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ENVIRONMENTAL IMPACT ON GROUNDWATER AT SAINT KATHERINE AND FEIRAN OASIS AREAS, SOUTHERN SINAI, EGYPT

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Abstract.

Groundwater plays and will continue to play a critical role in satisfying water requirements for Saint Katherine and Feiran Oasis. Thus, sustainable groundwater development and presentation of groundwater quality should receive priority attention. Environmental impacts include both human activities and natural phenomena, but human activities could impair groundwater quality and contribute to maximum damage through over-exploitation and irrational use. The problems of groundwater quality and quantity have been intensified during the last few years in response to ever-increasing population.

The objective was to assess the impact of urbanization on recharge and groundwater quality. New sources of recharge are developed within urban areas, including septic tanks, and intensive irrigation of domestic gardens. The quantity of recharge depends up on the density of urban development, and the amount of water imported from external sources. A continuous decline of groundwater levels in wells indicates that the aquifer is subjected to a continuous intensive exploitation. Reduction of groundwater withdrawal is recommended to avoid the deficit in water supply and deterioration in water quality.

The hydrochemical compositions of water samples collected from the populous areas are characterized by high ionic concentrations of different ions, dominance of chloride and sulphate ions and low bicarbonate content. However, undesirable levels of chloride and sulphate ions were above the recommended levels. The elevated chloride concentrations in water may be indicative of mixing from higher chloride water, while elevated sulphate concentrations are attributed to the oxidation of organic and inorganic sulphide in soil profile. Nitrate-N concentrations are significantly higher in urban area (>1 PPM) than the non-urban sites, this is attributed to the microbial degradation of organic nitrogenous material including human and animal wastes as well as fertilizers used in domestic *gardens. High concentrations of trace metals are noted in groundwater at dense populated areas. The results of bacteriological analyses show that only 11 wells are free of total Coliform and E. Coli type, these wells are located outside the populated areas. The presence of such bacteria affirms the presence of faecal pollution. Accordingly, the groundwater in populous areas should chemically treat before drinking. It is vital that a groundwater quality-monitoring program be established as a matter of priority.*

Introduction

The area of study is located in south Sinai (Fig. 1). It is bounded by latitudes 28° 25' & 28° 45' N and longitudes 33° 35' and 34° 00'E.

During the last decades Saint Katherine-Feiran oasis areas have received particular Governmental attention due to intensive tourism for Saint Katherine monastery and increasing population extension. The groundwater is the main water resource for the development of these vital areas where surface water is limited and exists only at w. Talah for several months of the year along its down stream course. The problems of groundwater quality and quantity have been intensified in response to increased growth and concentration of populations. The people attain water from shallow wells and dispose the sewage via earth closets and septic tanks, from which water seeps to groundwater. Most wells are situated between houses, not sealed and opened to faecal and other contamination from varieties of sources. Most water withdrawn from wells is actually used to collect wastes. In any evaluation of groundwater resource, the quality of water is almost of equal importance with quantity available. In fact, most human activities have a direct and usually adverse impact on water quality.

The area under study was subjected to several geological, geophysical and hydrogeological studies, among them El Shazly et al., (1985), El Shamy et al., (1989), El Shendy, (1989) and El Shamy and El Rayes, (1992). Although much has been written about groundwater occurrences in the studied areas, little is currently known about the impact that changes in land use will have on groundwater quality.

Aim and methods of study

The present work aims to evaluate the environmental impacts caused by rapid urbanization on groundwater at Saint Katherine and Feiran oasis areas. Field observations and measurements were carried out during March 1998 along the course of W. Feiran-W. El-Sheikh. The depths to water, pH and conductivity were measured in the field. Separate samples were collected for the analyses of major ions, heavy metals and nitrates. Samples were also collected from wells for bacteriological analysis. A computer program WTEQP and GWW were used for geochemical calculations and graphical presentation of chemical analyses.

Environmental setting

Geology

Saint Katherine area is occupied entirely by granitic and volcanic rocks (Fig. 2) which are invaded by a few numbers of acidic and basic dykes. The acidic dykes are resistant to weathering and usually form positive relief features. Acidic dykes of nearly N-S direction create good reservoirs in which Haroun and Zitona wells were dug. The basic dykes are found and dominate the fault zones oriented NNW-SSE. These dykes act as dams that collect water, when intruded in the sheared medium-grained alkali feldspar granites (El Shamy, et al., 1989). Several NW-SE and NE-SW dykes dissect W. El Sheikh and W.El Raha were reported by El Shazly et al., (1985). The area is generally affected by three main sets of faults and joints, they have three main trends namely, N-S, NNW-SSE and NE-SW. The joints are mostly vertical or steeply dipping, their lengths range between 60 cm and 3.6 Km with space interval of 20 to 80 cm (El Shamy, et al., 1989). Such structural features permit the accumulation and movements of groundwater.

The bed rocks in W. Feiran consist of granite, granodiorite and gneiss (Issar and Eckstein, 1969). Lacustrine deposits assigned to Plio-Pleistocene age have been reported in W. Feiran. It consists of laminated and massive marls, sandy marls graded bedded sandstone, silt and clay intercalated with gravel (Abdel Wahab, H. et al., 1997).

The Quaternary sediments exist as wadi fillings along the course of W. Feiran and their tributaries. It is composed of pebbles, cobbles, graveles, sand and silt. Its thickness varies from place to place, ranging between 30 and 100 m depends mainly on the configuration of the basement surface (El Shamy and El Rayes,(1992).

Hydrogeology

Two aquifer systems exists at St. Katherine-Feiran oasis areas namely, the basement rocks and the Quaternary aquifers. The basement rocks are highly jointed, faulted and fractured and invaded by acidic and basic dykes. These structural features permit the accumulation and movement of groundwater. The Quaternary aquifer exists along the main wadi, its thickness varies from place to place, ranging between 30 and 100 m depending on the surface of the basement rocks. The accumulation of groundwater within this aquifer depends on the presence of dykes crossing the main wadi. At Feiran oasis the main wadi is characterized by several meanders and growing of the Palm Groves. These factors reduce the velocity of surface runoff during floods, consequently increases the rate of infiltration and aquifer recharge.

El shazly et al., (1985) pointed that the wells in W. El Sheikh and W. El Raha show limited production of water. Continuos decline in the water level and daily production of Haroun and Zitona wells were recorded by El Shamy et al., (1989), they attributed this conditions to over pumping to cover the increasing demand for water. Desert Research Institute measured the depths to water during 1981 for Zitona and El-Watia wells to be 43 and 30 m, respectively. Recently, (1998) the depths to water at Zitona and El Watia wells were recorded by the Author to be 44 and 36 m, respectively. The increases in depth to water indicate that the aquifer is subjected to a continuous intensive exploitation.

Urban development can radically change the distribution of groundwater recharge. New sources of recharge are developed, including septic tanks and intensive irrigation of domestic gardens. The quantity of recharge depends up on different factors among them the density of urban development, and the amount of water imported from external sources i.e. the groundwater is transported from El Watia well to Katherine city. Reduction of groundwater withdrawal is recommended to avoid the deficit in water supply and deterioration in water quality.

Groundwater pollution problems

Hydrochemical composition

The plotting of the chemical analyses (Table 1) on Schoeller's diagram (Fig. 3) indicate the presence of two distinct hydrochemical composition, one of them characterize the water samples collected from the populous areas and the other represent the non-populous areas. The hydrochemical compositions of water samples collected from the populous areas are characterized by high ionic concentrations, dominance of chloride and sulphate ions and low bicarbonate content. Among the cationic concentrations, calcium ion prevails and followed by sodium ions. The hydrochemical composition reflects the mixing processes of meteoric water with sewage water that seeps from septic tanks, where the ionic concentrations (EPM) of both potassium and sodium is lesser than chloride r(K+Na)/rCl <1 similar to normal sea water. The hydrochemical parameters rCl- r (K+Na)/rMg <1 and rCl- r(K+Na)/rMg >1 reflects the presence of Mg Cl_2 and Ca Cl_2 water types. Two assemblages of salt combinations are found (Table 2), these are:

Kcl, NaCl, $MgCl_2$, Mg SO_4, Ca SO_4 and Ca $(HCO_3)_2$

Kcl, NaCl, $MgCl_2$, $CaCl_2$, Ca SO_4 and Ca $(HCO_3)_2$

It is worth to mention that these salts are similar to that of sea water and old marine water.

On the other hand, the hydrochemical compositions of water samples collected from non-populous areas are characterized by low ionic concentrations (<3 EPM), low concentrations of sulphate and Chloride ions and high bicarbonate content (Fig. 3). Among the cationic concentrations, calcium ion prevails and followed by sodium ions. The hydrochemical composition reflects meteoric water genesis, where the ionic concentrations (EPM) of both potassium and sodium is greater than chloride r(K+Na)/rCl >1. The hydrochemical parameters r(K+Na)- rCl/rSO_4 <1 and r(K+Na)- rCl/rSO_4 >1 reflects the presence of $Na_2 SO_4$ and Na HCO_3 water types. Two assemblages of salt combinations are found (Table 2), these are:

Kcl, NaCl, $Na_2 SO_4$, Mg SO_4, $Mg(HCO3)_2$ or Ca SO_4 and $Ca(HCO_3)_2$

Kcl, NaCl, $Na_2 SO_4$, Na HCO_3, $Mg(HCO3)_2$ and $Ca(HCO_3)_2$

Major ions

Groundwater is found to be fresh, where TDS <1000 PPM (Table 1) exceptionally some wells (6, 9,11). However, undesirable levels of Chloride and Sulphate ions were above the recommended levels (250 PPM) given by WHO, (1984). Figure (4) show a general increase in Chloride with increasing in Sulphate concentrations up to 2 and 3.5 EPM, respectively, although there is a notable amount of scatter around the trend. Increases in concentrations within these ranges potentially represent changes due to geochemical reactions occurring along the flow path. The groundwater samples that lie significantly off the trend represent a water composition that has been influenced by unique local effects. The chloride ion is a conservative parameter. The elevated chloride concentrations in the evolved water may be indicative of evaporative effects within local flow system controlled by local topography or mixing from higher chloride water. The elevated sulphate concentrations in groundwater are attributed to the oxidation of organic and inorganic sulphide in soil profile.

The relative enrichment of calcium over other metals in groundwater from basement rocks has been attributed to the higher susceptibility of ca-bearing minerals to hydrolytic weathering processes (Acworth, 1987; Jons, 1985).

Trace metals

The results of trace element analyses of groundwater samples are presented in table (1). Generally, copper and zinc concentrations are below the recommended limits (<0.05 and 5 PPM, respectively) given by WHO, (1984). Lead concentrations in 9 water samples are higher than the WHO guideline of <0.1 PPM, these water samples are located within populous areas. The levels of manganese were found below the excessive limits(0.5) given by WHO, (1984), exceptionally, higher concentrations are noted in two water samples(22&23) in Feiran oasis.

Nitrate

Nitrate is generally the contaminant of most concern in urban areas, because of its widespread distribution and its adverse impact on groundwater resources. High nitrate concentrations in groundwater in urban areas have been associated with widespread fertilizers use and leaks from septic tanks (Appleyard and Bawden, 1987, Attwood and Barber, 1989 and Gerritse et al., 1990). Nitrate originates in the subsurface through the microbial degradation of organic nitrogenous material including human and animal wastes as well as fertilizers and plant refuse (Taylor, R. G. and Howard, W. F., 1994). Nitrate-N concentrations in groundwater samples that located in urban areas are greater than 1 PPM and are probably associated with widespread fertilizer use on domestic gardens and seepage from septic tanks. On the other hand, its content in groundwater in non-urban area is less than 1 PPM. Nitrate-N levels in water samples are lesser than the recommended limits (10 PPM) given by WHO, (1984).

Bacteriological studies

Safe water is essential for good health of human. Contamination of groundwater with fecal material is common in areas with poor sanitation, therefore the determination of microbiological quality of water is essential.

The Coliform group of bacteria and Escherichia Coli (E. Coli) in particular are one of the most frequently used indicators of bacterial contamination but are themselves harmless or non-pathogenic. E. Coli groupe are present in large numbers in the intestine and faces of animals. If E. Coli are present then it is possible that the less numerous pathogenic or harmful bacteria, are also present (Hamill and Bell, 1986). Coliform bacteria may be persistent in groundwater and residence times up to 120 days have been recorded (Matthess, 1982). Hoxley and Dudding(1994) indicate that the bacteria can travel more than 500 m from contamination source. The total bacterial counts will indicate a change in the condition of water source, but it does not differentiate between harmless and potentially dangerous bacteria (Geldreich, 1971). The results in table (1) show that only 11 wells are free of total Coliform, these wells are located outside the populated areas. The other wells showed varied densities of total The recommended limits given by WHO, (1984) were 10 MPN/100 ml. E. Coli type was found in 15 of examined water samples `(Table 1), this type should not be present in drinking water (WHO, 1984). The presence of such bacteria affirms the presence of fecal pollution. Accordingly, the groundwater in populous areas should chemically treat before drinking.

Conclusions

Environmental impacts include both human activities and natural phenomena, but human activities could impair groundwater quality and contribute to maximum damage through over-exploitation and irrational use. Urban development can radically change the distribution of groundwater recharge. New sources of recharge are developed, including septic tanks and intensive irrigation of domestic gardens. The quantity of recharge depends up on the density of urban development, and the amount of water imported from external sources for example the groundwater is imported from El Watia well to Katherine city. The increases in depths to water of both Zitona and El Watia wells indicate that the aquifer is subjected to a continuous intensive exploitation.

The hydrochemical compositions of water samples collected from the populous areas are characterized by high ionic concentrations, dominance of chloride and sulphate ions and low bicarbonate content. However, undesirable levels of Chloride and Sulphate ions were above the recommended levels. The elevated chloride concentrations in water may be indicative of mixing from higher chloride water, while elevated sulphate concentrations are attributed to the oxidation of organic and inorganic sulphide in soil profile. The hydrochemical compositions indicate the mixing processes of meteoric water with sewage water, where $r(K+Na)/rCl < 1$. The hydrochemical parameter reflects the presence of $Mg\,Cl_2$ and $Ca\,Cl_2$ water types, both characterize marine water genesis. On the other hand, the hydrochemical compositions of groundwater samples collected from non-populous areas are characterized by low ionic concentrations, low concentrations of sulphate and chloride ions and high bicarbonate content. The hydrochemical composition reflects meteoric water genesis, where $r(K+Na)/rCl > 1$. The hydrochemical parameters reflect the presence of $Na_2\,SO_4$ and $Na\,HCO_3$ water types of meteoric origin. Nitrate-N concentrations are significantly higher in urban area (>1 PPM) than the non-urban sites, this is attributed to the microbial degradation of organic nitrogenous material including human and animal wastes as well as fertilizers used in domestic gardens. High concentrations of trace metals are noted in groundwater at dense populated areas. The results of bacteriological analyses show that only 11 wells are free of total Coliform and E. Coli type, these wells are located outside the populated areas. These types of bacteria should not be present in drinking water (WHO, 1984). The presence of such bacteria affirms the presence of faecal pollution.

Recommendations

1-Reduction of groundwater withdrawal is recommended to avoid the deficit in water supply and deterioration in water quality.

2-The groundwater in populous areas should chemically treat before drinking.

3-Human activities in the recharge area should be compatible with maintaining good groundwater quality. Protection of aquifer must include monitoring sewage throughout recharge area.

4-Most wells are situated between houses, not sealed and opened to faecal and other contamination from varieties of sources, therefore careful well location is recommended.

5- Introducing restrictions on the use of fertilizer in aquifer recharge area.

6-The sealing of all unused and unprotected wells is a priority to prevent continued contamination of groundwater.

7 -Construction of proper sewer system is a must.

8-It is vital that a groundwater quality monitoring program be established as a matter of priority.

9-Control of land use changes (urbanization and population extension) within the catchement area.

References

Abdel Wahab, H. Sh., and Keddy, Y., and Giegen, R., (1997): Mineralogy and geochemistry of the Pleistocene lacustrine beds in W. Feiran, S. Sinai, Egypt: Implications for environmental and climate changes. Egypt J. Geol., vol., 41 /2A: pp. 145-171.

Appleyard, S. J., and Bawden (1987): The effects of urbanization on nutrient levels in the unconfined aquifer underlying Perth, Western Australia: Proc. International Conf. on groundwater system under stress, Brisbane, pp. 587-594.

Attwood, D. F., and Barber (1989): The effects of Perth urbanization on groundwater quality- a comparison with case histories in the USA: Proc. Swan Coastal plain management Conf. Perth, 1988, Western Australia: Water Resources Council Publication, p. 177-190.

Conoco, (1987): Geological map of Egypt, South Sinai. scale 1: 500,000, The Egyptian General Petroleum Corporation.

Desert Research Institute, (1981): Agricultural and water investigations of Sinai. Internal report. part 4, Geology, pp 135.

El-Shamy, I. Z., El-Ghawaby, M. A. and El-Rayes, A. E., (1989): Geologic factors affecting groundwater occurrences in the basement rocks of St. Katherine area, S. Sinai, Egypt. Proc. 2nd Conf. Geol. Sinai Develop. Ismailia, pp. 27-32.

El-Shamy, I. Z., and El-Rayes, A. E., (1992): Hydrogeologic assessment of St. Katherine area, S. Sinai, Egypt. Proc. 3rd Conf. Geol. Sinai Develop. Ismailia, pp. 71-76.

El-Shazly, M. M., Mohamed, S. S., Abd Al-latif, T. A.,(1985): Groundwater potential St. Katherine Monastery environs, Sinai, Egypt. Egypt J. Geol. 29, pp. 89-100.

El-Shendi, E. A., (1989): New approach for locating promising well sites in St. Katherine and surroundings, S. Sinai, Egypt. Proc. 2nd Conf. Geol. Sinai Develop. Ismailia, pp. 97-102.

Geldreich, E. E., (1971): Microbiology- General, J. Water Pollut. Control Fed. 43, pp. 1202-1217.

Gerritse, R. G., Barber, C. and Adendy, J. A.,(1990): The impact of residential urban area on groundwater quality: Swan Coastal plain, Western Australia: Australia CSIRO Water Resource Report no. 3, 27 p.

Hamill, L., and Bell, F. G., (1986): Groundwater resource development, British Library, ISBN 0-408-01 409-1, 344 p.

Hoxely, G., and Dudding, M., (1994): Groundwater contamination by septic tank effluent: two case studies in Victoria, Australia: Proc., xxv Congress international Assoc. of hydrogeologiste, Adelaide, v. 1. pp. 145-152.

Issar, A., and Eckstein, Y., (1969): The lacustrine beds of W. Feiran, Sinai: Their origin and significance. Israel, 1. Earth Sci., 18, 21-27.

Matthess, G.,(1982): The properties of groundwater: New York, John Wiley& Sons, 406 p.

Taylor, R. G., and Howard, K. W. F., (1994): Groundwater quality in rural Uganda: hydrochemical considerations for the development of aquifers within the basement complex of Africa. Groundwater quality Edited by H. Nash and G. J. H. McCall. Published in 1994 by Chapman & Hall. ISBN 0 412 58620 7.

World Health Organization, (1984): Guidelines for drinking water. Quality, vol. 1. Recommendations. World Health Organization, Geneva, 130 pp.

بسم الله الرحمن الرحيم

التأثير البيئي على المياه الجوفية في منطقة سانت كاترين وواحة فيران.–جنوب سيناء–مصر

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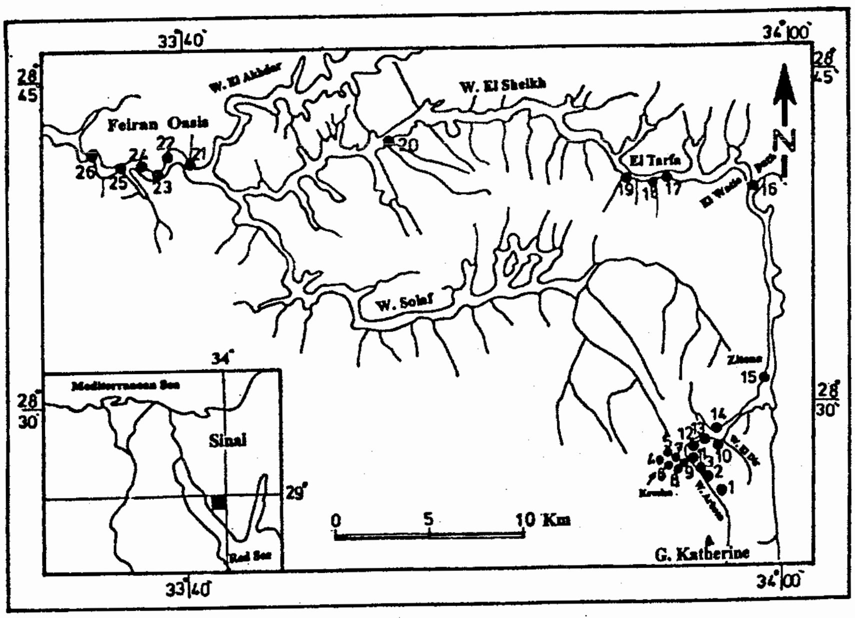
تلعب المياه الجوفية دورا حيويا لتلبية الاحتياجات المائية المتزايدة لمنطقة سانت كاترين وواحة فيران ولذلك فان التنمية الدائمة للمياه الجوفية والحفاظ عليها من التلوث يجب أن تكون من أهم الأولويات. في السنوات القليلة الماضية ذادت الكثافة السكانية فى هذه المناطق وقد اثر ذلك على المياه الجوفية كما ونوعا.

يهدف هذا البحث إلي دراسة تأثير العوامل البيئية على المياه الجوفية ولهذا السبب فقد تم عمل قياسات حقليه لمناسيب المياه الجوفية وجمع العينات لتحليلها كيميائيا وبكتريولوجيا وقد دلت قياسات مناسيب المياه الجوفية على وجود نقص مستمر لهذه المناسيب وينتج ذلك من الضخ الزائد لتلبية الاحتياجات المتزايدة للمياه. وتعتمد تغذية الخزانات الجوفية في تلك المناطق على مياه الأمطار أثناء السيول بالأضافه إلى وجود مصادر جديده للتغذية في المناطق السكانية مثل مياه المجارى المتسربة من الخزانات الأرضية ومياه الرشح من رى الحدائق الخاصة وتعتمد كمية التغذية على الكثافة السكانية وكمية المياه المنقولة من مصادر خارج الكتلة السكنية.

وقد دلت نتائج التحاليل الكيميائية على زيادة التركيزات الآيونيه للكلوريدات والكبريتات في المناطق ذات الكثافة السكانية العالية وذلك على حساب أيون البيكربونات وقد أصبحت نسب هذه الآيونات أعلى من المسموح به عالميا في مياه الشرب. ويعزى الارتفاع فى نسب الكلوريدات الى خلط مياه المجارى الغنية بهذا الأيون مع المياه الجوفية وترجع الزيادة فى أيون الكبريتات الى أكسدة المواد العضوية والغير عضويه الموجودة فى نطاق التربة.

وقد دلت المعاملات الهيدروكيميائيه على ظهور أنواع جديده للمياه مثل $CaCl_2$و$Mg\ Cl_2$ التي تميز المياه بحرية الأصل.وقد لوحظ ارتفاع تركيز آيون النترات فى المناطق الأهله بالسكان ويرجع ذلك الى التفكك الميكروبى للمواد العضوية الموجودة فى فضلات الإنسان والحيوان وكذلك الى الاستخدام المفرط للأسمده النيتروجينيه فى الحدائق الخاصة. وقد دلت التحاليل البكتريولوجيه على ان هناك خمس عشر بئرا ملوثه بمجموعة الإشريشيا كولآى وهذه الآبار توجد داخل المناطق السكنية.وهذا يؤكد وجود تلوث بمياه المجارى. وقد انتهت الدراسة بمجموعه من التوصيات.



Figure(1) Location map of the studied area and sample sites.

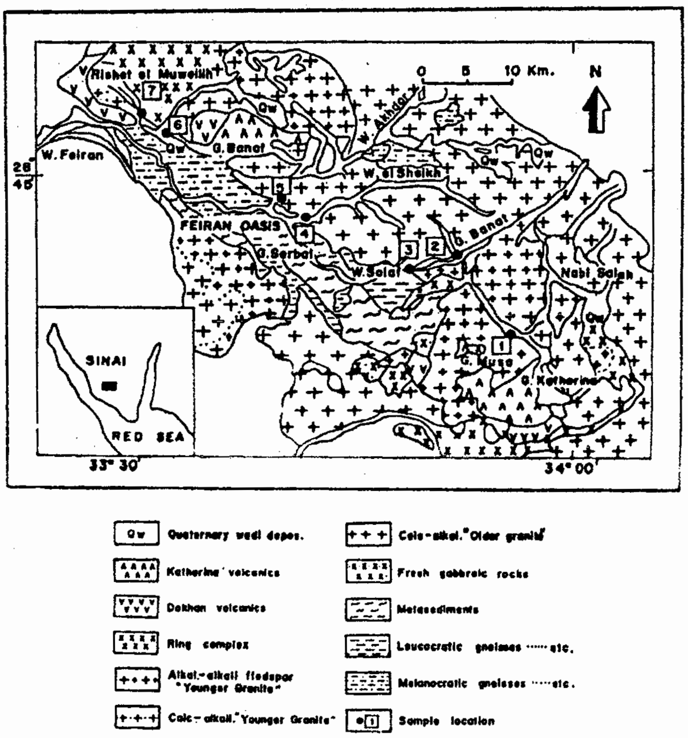
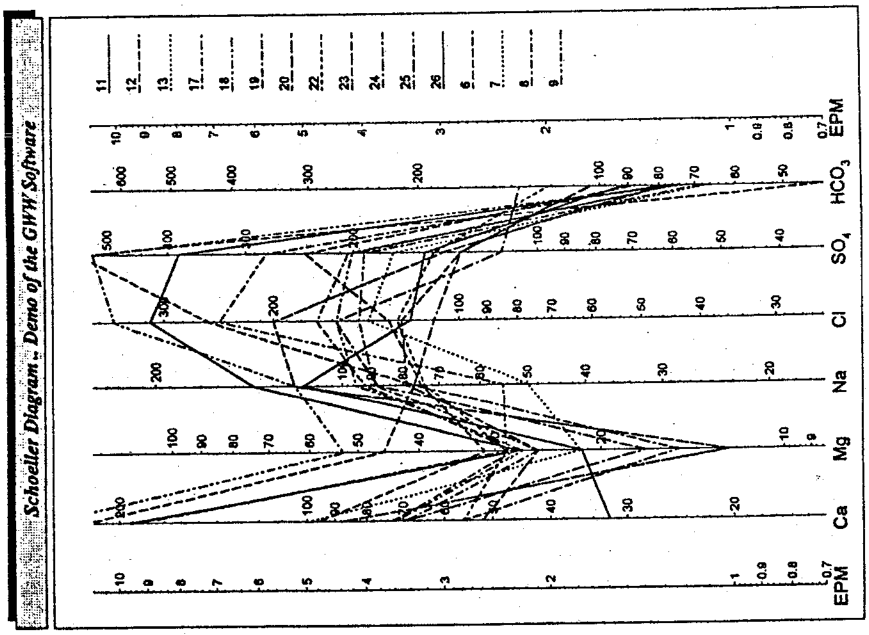
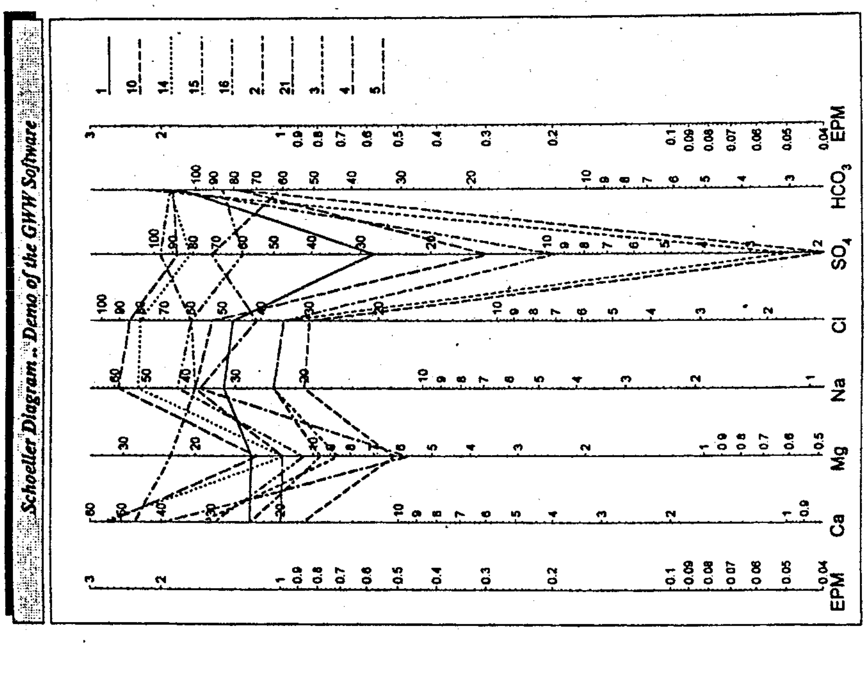
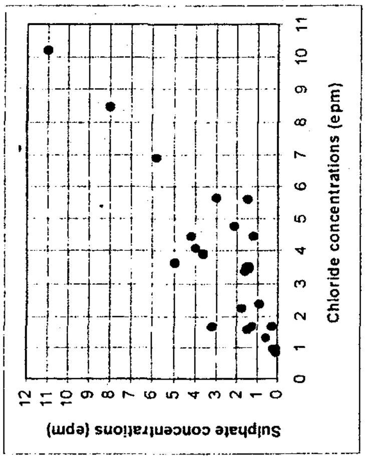


Figure (2) Geologic map of the studied area. (After Conoco, 1987)





Figure(3) Schoeller Diagram for groundwater samples presentation.



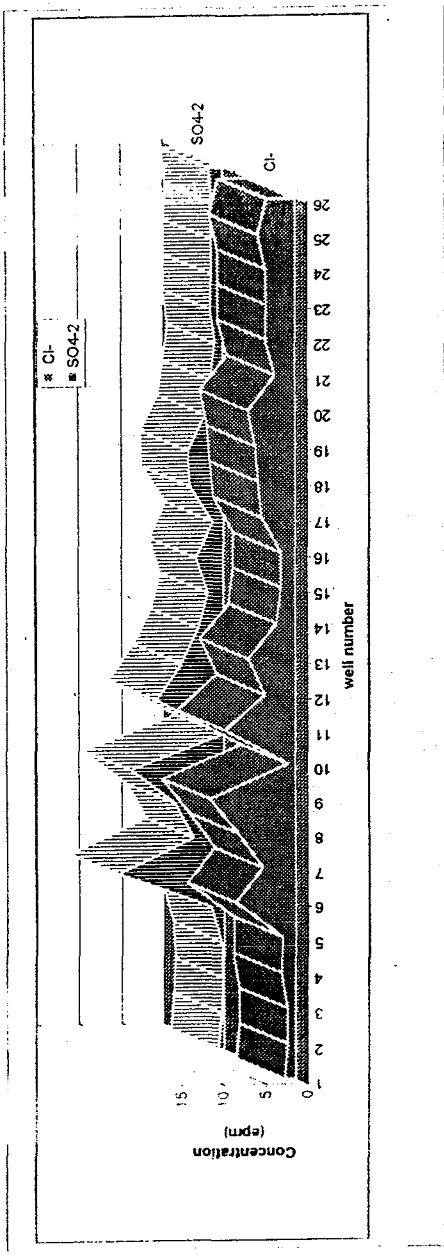


Fig.(4) Relationship between chloride and sulphate ions(epm) in groundwater samples

Table(1) Chemical and bacteriological analyses of groundwater.

well No	Location	pH	Ec'us /cm	TDS ppm	Cations (ppm)				Anins (ppm)				Trace element (				No3-N ppm	Total count/ml	Coliform 100 ml	E.Coli 100 ml
					K^+	Na^+	Mg^{+2}	Ca^{+2}	$Co3^{-2}$	HCO^{-3}	Cl^-	$SO4^{-2}$	Pb	Zn	Cu	Mn				
1	St.Kth W. Arbeen	7.3	582	208.3	3	32	14.4	24	6	109.8	47	27.86	0.08	0.01	0.01	0.17	0.031	400	nil	nil
2	St.Kth 'W. Arbeen	7.5	445	171.3	3	24	9.6	24	8.4	117.1	35	9.6	0.08	0.08	0.01	0.01	0.034	450	nil	nil
3	St.Kth W. Arbeen	7.1	391	177.2	3	24	8.64	32	6	134.2	35	2.4	0.08	0.08	0.01	0.01	0.035	455	nil	nil
4	St.Kth 'Keweiza	7.6	535	209.5	8	38	12	20	18	79.3	53	14.4	0.1	0.02	0.01	0.21	0.041	900	nil	nil
5	St. Kth'Keweiza	7.5	630	242.9	5	37	5.76	40	12	61	41	72.1	0.1	0.02	0.01	0.25		930	nil	nil
6	St.Kth 'Keweiza	7.3	1676	1181	6	77	45.6	228	6	42.7	255	552.4	0.04	0.05	0.01	0.05	3.3	1300	70	80
7	St.Kth'Keweiza	7.9	1042	534.6	5	50	21.6	100	12	67.1	140	172.9	0.09	0.02	0.05	0.04	2.1	1300	75	63
8	St.Kth 'Keweiza	7.1	1556	845.5	5	55	28.8	188	6	79.3	245	278.6	0.04	0.02	0.03	0.12	2.51	2500	58	42
9	St.Kth 'Keweiza	7.4	2550	1371	6	120	52.8	268		73.2	360	528.3	0.05	0.03	0.03	0.13	5.33	7200	230	90
10	St.Kth W. El Dir	7.6	268	119.9	1.5	20	6.24	17.6	3	80.5	30	1.9	0.01	0.01	0.01	0.02	0.04	200	nil	nil
11	St.Kth Al-Melkah	7.4	1800	1113	12	140	27.36	192	4	78.1	315	384.2	0.15	0.02	0.02	0.1	3.8	1500	90	15
12	St.Kth Al-Melkah	7.1	1016	623.2	3.5	75	31.2	96	4	87.84	130	240.2	0.15	0.04	0.02	0.12	3.3	1300	77	12
13	St.Kth Al-Melkah	7.4	990	607	5	120	12.4	88		78.1	200	144.1	0.12	0.07	0.07	0.03	2.53	1200	99	23
14	St.Kth 'Harun	7.4	670	347.8	5	52.4	12	56	6	115.9	80	81.7	0.08	0.03	0.05	0.04	0.7	700	nil	nil
15	St.Kth 'Zeitona	7.9	524	401.7	5	38	23	46.4	6	115.9	60	97	0.04	0.02	0.02	0.1	0.13	730	nil	nil
16	EL-Watia path	7.8	528	249.3	5	42	10.56	29.6		85.4	60	60.04	0.04	0.02	0.02	0.1	0.14	730	nil	nil
17	El-Tarfah	7.5	967	602	5.4	89	25.44	69.6	3	68.3	145	192.19	0.09	0.05	0.03	0.04	3.2	1150	300	9
18	El-Tarfah	7.8	946	596	6	95	27	72		75	158	201	0.09	0.07	0.04	0.04	4.5	1230	380	77
19	El-Tarfah	7.9	1150	610	6	92	28	73		75	170	204	0.1	0.06	0.05	0.05	5.6	1423	501	120
20	Sahab	7.5	1068	608	5	120	12.4	88		78.1	200	144.1	0.15	0.01	0.04	0.07	1.1	800	nil	nil
21	N. Feiran	7.8	633	361	5	54.1	14	58		114	85	88	0.05	0.04	0.03	0.05	3	900	nil	nil
22	Feiran	7.7	890	511	5	74	28.8	56	12	122	126	149	0.54	0.01	0.03	0.59	8.9	5000	900	230
23	Feiran	7.1	895	476.6	4.5	79.1	25.44	52	6	103.7	124	134.5	0.5	0.03	0.03	0.6	5.5	3200	700	180
24	Feiran	7.6	1119	463.2	5	77	15	56	9	103.4	110	134.5	0.18	0.02	0.03	0.2	3.2	2200	450	80
25	Feiran	7.7	1150	529	7	88	17	70	7	136	158	115	0.17	0.04	0.04	0.3	6.1	3000	355	60
26	Feiran	8.2	880	505.4	5	116	21.6	32	12	91.5	120	153.7	0.1	0.04	0.04	0.03	1.5	1200	165	23

All cations-anions balances are within 5 %

Table(2) Hypothetical salt combinations and hydrochemical parameters of groundwater

well	hypothetical salt combinations										r(K+Na)-rCl/	rCl-r(K+Na)
No	K Cl	Na Cl	Na SO_4	Na HCo_3	Mg Cl_2	Mg SO_4	$Mg(HCO_3)_2$	Ca Cl_2	Ca SO_4	$Ca(HCO3)_2$	rMg	/rSO4
1	2.08	33.77	2.33			13.3	17.35			31.17	0.2414	
2	2.43	26.77	4.83			1.07	24.41			36.47	0.65	
3	2.33	26.45	1.45	2.42			20.7			46.64	2.6	
4	5.39	35.15	8.11	1.21			23.45			26.68	1.167	
5	3.09	25.48	12.76			11.16			13.03	34.47	0.39	
6	0.67	17.75			16.5	2.35			58.36	4.37		0.824
7	1.43	23.93			18.29	1.34			38.44	16.57		0.93
8	0.87	20.11			15.94			12	40.52	10.56		1.599
9	0.65	22.58			18.78			3.52	49.1	5.35		1.11
10	1.74	35.06	1.73	1.04			22.17			38.26	1.5	
11	1.7	33.4			12.24	0.1			44.66	7.88		0.92
12	0.84	30.43			3.93	20.07			29.23	15.48		0.044
13	0.84	48.74			1.87			5.4	22.69	12.9		1.45
14	2.1	34.59	2.36			15.72			11.14	34.09	0.083	
15	2.17	27.5	0.58			31.67			2.52	35.69	0.045	
16	3.01	35.93	6.57			20.19			2.04	32.26	0.216	
17	1.46	40.44			1.61	20.23			22.32	12.97		0.038
18	1.49	40.93			2.71	19.29			23.1	12.42		0.077
19	1.49	39.64			5.61	17.18			24.11	11.98		0.283
20	1.2	48.51			7.14	2.34			27.9	12.9		0.284
21	1.99	37.35	1.68			17.61			10.71	30.65	0.196	
22	1.53	37.84			0.52	27.33			6.55	26.22		0.084
23	1.47	41			0.21	25.49			8.66	23.17		0.014
24	1.73	37.56	5.72			16.38			13.39	25.22	0.136	
25	2.02	43.03			2.85	12.88			12.79	26.4		0.321
26	1.52	38.4	20.66			17.03	3.67			18.7	0.559	

r means equivalent per million