–Riyadh water system from the Arabian Gulf. The Jubail desalinated water scheme has an initial delivery capacity of 0.5 MCM/day, with an ultimate capacity of 0.85 MCM/day.

Minjur and Jubaila formations

The Minjur aquifer is the largest groundwater reservoir in the Riyadh region (Figure 1). In 1968, it was estimated that its sandstone contained 460,000 MCM of water for general use.[1] The Minjur formation is mainly a littoral, continental sandstone and the aquifer is an artesian one, and it contains better quality water as compared to Jubaila aquifer. The thickness of Minjur sandstone is about 315 m to 1500 m.[1] The depth of Jubaila formation varies approximately from 90 to 150 m and the thickness of Jubaila limestone is about 150 m.[1] This formation consists of carbonate rocks of shallow marine origin, mostly aphanitic limestones.[2] The water in this formation is contained in openings resulting from weathering and jointing rather than from primary porosity of the rocks. The water from Jubaila aquifer (Figure 1) is used mainly for agriculture. The wells in this aquifer are shallow at about 300 m deep. The recharge of these

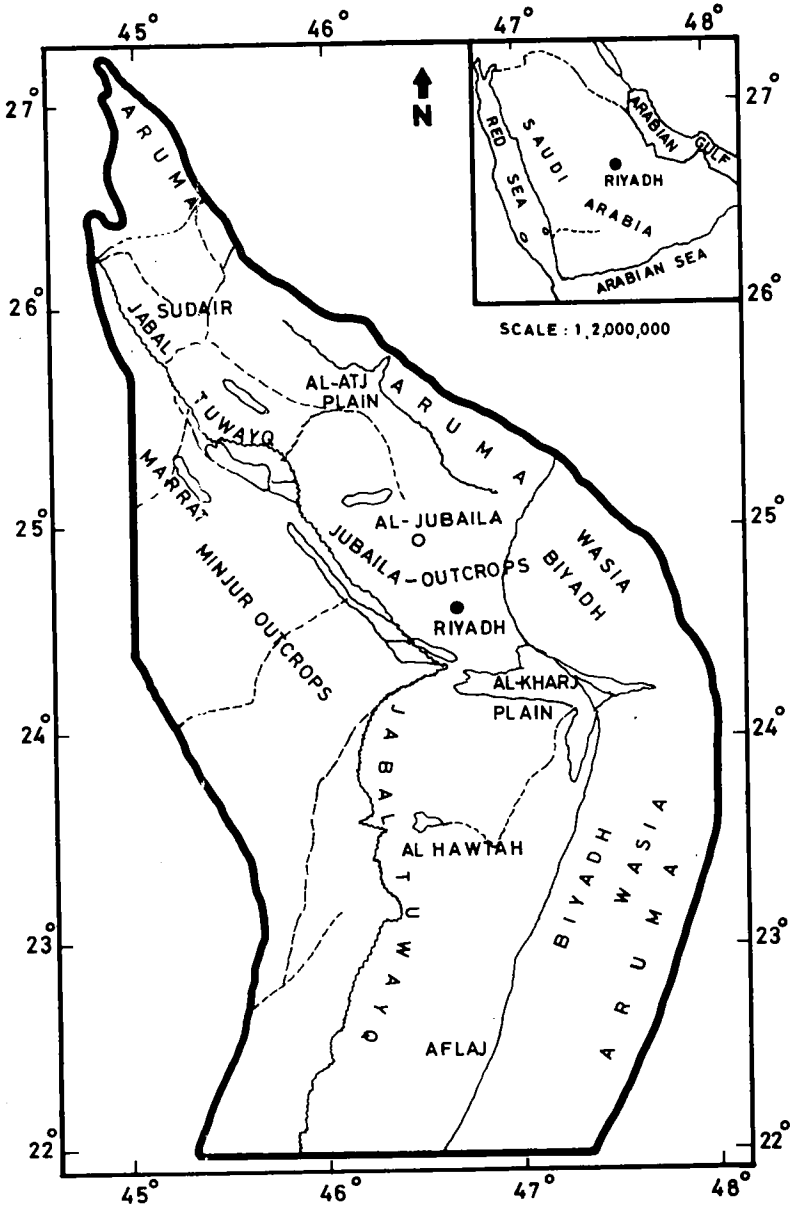

FIGURE 1 Map of Riyadh region showing ground water aquifers.[1]

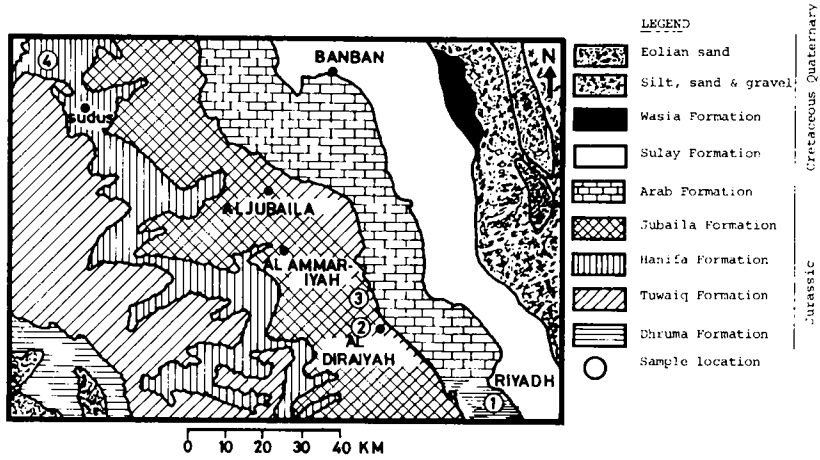

FIGURE 2 Map of Riyadh and its outskirts showing water sample locations.

aquifers is quite low, which results in continuously lowering the water table in the Riyadh region.[1]

EXPERIMENTAL PROCEDURE

The water samples were procured from four different locations in and around the city of Riyadh and its immediate vicinity (Figure 2). The source of water samples 1 & 2 is the Jubaila aquifer, while the source of water samples 3 & 4 is the Minjur aquifer (Tables I, II). The samples 1 & 2 were taken from two wells, and samples 3 & 4 were collected from two different places in Riyadh city water supply system. The water samples were properly preserved in special bottles provided by the Technical Service Laboratories, Toronto, Canada. The analysis of these waters was done at the Technical Service Laboratories, Toronto, Canada. The analysis techniques employed were mainly the neutron activation (NAA), inductively coupled argon plasma (ICAP) and the classical procedures.

The elemental concentrations of Al, B, Ba, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, Pb, Sb, Si, Zn were determined by ICAP and those of As, Se, W were determined with the help of NAA. The concentrations of chloride, bromide, bicarbonate, sulphate, total

TABLE I

Chemical data for the waters from Jubaila and Minjur aquifers (Riyadh region)

Sample	1		2		3		4		5[a]	
Cations$^+$ / Anions$^-$	ppm	epm	ppm	epm	ppm	epm	ppm	epm	ppm	epm
Na^+	287	12.48	140	6.09	84.2	3.66	94.2	4.10	143.86	6.62
K^+	<0.1	–	<0.1	—	<0.1	-	8.8	0.23	–	—
Ca^{++}	400	19.96	315	15.72	106	5.29	43.89	2.19	160.28	8.00
Mg^{++}	185	15.22	120	9.87	59.44	4.89	29.51	2.43	45.18	3.72
Cl^-	630	17.77	553	15.60	117	3.30	117	3.30	211.86	5.98
SO_4	816	16.99	419	8.72	185	3.85	185	3.85	404.00	8.41
HCO_3	37	0.61	15	0.25	15	0.25	18	0.30	207.71	3.41
pH-value	7.5		7.5		7.2		7.7		7.64	
T.H. (ppm) (as $CaCO_3$)	1430		977		353		171		1022	
E.C. (μmhos/cm)	4166		3908		406		943		1757	
T.D.S. (ppm)	2916		2825		284		660		1201	

[a]From reference 5.

TABLE II
Elemental concentration (PPM) of the water from Jubaila and Minjur aquifers (Riyadh region)

Elements detected	Concentration (PPM)				Max. permissible limits (PPM)	
	Sample No. 1	Sample No. 2	Sample No. 3	Sample No. 4	W.H.O. Ref. 8	Nat. Acad. Eng. Nat. Acad. Sci. Ref. 7
Aluminium (Al)	5.75	4.80	1.56	0.52	—	
Antimony (Sb)	0.3	0.1	0.3	1.3	—	
Arsenic (As)	<0.01	<0.01	<0.01	<0.01	0.05	0.1
Barium (Ba)	0.05	0.14	0.03	0.01		1
Boron (B)	0.99	0.71	0.77	0.45		
Bromide (Br)	<0.01	<0.01	0.19	<0.01		
Cadmium (Cd)	<0.01	<0.01	<0.01	<0.01	0.01	0.01
Chromium (Cr)	0.03	<0.01	<0.01	<0.01	—	0.5
Cobalt (Co)	<0.01	<0.01	0.04	<0.01	—	—
Copper (Cu)	<0.01	<0.01	<0.01	<0.01	1.5	1
Iron (Fe)	0.07	<0.01	<0.01	<0.01	1	0.3
Lead (Pb)	<0.01	<0.01	<0.01	<0.01	0.05	0.05
Manganese (Mn)	<0.01	<0.01	0.015	<0.01	0.5	—
Nickel (Ni)	<0.01	<0.01	<0.01	<0.01	—	—
Selenium (Se)	<0.01	<0.01	<0.01	<0.01	0.01	0.01
Silicon (Si)	9.83	8.11	7.42	3.10	—	—
Tungsten (W)	0.3	<0.1	<0.1	<0.1	—	—
Zince (Zn)	0.14	0.29	0.15	0.17	15	5

hardness, and total dissolved solids were determined using classical procedures. A total of about 24 elements were detected in these waters from the Minjur and Jubaila aquifers. Table I represents the results for the pH-value, total dissolved solids (T.D.S.), total hardness (T.H.), electrical conductivity (E.C.), and the concentration of cations and anions in these waters. Table II represents the elemental concentrations of Riyadh waters.

RESULTS AND DISCUSSION

Hydrogeochemical study of Riyadh waters

The purpose of this work is to study the geochemical and some hydrogeological properties of Riyadh ground waters. Also, the study

reviews the chemistry of these waters in terms of its potability. A. G. Hamza *et al.*[3] have reported some results for water samples from Riyadh and its outskirts, but their results are mainly qualitative, with quantitative analysis only for potassium and sodium.[4]

The water samples 3 & 4 do not represent the actual chemical composition for the Minjur aquifer water since these samples were taken from the Riyadh water supply system, where the water is purified for drinking purposes. For comparison purposes and to see the original chemical composition of water from Minjur aquifer, the analysis of an early report[5] (which represents the average results for the analysis of seven raw water samples of Minjur sandstone aquifer) is included in Table I as sample 5.

The important hydrochemical parameters for the water of the two aquifers are listed in Table III. The hydrochemical characteristics of these water samples indicate that water of Jubaila limestone aquifer (sample 1 & 2) belongs to Cl-Ca water type, while the water of Minjur sandstone aquifer (samples 3, 4, 5) belongs to SO_4-Mg water type. Water samples 1 & 2 show higher concentration of Ca, Mg, and SO_4 as compared to samples 3, 4, 5. The higher concentration of Ca indicates the leaching of limestone in oxidation zone. The high concentration of Mg and SO_4 could be due to the leaching of Ca or Mg sulphates in depth. In the region of Riyadh the two aquifers are overlain by anhydrite beds ($CaSO_4$). The hydrochemical parameter Na/Cl for samples 1 & 2 may indicate that the water of Jubaila aquifer is a mixture of connate marine and meteoric waters. The chemical data indicate the calcareous and sandy nature for the Jubaila and Minjur aquifers respectively.

TABLE III

Hydrochemical parameters for waters from Minjur (samples 3, 4, 5) and Jubaila (samples 1, 2) aquifers

Hydrochemical parameters	Water samples				
	1	2	3	4	5[a]
Ca^{2+}/Mg^{2+}	1.31	1.59	1.08	0.90	2.15
Na^{+}/Cl^{-}	0.7	0.39	1.11	1.24	1.10
Cl^{-}/HCO_3	29.13	62.4	13.2	11.00	1.75

[a]From reference 5.

All the water samples show relatively high value for the T.D.S., which could be due to slow movement of ground water, long contact of water with rocks and the high solubility of aquifer minerals. The high value of T.D.S. may also indicate the high aridity of Riyadh region. Figure 3 is a comparative graph of six major ions for the waters of the two aquifers (samples 1, 2, 5) to show their relation to the sea water. The concentration of Ca is high in all the samples which may be due to Jubaila limestone for samples 1 & 2, and due to the leaching of carbonates during recharge for samples 3, 4 and 5. The concentration of Na ions is low in all the samples, which seems to be due to exchange of ions. According to Wells[6] (see Wilcox), the absorption of Na ions by fine clay takes place in deep water conditions to maintain the balance between cations and anions.

Potability of Riyadh ground water

Tables I and II show the results of chemical analysis of the Riyadh ground waters. A total of 24 elements have been found in these water samples. Metals like iron, copper nickel, and the potentially toxic elements such as arsenic, cadmium, lead, and selenium are less than 0.01 ppm. The water from Jubaila limestone aquifer has higher concentration of Al, Ca, Mg than the water from Minjur sandstone aquifer as it is in contact with calcite ($CaCO_3$) and dolomite ($CaMg[CO_3]_2$). The concentration of all the elements in the waters of the two aquifers is below the maximum permissible limits recommended by different world health organizations.[7,8]

It can be seen (Table I) that the dominant ions are Ca^{++}, Mg^{++}, Na^+, Cl^-, SO_4^{--}, and HCO_3^- while traces of K^+ are present. The values for T.H., E.C., and T.D.S. are higher for samples 1 & 2 (Jubaila limestone aquifer) than for samples 3, 4, and 5 (Minjur sandstone aquifer). This indicates that the water of Jubaila aquifer is harder than the water of Minjur aquifer. Also, the pH value for these waters ranges between 7.2 and 7.7 showing that these waters are slightly alkaline. An examination of Table I shows that water from each source is rich in sulphate, chloride, and calcium ions. Sample 1 contains the highest percentage (45%) of Na^+ ions while Mg^{++} ions are approximately evenly distributed in all the samples, the average being 29%.

The present study of the chemical composition of the water

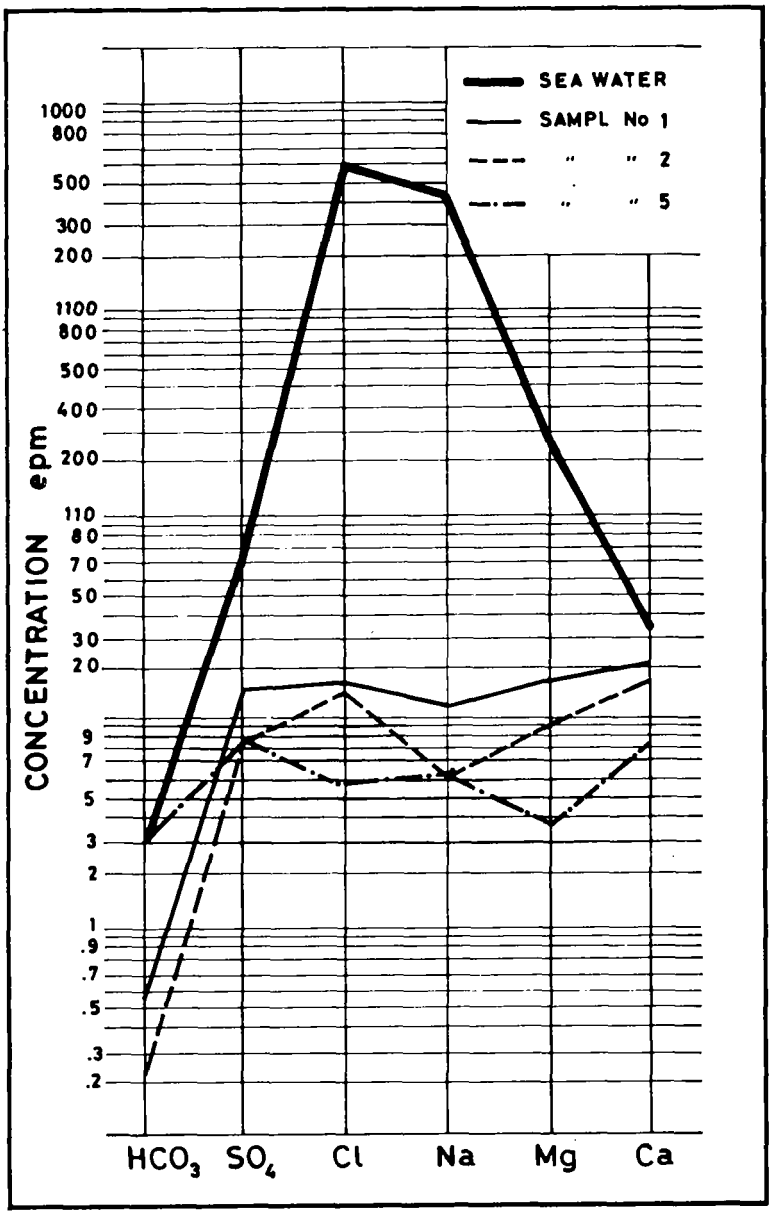

FIGURE 3 Comparative graph of Riyadh waters.

samples from Riyadh city and its suburbs indicates that the water from these regions are hard, slightly alkaline and would require treatment for softening and some degree of desalination before its use for domestic supply. Also, water from the Minjur aquifer is of better quality in regard to its potability as compared to water from Jubaila aquifer.

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