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Hydrochemical classification of the groundwater of Umm Al-Aish, Kuwait

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ABSTRACT

The Umm Al-Aish area is considered one of the most important fresh water well fields in Kuwait. Chemical analyses carried out in 1983 showed that the aquifer salinity ranges from 300 to 600 ppm. Chemical classification of groundwater indicates that there are four major groundwater groups: Group 1, calcium bicarbonate water type has a symbol (1113313) in which Na > Cl; Group 2, calcium chloride water type (3131313), in which Cl > Na; Group 3, calcium sulphate water type (1313313), in which Na > Cl; Group 4, calcium sulphate water type (3311313), with Cl > Na. The overall chemistry of Umm Al-Aish groundwater indicates that alkaline earths exceed alkalis, and strong acids exceed weak acids, suggesting that the area is being recharged during infrequent torrential rain storms.

INTRODUCTION

Since 1963 the Ministry of Electricity and Water has drilled 26 production water wells for the purpose of drinking water utilization. Aquifer salinity in these wells ranged between 500 and 1500 ppm in 1966, but deterioration of water quality has been noticed in some water wells where salinity measurements made in 1977 showed a range of salinity from 400 to 2000 ppm toward the periphery of the basin. Due to salinity deterioration, the number of production wells was limited to 8, located mainly in the central and southwest parts of the area. Chemical analyses carried out in 1983 showed the salinity to range between 300 and 600 ppm. The purpose of this paper is to classify the groundwater of Umm Al-Aish and to trace the areal distribution of the groundwater groups as well as the horizontal trend of water quality with time.

AREA AND TOPOGRAPHY

Umm Al-Aish area is located in the north of Kuwait and covers an area of 92 km^2 (Fig. 1). The drainage divide surrounding Umm Al-Aish basin encloses an area of 790 km^2. The land surface rises gently from Umm Al-Aish basin floor to the west at the rate of 3·6 to 4·5 m/km, and slightly more steeply to the east (3·6 to 6 m/km). The western wadis are around 15 km long while the eastern wadis are from 4 to 8 km long. The area is characterised by a scarcity of rainfall, the 15 year average precipitation being 96·5 mm (Fig. 2).

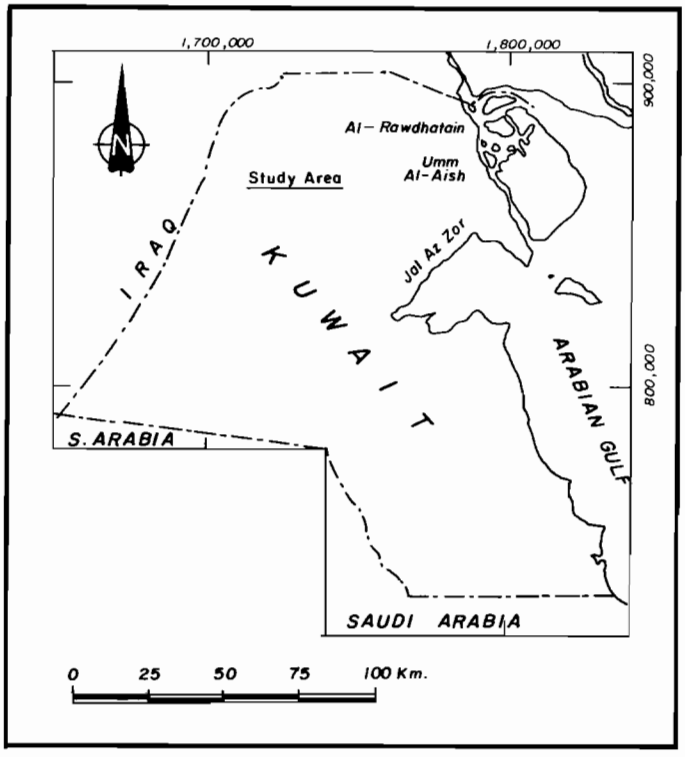

Fig. 1. Extent and location of the study area.

LITHOLOGY AND STRATIGRAPHY

KUWAIT GROUP (NEOGENE)

In the north of Kuwait this group can be divided into three formations, based on the presence of an intermediate evaporite development. These divisions are, from the top downwards, the Dibdiba, Fars and Ghar Formations.

Dibdiba Formation

This consists mainly of sand and gravel with intercalated layers of sandy clay, and locally cemented by lime and gypsum. The deposits are interpreted as part of an extensive fluviatile system deposited by powerful rivers originating in the Arabian hinterland.

Fars Formation

This formation occurs in the north of Kuwait, and borings for oil have proved the occurrence of over 100 m of fossiliferous clays, marls, anhydrite, gypsum and shallow water limestone.

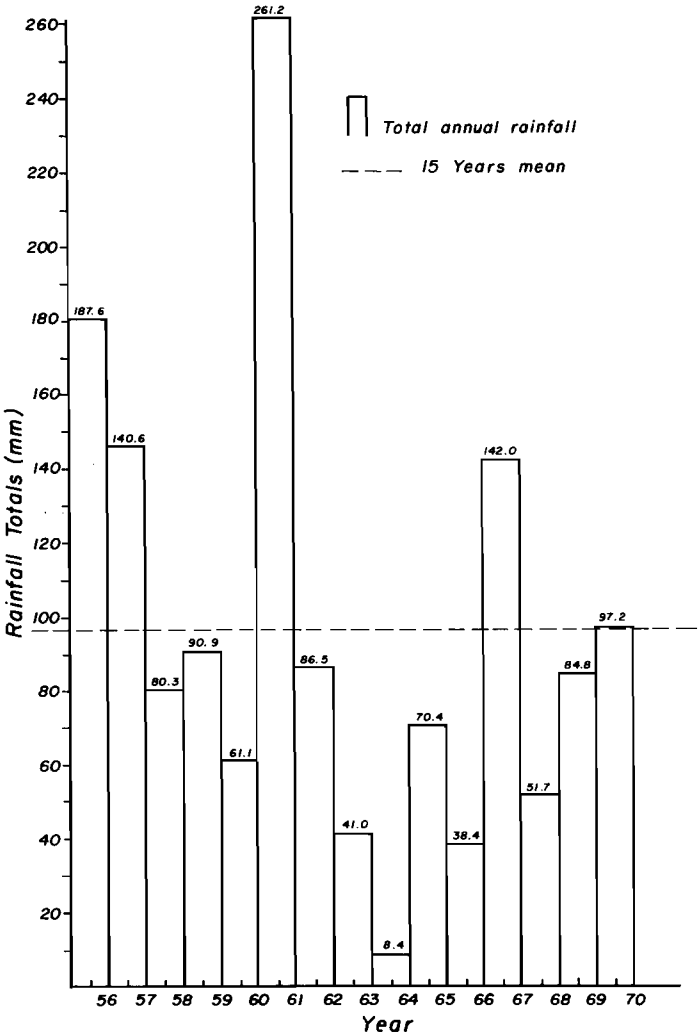

Fig. 2. Total annual rainfall (1956–1970).

Ghar Formation

This is the basal unit of the Kuwait Group and is predominantly of sands and gravels with occasional lenses of sandy limestone, clay or anhydrite. The sands are generally coarse and unconsolidated and because they are not fossiliferous they cannot be easily differentiated from the similar beds of the Dibdiba Formation where the distinctive horizon of the lower Fars is absent (O'Brien 1952).

AQUIFER OCCURRENCE

Water is found at a depth of 55 to 75 ft (16·7 to 22·8 m) below land surface in the Umm Al-Aish basin. The usable water occurs along the major peripheral wadis. Groundwater occurs and moves under leaky artesian conditions. Three sandstone units,

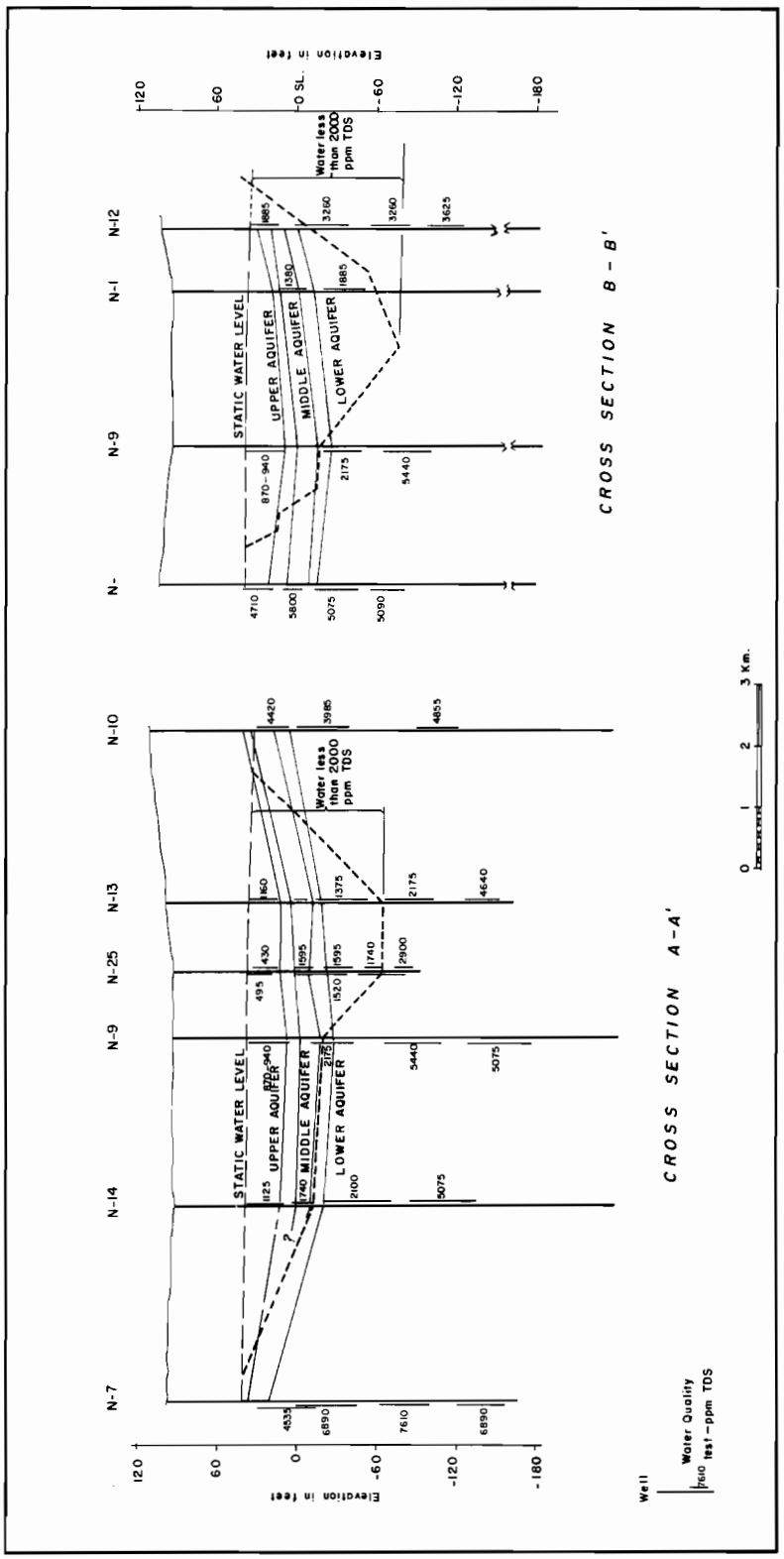

Fig. 3. Cross section showing the aquifer occurrence (after Parson 1963). The approximate positions of sections A–A′ and B–B′ are shown in Fig. 4.

which for convenience are called aquifers, are separated from one another by beds of sandy siltstone and clayey siltstone. The base of the upper aquifer is at a depth of 71 ft (21·6 m), the middle one extends from 91 to 101 ft (27·7 to 30·7 m) and the top of the lowest aquifer is at a depth of 115 ft (35 m). The upper aquifer attains a thickness of about 25 ft (7·6 m), while the middle aquifer is 10 to 15 ft (3 to 4·5 m) thick and is separated from the upper aquifer by a sandy or clayey siltstone. The lowest aquifer attains a thickness of about 60 ft (18·2 m) and is separated from the middle aquifer by a variable thickness of sandy and clayey siltstone. The base of the lower aquifer is not well defined (Fig. 3) (Parson 1963).

AQUIFER PROPERTIES

More than 75 pumping tests have been carried out by the Ministry of Electricity and Water at Umm Al-Aish area for aquifer evaluation. It is found that the transmissivity ranges between 80,000 and 26,000 gpd/ft and the storage coefficient ranges from $5{\cdot}06 \times 10^{-4}$ to $0{\cdot}13 \times 10^{-4}$ (Parson 1963).

WATER QUALITY

Quality of the groundwater ranges from less than 500 to more than 1800 ppm TDS in the aquifer (Parson 1963). Groundwater in the Rawdatain and Umm Al-Aish areas ranges from 205 ppm to very brackish, i.e. more than 7000 ppm TDS. Water becomes more mineralized with increasing depth, and also outside of the basin and wadi areas (Bergstrom & Aten 1964).

GROUNDWATER CHEMISTRY

Periodical chemical analysis carried out by the Ministry of Electricity and Water shows an appreciable variation in the field salinity. The salinity of the aquifer ranged from 500 to 1500 ppm in 1966 as shown in Fig. 4. Areal distribution of TDS in 1977 shows that the water quality has deteriorated slightly with time in the periphery of the basin, ranging from 400 to 2000 ppm (Fig. 5). This deterioration is probably due to a hydrogeologic condition whereby water of poor quality surrounds the fresh water in the centre of the basin. Due to the increase in salinity some of the wells were shut down. Chemical analysis carried out in 1983 showed that the aquifer salinity then ranged from 300 to 600 ppm, being limited to eight water wells in the center of the basin (Fig. 6).

METHODOLOGY

The method used for the presentation and interpretation of the groundwater analysis is the nomograph proposed by Schoeller (1935) using a numerical approach derived by Haddad (1981). All methods of classification depend on the variation of ionic ratio and ionic percentage. Generally, the classification takes into consideration the major cations and anions. The ratios are arranged and given symbols as follows: Cl/HCO_3, SO_4/HCO_3, Cl/SO_4, $(Na + K)/Cl$, $Ca/(Na + K)$, $Mg/(Na + K)$, Ca/Mg. Three possibilities exist: the ratios being less than one, equal to one and more than one. A ratio of value less than one is given the symbol 1, a ratio of value equal to one is given

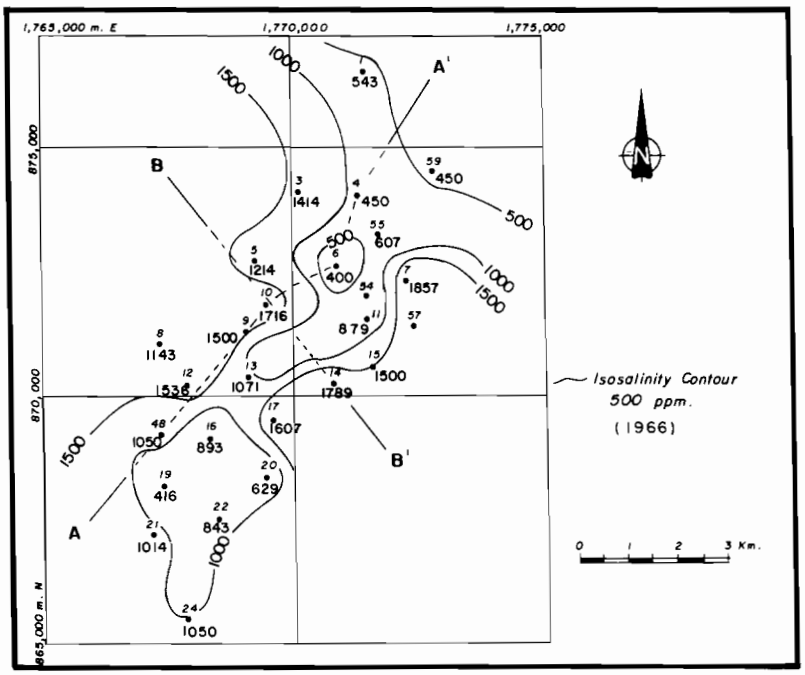

Fig. 4. Areal distribution of isosalinity, 1966.

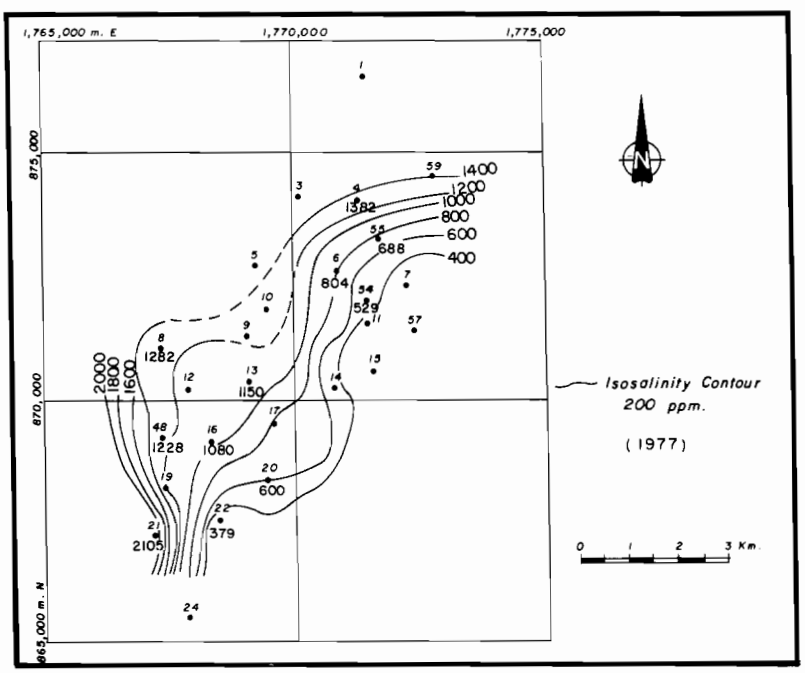

Fig. 5. Areal distribution of isosalinity, 1977.

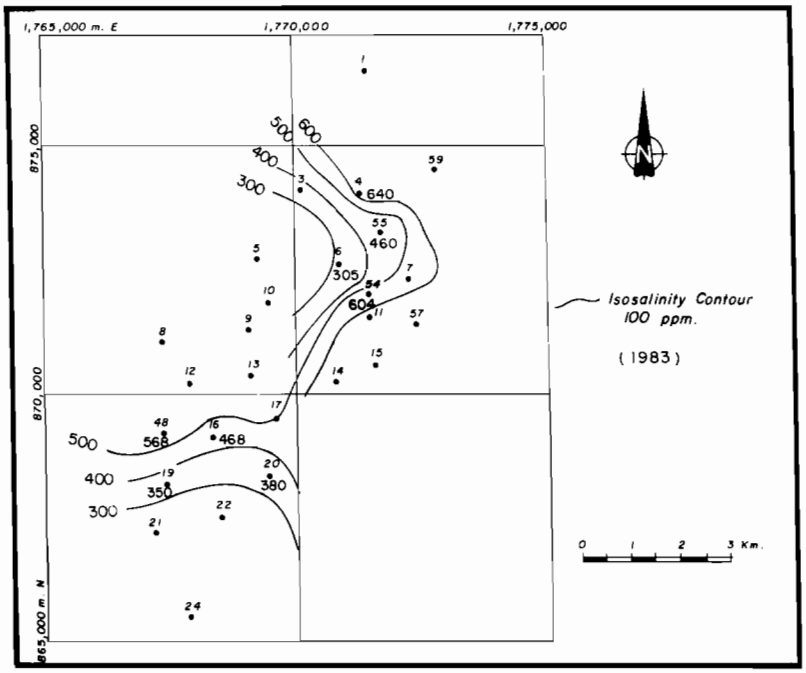

Fig. 6. Areal distribution of isosalinity, 1983.

the symbol 2, a ratio of value greater than one is given the symbol 3 (Al-Ruwaih 1980). This classification is considered of great help in providing rapid classification and evaluation of a large number of samples.

AREAL DISTRIBUTION OF GROUNDWATER CHEMICAL TYPES

The hydrochemical classification of the groundwater in Umm Al-Aish basin is based on samples collected and analysed in May 1983, as well as some chemical analyses obtained from the Ministry of Electricity and Water which had been carried out in 1974 and during the period 1977–1980. Four major groundwater groups were recognized (Fig. 7). These are Group 1 (1113313), calcium bicarbonate water type, in which Na > Cl. This water occurs in a southwest strip around the Wells U19 and U20 and also around Well U6. The same group is centered around Well U55 but here Cl > Na, and there is also an increase in salinity due to concentration of chloride ion. Group 2 (3131313) is a calcium chloride water type in which Cl > Na. This group is concentrated around Wells U54 and U48 on the periphery of the field. Group 3 (1313313) is a calcium sulphate water type in which Na > Cl, and is located around Well U16. The fourth chemical group (3311313) is calcium sulphate water type in which Cl > Na, and it centers around Well U4. A summary of the groundwater chemical groups is shown in Table 1. Table 2 presents the chemical analysis of Umm Al-Aish water as in 1983. The close correspondence of the groundwater groups with the total dissolved solid map of 1983 (Fig. 6), which has limited variations in the

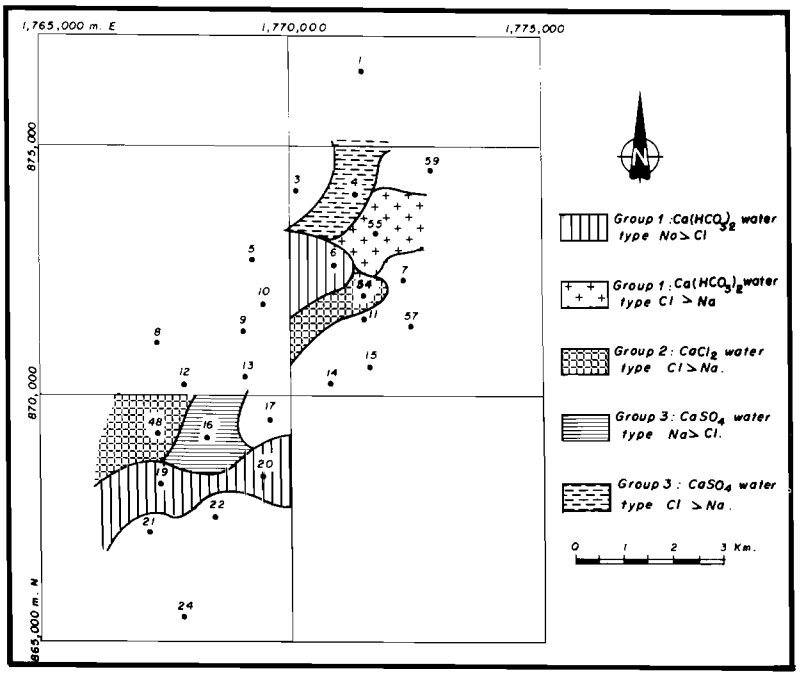

Fig. 7. Areal distribution of groundwater chemical groups, 1983.

horizontal direction, shows a clear correlation between salinity distribution of the groundwater and the mapped groups. The average composition of groundwater chemical groups is shown in Scholler nomograph which displays the relative concentration of cations and anions in each group (Fig. 8). The chemical analyses have also been plotted on a Piper (1944) Diagram (Fig. 9) which shows that alkali earths exceed alkalis and strong acids exceed weak acids, suggesting that the area has been recharged during infrequent torrential rain storms.

Table 1. Summary of groundwater chemical groups for the period 1974, 1977–80, 1983.

Group	Water type	Relative predominance of cations and anions
1 3313313	Calcium sulphate	Ca > Na > Mg; SO_4 > Cl > HCO_3; Na > Cl
2 3311313	Calcium sulphate	Ca > Na > Mg: SO_4 > Cl > HCO_3; Cl > Na
3 3333113	Sodium chloride	Na > Ca > Mg; Cl > SO_4 > HCO_3; Na > Cl
4 1113113	Sodium bicarbonate	Na > Ca > Mg; HCO_3 > SO_4 > Cl; Na > Cl
5 1113313	Calcium bicarbonate	Ca > Na > Mg; HCO_3 > SO_4 > Cl; Na > Cl
6 1133313	Calcium bicarbonate	Ca > Na > Mg; HCO_3 > Cl > SO_4; Na > Cl; HCO_3 > Cl
7 1313113	Sodium sulphate	Na > Ca > Mg; SO_4 > HCO_3 > Cl; Na > Cl; HCO_3 > Cl.
8 3313113	Sodium sulphate	Na > Ca > Mg; SO_4 > Cl > HCO_3; Na > Cl
9 1133113	Sodium carbonate	Na > Ca > Mg; HCO_3 > Cl > SO_4; Na > Cl
10 3131313	Calcium chloride	Ca > Na > Mg; Cl > HCO_3 > SO_4; Cl > Na

Table 2. Chemical analysis of Umm Al-Aish groundwater, 1983

Well No.	E.C. mmhos/cm	TDS ppm	pH	Ca ppm	Mg ppm	Na + K ppm	Cl ppm	SO_4 ppm	HCO_3 ppm
4	1·006	644	7·80	57·0	9·5	33·4	45·0	18·4	36·6
6	0·478	306	8·11	54·3	8·5	37·0	23·0	8·9	67·9
16	0·732	468	7·96	52·4	12·2	35·3	32·6	18·0	49·5
19	0·550	352	7·94	55·8	12·0	32·1	15·8	5·2	67·1
20	0·600	384	7·89	56·6	10·8	32·5	31·4	8·2	68·5
48	0·889	569	7·93	60·5	11·8	32·6	53·4	16·2	46·6
54	0·945	605	7·86	69·5	11·2	19·3	60·0	10·2	39·9
55	0·721	461	7·86	60·7	10·9	28·2	36·6	19·9	43·7

CONCLUSION

A study of the salinity of the Umm Al-Aish aquifer was carried out in 1983. TDS from 8 water wells ranged from 300 to 600 ppm. Four major groundwater chemical groups were determined. These are: calcium bicarbonate (1113313), calcium chloride (3131313), calcium sulphate (1313313) and calcium sulphate (3311313) water types. Areal distribution of isosalinity map shows a clear agreement with the distribution of groundwater chemical types where fresh water is limited to the southwest and central parts of the aquifer.

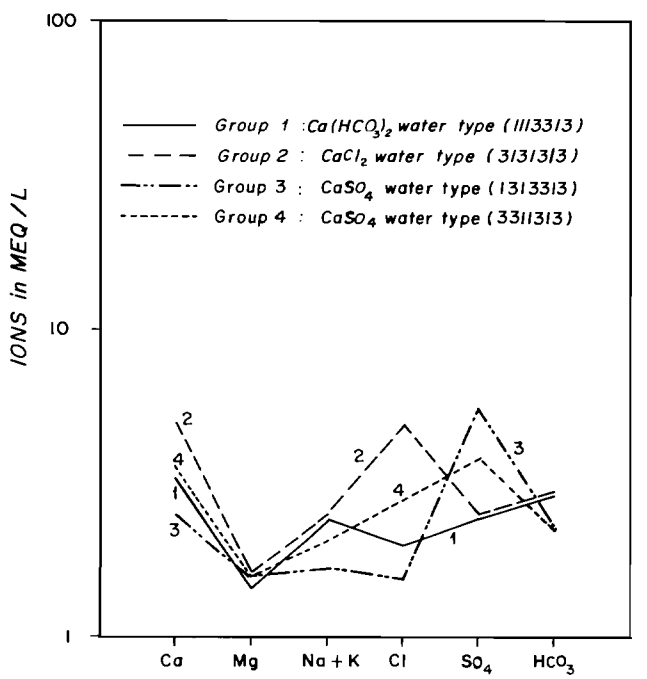

Fig. 8. Average chemical characteristics of the groundwater groups, 1983.

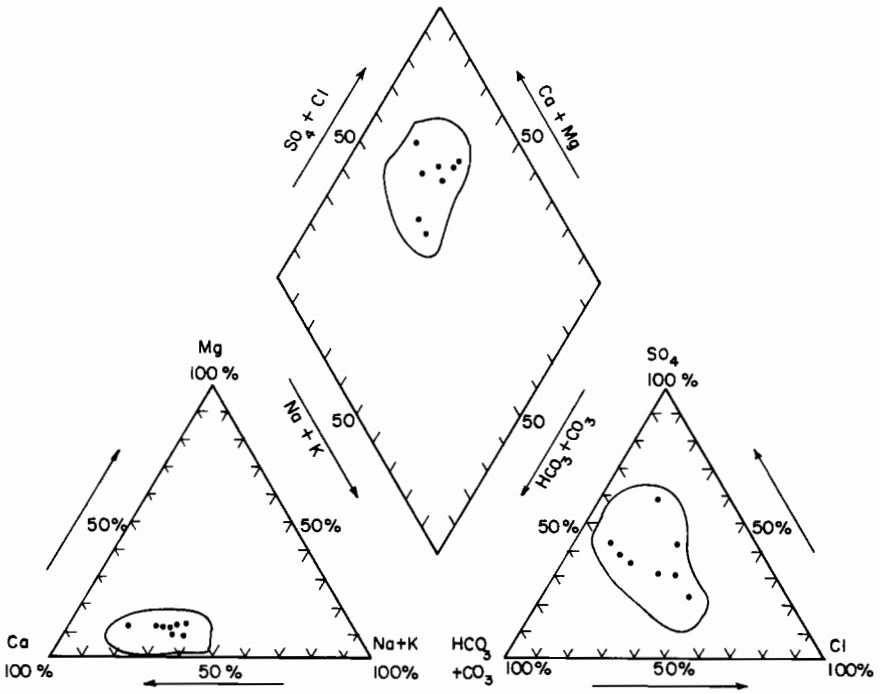

Fig. 9. Groundwater analysis of Umm Al-Aish area, 1983, using Piper's method.

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التقسيم الهيدروكيميائي للمياه الجوفية في منطقة ام العيش ، الكويت

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خلاصة

تعتبر منطقة ام العيش من المناطق الهامة في الكويت نظرا لوجود حقل الابار المنتج للمياه العذبة فيها . اثبتت التحاليل الكيميائية التي اجريت في عام ١٩٨٣ ان ملوحة الخزان المائي تتراوح ما بين ٣٠٠ و ٦٠٠ جزء في المليون من الاملاح الذائبة ، كما اظهر التصنيف الكيميائي لمياه ام العيش ان هناك اربعة انواع من المياه العذبة هي نوع بيكربونات الكالسيوم ورمزه (١١١٣٣١٣) وفيه يكون تركيز ايون الصوديوم اكبر من تركيز ايون الكلور ، ونوع كلوريد الكالسيوم (٣١٣١٣١٣) والذي يتميز بأن تركيز ايون الكلور فيه اعلى من تركيز ايون الصوديوم ، ونوع كبريتات الكالسيوم (١٣١٣٣١٣) وفيه يزيد تركيز ايون الصوديوم عن تركيز ايون الكلور ، ونوع كبريتات الكالسيوم (٣٣١١٣١٣) وفيه يكون تركيز ايون الكلور اكبر من تركيز ايون الصوديوم .

ولقد تبين من التحاليل الكيميائية لمياه منطقة ام العيش ان تركيز القلويات الارضية (كالسيوم ومغنيسيوم) يزيد عن تركيز القلويات (الصوديوم والبوتاسيوم) وان تركيز الاحماض القوية اكبر من تركيز الاملاح الضعيفة .

ويشير البحث إلى ان المياه العذبة في منطقة ام العيش ربما تكونت نتيجة لتجمع مياه الامطار الغزيرة غير المنتظمة في فترات متباعدة .