Hebron University

College of Graduate Studies & Academic Research

Groundwater Quality of Springs and Dug Wells in Dura Area

By

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List of Abbreviations

Symbol	Mean
$AgNO_3$	Silver Nitrate
Apr	April
ARIJ	Applied Research Institute-Jerusalem
Aug	August
Aver	Average
D	day
Dec	December
E	East
EC	Electrical Conductivity
EDTA	Ethylendiaminetetraacetic acid
Evap	Evaporation
FC	Fecal Coliform Bacteria
Feb	February
Fig	Figure
Ft	feet
HCl	Hydrochloric acid
h	hour
Jan	January
Jul	July
Jun	June
Km	Kilometer
km^2	Square Kilometer
L	Liter
m	Meter
M^3	Cubic Meter
Mar	March
Max	Maximum
MCM	Million Cubic Meter
meq	Milliequivalent
mg	Milligram
ml	Milliliter(volume)
Mon	Month

N	North
Nov	November
ºC	Degree centigrade
Oct	October
OPT	Occupied Palestinian Territory
pH	Acidity value
RH%	Relative humidity
SAR	Sodium adsorption ratio
Sep	September
SSP	Soluble Sodium Percentage
Sun.dur	Sunshine Duration
TC	Total Count Bacteria
T.Col	Total Coliform Bacteria
Tem	Temperature
WHO	World Health Organization

Abstract

The springs and dug wells in Dura area were found to be discharging from Eocene Alluvial Aquifer, or from local perched aquifers of Allbian Lower Cenomanian Aquifer. The rock of these aquifers consists of limestone, dolomite, marl, calcareous karstic limestone and chalk. In addition, the rain was the main source of discharge the catchment in the study area. The major water type are the earth alkaline water with prevailing bicarbonate, the earth alkaline water with prevailing bicarbonate and chloride, the earth alkaline water with increased portions of alkalis with prevailing chloride or with prevailing bicarbonate are also available (PHG, 2005).

Fourty eight springs and dug wells were sampled and tested for different water quality parameters (Na^{+}, K^{+}, Mg^{+2}, Ca^{+2}, NH_4^{+}, NO_3^{-}, SO_4^{-2}, Cl^{-}, HCO_3^{-}) for two time readings the first one in April 2007 (the winter reading) when groundwater recharge from rainfall is at its peak, and the second one in October 2007 (the summer reading) when groundwater recharge is not existent, a long drought period has passed and so large amounts of water have been pumped from wells.

Five wells (Bir Abdh, Ain Abu Sief, Ain Fares, Al Sapih and Bir Musa Al Drapi) were considered suitable for drinking purposes according to WHO standards, the rest fourty three springs and dug wells were unsuitable for drinking purposes. Although all the springs and dug wells in the study were considered suitable for irrigation purposes depending on the SSP and SAR values.

Chapter one

1.1. Introduction

Water is essential to sustain life and a satisfactory (adequate, safe and accessible) supply must be available to all. Improving access to safe drinking-water can result in tangible benefits to health. Every effort should be made to achieve a drinking-water quality as safe as practicable.

The Middle East in general; and south Palestine in particular belong to the arid and semi arid areas. Such areas are characterized normally by low rainfall and high temperature and evapotranspiration. The shortage of water because of many reasons; scarcity of naturally available water resources, rapid increasing demand on these resources due to the rapid population growth and the lack of proper management of these water resources and the inefficient usage of these resources in some cases.

Study area is Dura agricultural surrounded area (10 km southern west of Hebron city). Study catchment has an area of about 112.1 Km^2 with a total population of 30000 people, within this catchment more than 70 springs and dug wells were used for drinking and other agricultural purposes. These springs and dug wells are located in different sites of Dura district; many green houses are located in some sites like Wad Abu Qamra where intensive use of fertilizers and manure takes place. A damping site for Dura municipality is located in kreesh near Ain Fares. No sewer net work exists in the study area. The water table for these dug wells range from (6-30 m) depth figure (1.3) (personal communicatios).

1.1.1. Water Resources in Palestine

Palestine is one of few countries in the world, which depends on groundwater more than surface water. Almost 100% of the Palestinian water consumption nowadays comes from groundwater.

There are two main aquifers in Palestine:

1.1.1.1. Coastal Aquifer

Extends along the coast of the Mediterranean Sea from south of Haifa in the north to Al Arish in the south. The Palestinian Gaza Strip is located entirely within this aquifer.

The over pumping of the aquifer resulted in the deterioration of its water quantity, due to salt water intrusion from the sea and the up coming of salt water from underneath. The aquifer is now in critical conditions.

1.1.1.2. Mountain Aquifer

This is the main aquifer in Palestine. It covers all the West Bank. The total annual recharge of the aquifer (according to article 40 of Oslo B agreement) is 679 MCM, of which 78 MCM are brackish water (Abu Ju`ub, 2002).

This aquifer is made of three main basins:

1-Western Groundwater Basin:

This constitutes the western part of the West Bank Aquifer. It consists of two sub-basins, Nahr El Auja El-Tamaseeh and Hebron Beer Shaba that drain the lower and upper Cenmanian aquifers with a total pumpage and spring discharge ranging from 380 – 400 MCM/yr. The storage capacity of this basin is about 360 MCM/yr (Gvirtzman, 1993). 80% of the recharge area of this basin is located within the West Bank while 80% of the storage area is located within the Israeli boarders. The groundwater movement in this basin is westwards towards the coastal plain in the west. As part of this aquifer extends under Israel, it is considered as a shared basin between Israel and Palestinians. There are 35 springs within this basin with each having an average discharge of greater than 0.1 liter/ sec in the West Bank (WBWD, 1994).

The study area in this research is located in the Western basin as shown in Figure (1.1)

2-Northeastern Groundwater Basin

This consists of the Nablus-Jenin basin, its storage capacity is approximately 140 MCM/yr (Gvirtzman, 1993). Palestinians consume about 18% of its annual safe yield for both irrigation and domestic purposes.

3-Eastern Groundwater Basin

This constitutes the eastern flank of the West Bank Aquifer. Its groundwater generally flows towards the east, the available potential resource of this basin is between 100 and 150 MCM/yr (Tahal, 1990).

1.1.1.3. Aquifer Geology

The basin consists of two main strata, the Upper and Lower Cenomanian, separated by an impermeable layer of several hundred meters in thickness. The Upper Cenomanian, which is a relatively thin stratum, drains naturally eastward into a series of springs used by Palestinians. This stratum has limited storage capacity and its recharge is dependent on the rainfall of the previous season. The Lower Cenomanian on the other hand, is a deep stratum with fresh water flowing naturally from high mountain recharage areas in the east down to Jordan Valley, where it mixes with a layer of saline ground water (Shuval, 1996).

1.1.1.4. Springs

There are 527 springs in the West Bank, of which 114 have a minimum discharge rate of 0.1 liter/sec. Usually there are fluctuations in the yield of some of these springs in the different years, depending on the rainfall quantities, and thus the recharge to the groundwater. However, their average annual yield is estimated to be around 60.8 MCM /yr. Most of the water quantities from springs are used for irrigation, while only around 1.6 MCM /yr are used for domestic consumption for the time being (Nasser Eddin and Nuseiba, 1995). The groundwater basins are shown in figure (1.1)

1.1.2. Water Situation

Water has historically played a significant role in shaping the hydrogeopolitical boundaries in the Middle East (El-Fadel et. al., 2001). The available water resources in the Middle East are scare, limited, fragile and threatened. They are already exploited especially in Palestine. Palestine is experiencing a sever water crisis caused mainly by the lack of control over the Palestinian water resources. The water resources are limited in absolute terms. The average per capita availability is extremely low, a large proportion of the water resources in the Middle East in general, and in Palestine in particular, are transboundary and final arrangements on water resources allocation between Palestinians and Israelis are not yet in place for "fair and equitable apportionment".(Abu Zahra, 2000).

The dispute between Israelis and Palestinian over shared water resources of the Mountain Aquifer is one potential obstacle in the path of the peace in the Middle East. This aquifer is the only source of water for Palestinians in the West Bank (El-Fadel et. al., 2001).

Fig. (1.1)Map of Water Sources in the Region (Adapted from "Water and War in the Middle East," Info Paper No. 5, July 1996)

1.1.3. Groundwater in the West Bank

Groundwater from the West Bank Aquifer System has been used for domestic and irrigation purposes both by the Palestinian in the West Bank. However, following the 1967-war, Palestinians were prevented from developing their utilization of groundwater in the West Bank. A series of Military Orders put all water resources in the newly Occupied Palestinian Territory (OPT) under Israeli control. Military Order No.2 (June 7th, 1967) declared all water resources in the OPT to be "Israeli State Property". Consequently, three subsequent Military Orders in 1967 and 1968 granted full control to the military authority designated an officer to be appointed by the Israeli Military Commander for implementation of the orders. These Military Orders established a permit system to prevent the Palestinians from drilling new wells, fixing pumping quotas, and declaring all prior settlements of water disputes to be invalid. (UNEP, 2003, Diabes, 2003, Israeli Military Orders No. 92, 158, 291)

1.1.4. Water Supply and Demand

In the West Bank the annual renewable quantities of groundwater in the Western, Northeastern, and Eastern basins in addition to springs are estimated at 691-811MCM/year. Out of that only143MCM/year are accessible for the Palestinian in the West Bank due to the political situation (IUGG, 2003).

According to the 2005-Israeli Water Commission's data, approximately 4 million Palestinian inhabitants in the Occupied Palestinian Territory (OPT) utilized only about 323 MCM/yr of their water resources, with their domestic, industrial and agriculture needs. For comparison approximately 7 million Israelis utilized about 2009 MCM/yr. On a per-capita basis and according to the Israeli Water Commission, water consumption by the Palestinian is 83 m^3/yr compared to about 277m^3/yr for Israelis. In other words, the per-capita consumption in Israel is 4 to5 times higher than the Palestinian per-capita in the OPT (Arij, 2007).

1.1.5. Groundwater Quality

Many studies have investigated the effect of septic tanks on the water quality of the shallow local aquifer system, taking the springs of the village of Sinjil as an example (Abdul-Jaber, 1994). (Abdul-Jaber, 1995) evaluated the chemistry of some springs and groundwater wells from the central and northern parts of the West Bank; He showed that there are four water types represented in the West Bank. The most abundant type is the earth alkaline with prevailing bicarbonate, followed by the earth alkaline with increased portions of alkalis and prevailing bicarbonate, then the earth alkaline water with increased portions alkalis and prevailing chloride and lastly the alkaline water with prevailing chloride. Studied the effect of contamination from wastewater on the shallow perched aquifer systems in the northern West Bank concluded that most of the springs and wells within the heavily populated areas were probably contaminated with wastewater through the infiltration from septic tanks and open conduit of row sewage (Abdul-Jaber et. al., 1997).

(Abed Rabbo et. al., 1997) reported that the water of the many springs and dug wells through the West Bank were polluted chemically and biologically.

(Qannam, 1997) classified and evaluated the water of the major springs and wells in the southern part of the West Bank, south of Jerusalem, for both drinking and irrigation purposes and highlighted the main environmental water hyphen related issues. The study showed that most of the water samples were found to be over saturated with respect to calcite, aragonite, dolomite and chalcedony, while under saturated with respect to gypsum and magnesite mineral phases. Only deep wells were found to be free of coliform bacteria. The water of a few springs exceeds the WHO guidelines for nitrate. The water of all the springs is good for irrigation.

(Scarpa et. al., 1998) introduced the results of a chemical and biological study of the wells extracting water from the unconfined aquifer system in northern West Bank. The excessive use of fertilizers, wide distribution of cesspits and uncontrolled disposal of wastewater were considered probable sources of the wide spread of biological contamination and the alarming nitrate, chloride and potassium levels that were found in many of the wells studied.

Septic systems can contaminate ground water with dissolved solids, nitrate, anoxic constituents (manganese, iron and hydrogen sulfide), organic compounds, and microorganisms. Lot size is a critical factor in determining the amount of natural attenuation that occurs between the location where septic effluents enter the aquifer, and the nearest down-gradient point of ground-water withdrawal and, thus, the potential for water-well contamination. There is a widespread misperception that nitrate is a universal indicator of ground-water contamination by sewage (McQuillan, 2004). Septic systems have caused regional nitrate contamination in many areas, but only in oxic aquifers. In anoxic conditions, the ammonia in sewage may not undergo nitrification, and ground-water nitrate contamination typically does not occur. Anoxic aquifers, however, are also vulnerable to chemical contamination from sewage. Microbial biodegradation of the organic matter added by septic effluent can change the chemistry of the aquifer, and cause increased amounts of manganese and iron to dissolve into the ground water from soil and rock. Chloride and stable isotopes are used to geochemically fingerprint the impacts of septic systems versus other sources of ground-water contamination. Chloride is a useful indicator parameter for septic-system impacts because it is a non-reactive solute that occurs in all sewage, and is not subject to adsorption, ion exchange, or redox reactions (McQuillan, 2004).

According to (Scarpa, 2000) springs discharging to the Mediterranean Sea drainage systems are contaminated with bacteria, some dangerously. Chemical pollutants were also observed in many of the springs. There are some rain-fed cisterns, but these too are often contaminated.

(PHG-Palestinian Hydrology Group, 2005) They found that the nitrate in 44% of the springs and wells tested exceeds the acceptable standard levels. They found that the high pollution of nitrate and chloride was as a result of sewage, fertilizers and manure contamination.The springs and dug wells water was dominated by the normal earth alkaline water with prevailing bicarbonate, chloride or sulfate. The study shows that nitrate is increasing during the last six years; also the majority of the springs and dug wells water is oversaturated with respect to aragonite, calcite and dolomite.

1.2. Geology

1.2.1. Regional Setting

Palestine is located on the northwestern part of the Arabian Shield. During its history, this shield separated from the great Afro-Arabian shield along the Red-Sea line. A branch of this breakage extended along the line of Aqaba, Wadi A'raba, the Dead Sea and the Jordan Valley, and continued northwards to Lebanon, Syria and Turkey. The West Bank of Jordan occupies the western part of this branch, known as the Jordan Rift Valley (Rofe and Raffety 1965, 1963).

The stratigraphy of the study area ranges between Lower Beit Kahel and Alluvium Formations which extend by the age from Lower Cenomanian to the end of Recent age (Abed and Wishahi, 1999). The characteristifcs of these geological formations in the area are as follows:

1.2.1.1. Lower Beit Kahel Formation

This Formation consists hard crystalline mottled dolomitic limestone with some shales of chalk. The presence of well jointed dolomitic limestone made this Formation to be a good aquifer. The thickness of this formation ranges between 92 and 180 m (Baida and Zukerman, 1992).

1.2.1.2. Upper Biet Kahel Formation

This formation related to the upper part of the Lower Cenomanian. It consists of limestone, marl, chalky limestone and dolomite with a total thickness of 110-250 m (ARIJ, 1997).

1.2.1.3. Yatta Formation

This formation consists of yellowish-gray chalky marl, limestone, dolomite and interbeded chalk. It is considered to be an aquiclude. The thickness of this formation ranges between 140 – 200 m (Rofe and Raffety, 1963).

1.2.1.4. Hebron Formation

It is regarded as equivalent to the upper part of Middle Cenomanian. It consists of dolomitic limestone and hard dolomite at the base, dolomite and chalky limestone in the middle, and dolomitic limestone at the top. The formation is extremely well jointed and karstified, therefore, it is considered as an excellent aquifer. The thickness of this formation range between 130- 260 m (ARIJ, 1997).

1.2.1.5. Bethlehem Formation

This formation is a part of upper Cenomanian. The upper part of this formation is a good aquifer as a result of a highly jointed and fractured hard dolomite. But the lower part is aquiclude which consists of chalk, limestone and dolomite. The thickness of the formation ranges between 30 – 150 m (ARIJ, 1997).

1.2.1.6. Jerusalem Formation

It is less variable in lithology and thickness than the other formations. Its thickness ranges between 50 – 140 m and consists of alternating well-bedded limestone and chalky limestone. Hydrogeologically this formation can be considered to be good aquifer (ARIJ, 1998).

1.2.1.7. Alluvial Deposits

These have the age of Helocene-Recent. They consist of laminated marls and muds and siliceous sand. Its thickness ranges between 0 – 20 m (ARIJ, 1995).

1.2.2. Water Discharge Systems

Springs and dug wells generally originate from two main aquifer systems in the study area:

1.2.2.1. The Lower Cenomanian Aquifer System

This system mainly composed of dolomite, limestone, marl and chalky limestone. This system feeds the springs of Set Al Room, Al Majour, Ain Abu Sief and others Figure (1.2).

1.2.2.2. The Upper Cenomanian Aquifer System

The aquifer system is mainly composed of limestone, chalky limestone and dolomite. It feeds Bir Shaheen, AlHriebat and some others Figure (1.2).

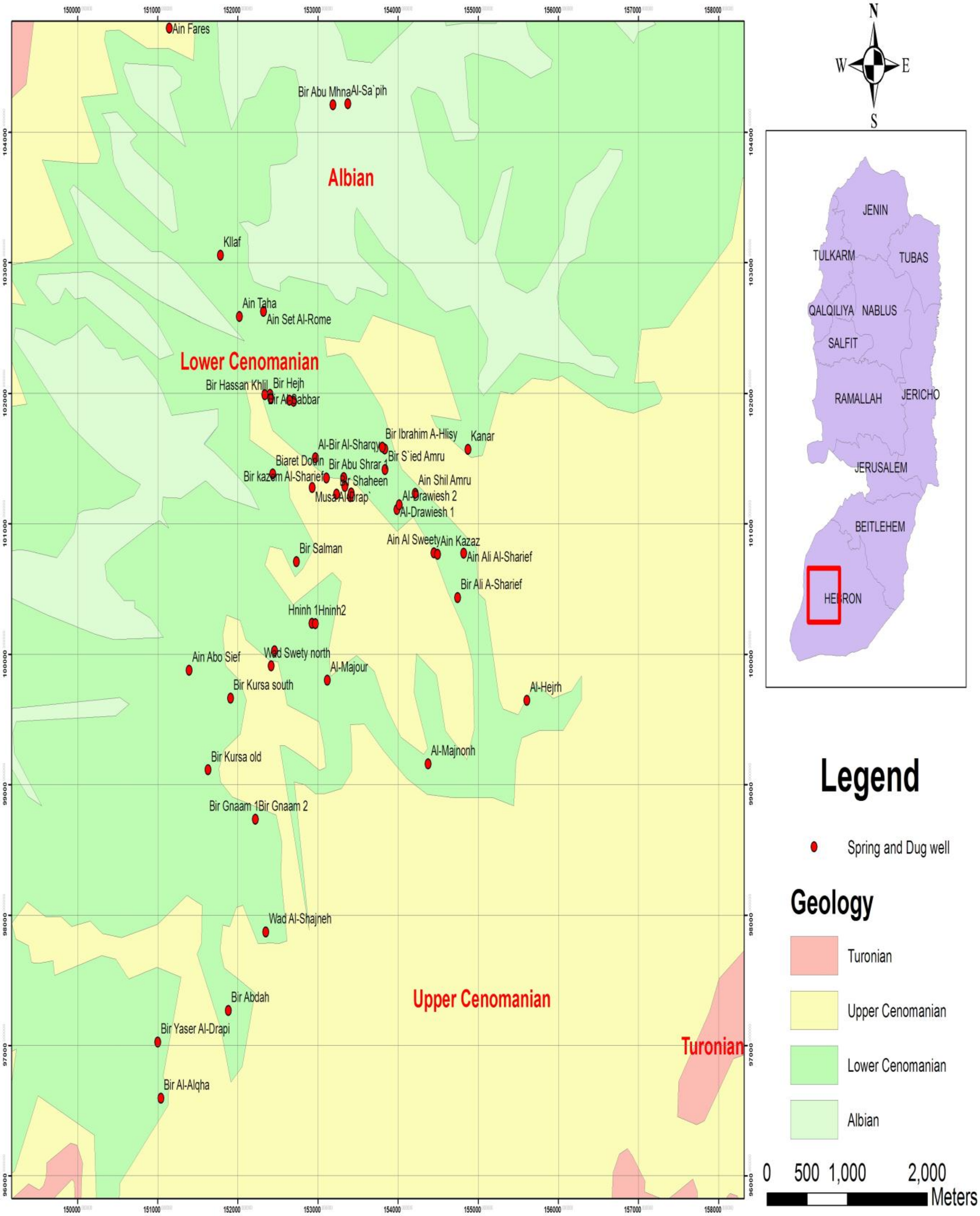


Fig. (1.2) The study area with the different geological systems.

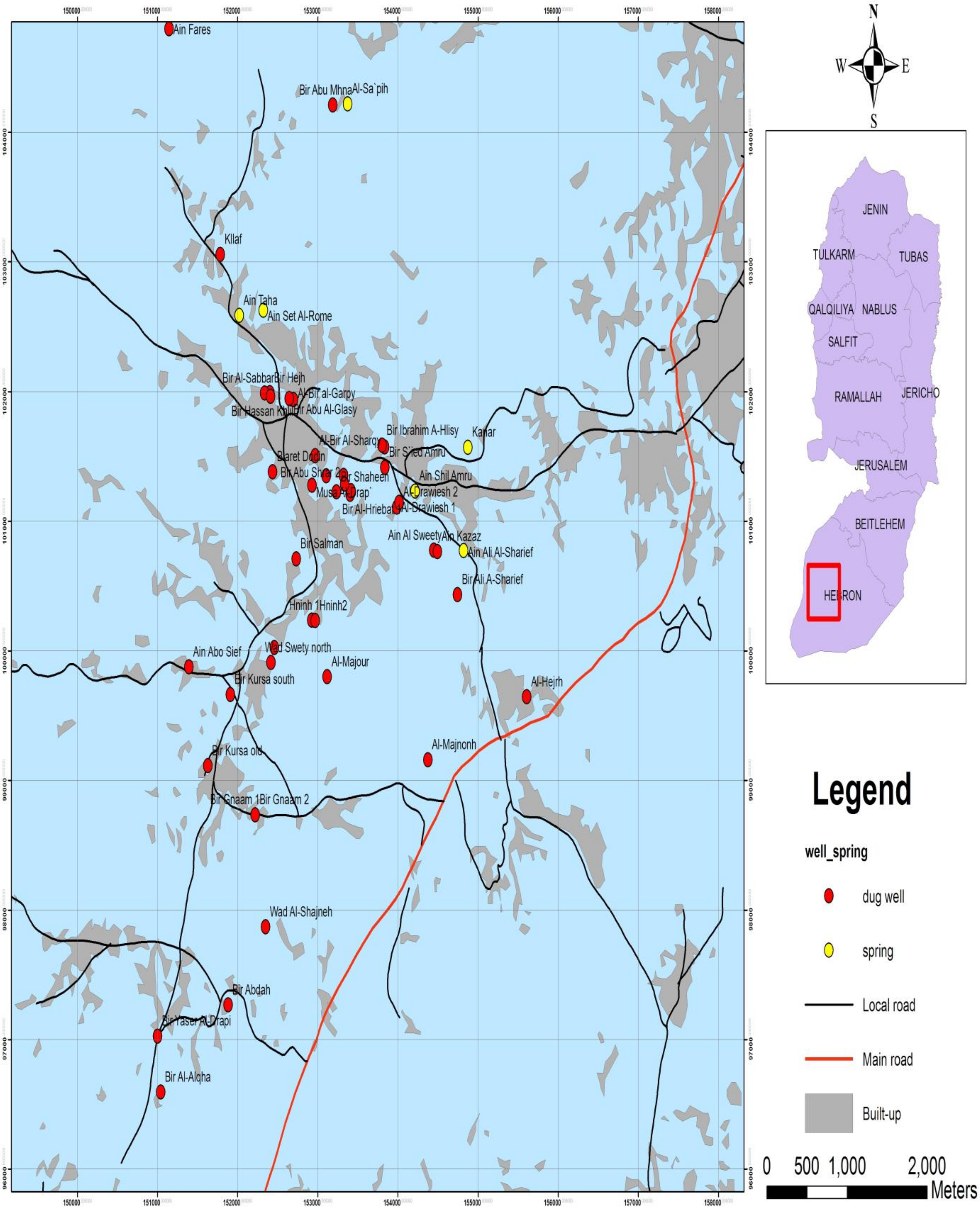


Fig. (1.3)The study area with the springs and dug wells.

1.3. Hydrology

1.3.1. Climate

The study area is highly influenced by the Mediterranean climate, which is characterized by long, hot, dry summer and short, cool, rainy winter. Rainfall is limited to the winter and spring months, mostly between November and March. Summer is completely dry. Snow and hail, although uncommon, may fall in the area especially over the highlands. The climate is influenced by the vast nearby Negev and Arabian deserts. Especially during spring and early summer, deserts storms move through with hot winds full of sands and dust (known as Khamaseen). These storms increase the temperature and decrease the humidity (ARIJ, 2007).

1.3.2. Temperature

The mean annual temperature in the study area is about 15°C; the average monthly air temperature in the study area is 8°C in winter and 26°C in summer, with a maximum average monthly temperature of 38°C and a minimum temperature of -3°C (Fig. 1.4), Table (1.1) (Hebron Claimatic Station,2007).

1.3.3. Relative Humidity

The relative humidity has an influence on people and on living organisms, especially the very low humidity experienced during the Khamaseen, the annual mean relative humidity ranges from 55%-60% (Fig. 1.5), Table(1.1) (Hebron Claimatic Station,2007). .

1.3.4. Rainfall

Dura district has a semi-arid, Mediterranean climate; the rainy season starts in October and continues to the end of April. Almost 70% of the Annual rainfall occurs between November and February. January is the highest rainfall month in the year. The average annual rainfall in the study area varies from 350 mm to 450 mm (Fig. 1.6), Table (1.1) (Hebron Claimatic Station, 2007).

1.3.5. Evapotranspiration

Potential evaporation is principally strong in summer as a result of high temperature, intensive sunshine and low humidity. Evaporation rate is relatively low during to the winter months when the solar radiation is lowest (Fig. 1.7), Table (1.1) (Hebron Claimatic Station, 2007).

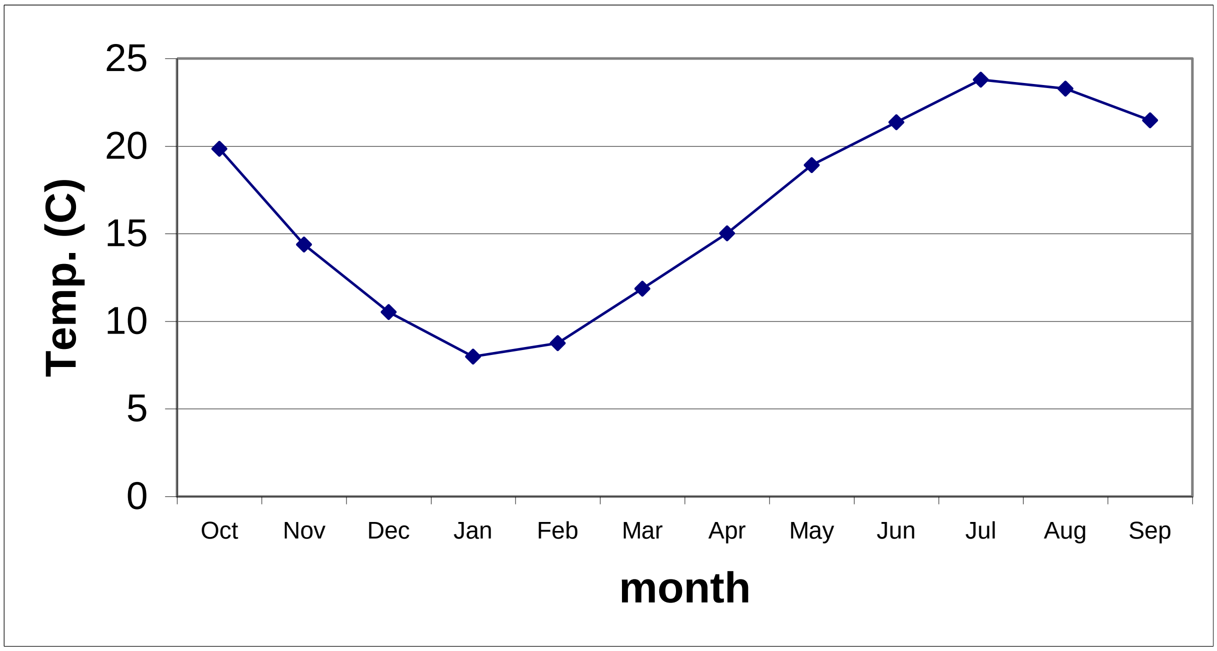


Fig. (1.4) Mean monthly temperature (◦C) in Dura district from (1970-2007) (Hebron Claimatic Station, 2007)

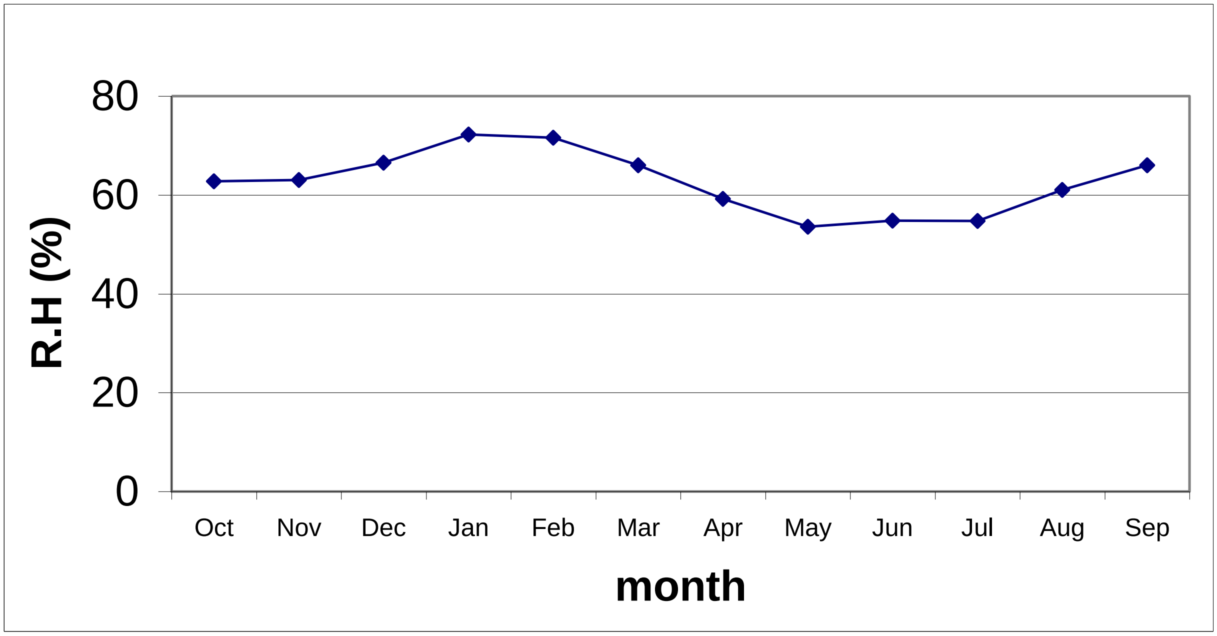


Fig. (1.5) Mean monthly Relative Humidity R.H (%) in Dura district from (1970-2007) (Hebron Claimatic Station, 2007)

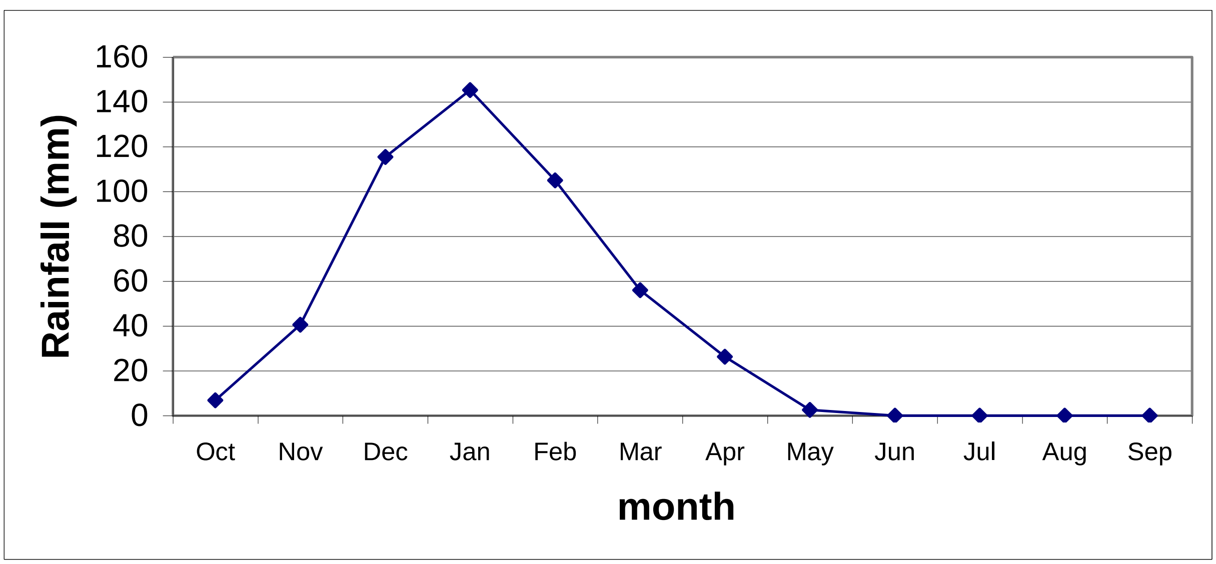


Fig. (1.6) Mean monthly rainfall (mm) in Dura district from (1970-2007) (Hebron Claimatic Station, 2007)

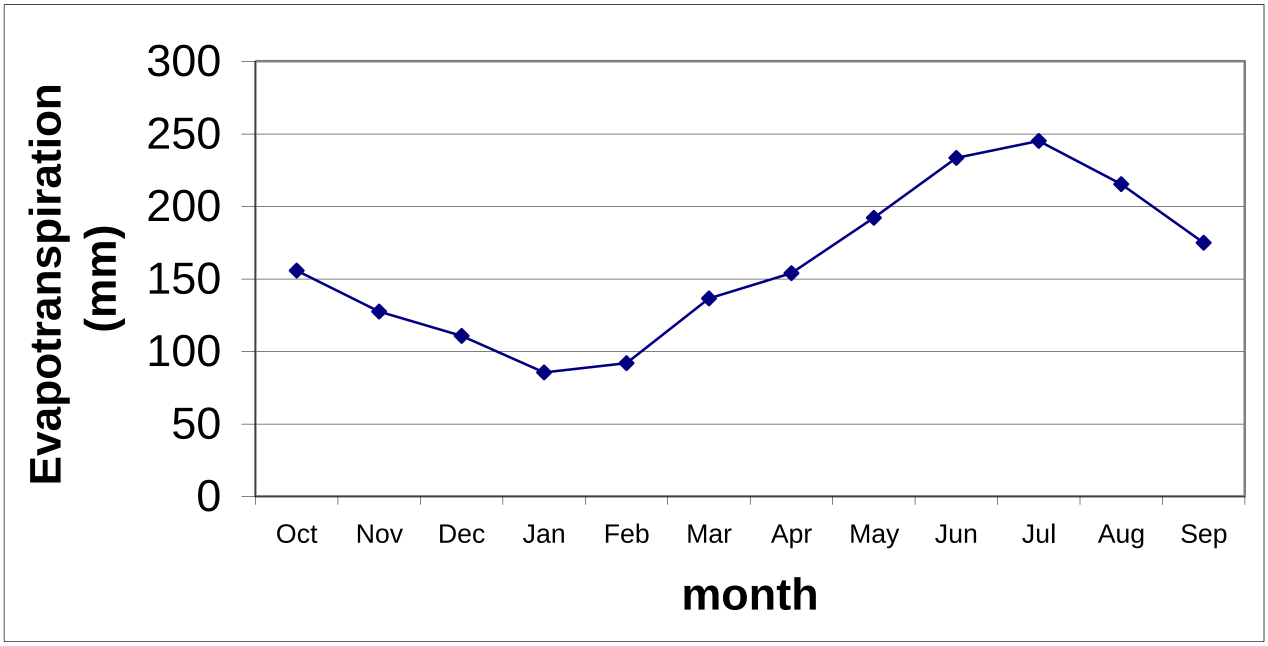


Fig. (1.7) Mean monthly evapotranpiration (mm) in Dura district from (1970-2007) (Hebron Claimatic Station, 2007)

Table (1.1): Metrological Average at the Hebron Weather Station from (1970-2007). (Palestinian Metrological Department, Hebron Station, 2008).

elements	month											
	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Mean Monthly Temp.(C)	8.0	8.8	11.9	15.0	18.9	21.4	23.8	23.3	21.5	19.9	14.4	10.5
.Mean RH. (%)	72	72	66	59	54	55	55	61	66	63	63	67
Total Rainfall (mm)	145.3	105.0	55.9	26.3	2.6	0.0	0.0	0.0	0.0	6.9	40.6	115.4
Total Evaporation (mm)	85.5	91.9	136.5	153.9	192.1	233.4	245.1	215.3	174.9	155.6	127.4	110.7

1.4. Hypothesis

The water of the springs and dug wells in the study area are contaminated chemically and biologically due to the anthropogenic activity (wastewater and agriculture). The water is contaminated with NO_3^-, Cl^-, T.Col and F.Col. The water has a poor quality. This study is designed and conducted to chech the hypothesis addressed above and to evaluate the water chemical parameters and the water quality in the study area.

The objectives of the study

- Determine the water properties (chemical, physical and biological) of the springs and dug wells in Dura area.
- Evaluate the water quality of springs and dug wells for domestic, drinking and irrigation purposes.

Chapter two: Methodology

2.1. Field work

A comprehensive sampling program including 48 springs Apendix (I) in Dura district was carried out from April, 2007 to October, 2007. The samples were collected from each spring twice, the first time in April, and the second time in October. One and half liter of water was collected in sterilized polyethylene bottles, these bottles were sterilized previously with 70% ethyl alcohol, each bottle was rinsed with water intended for sampling, then each bottle was completely filled with water sample and placed in a cold box until arrival the refrigerator in the laboratory.

The sampling in April, 2007 was to identify water quality during the spring season, when groundwater recharge from rainfall is at its peak, and the second in October, 2007 was to identify water quality for irrigation during the autumn season, when groundwater recharge is not existing after a long drought period has passed and so large amounts of water have been pumped from wells.

2.2. Laboratory work

The analysis of the water samples was conducted in the laboratory of soil and water at Hebron University.

The samples were analyzed chemically for the major cations (Ca^{+2}, Mg^{+2}, Na^{+1}, K^{+1} , NH_4^{+}) and major anions (HCO_3^{-1}, Cl^{-1}, SO_4^{-2}, NO_3^{-1}). Also the water samples were biologically analyzed for Fical Coliforem, Total Coliforem, and Total Plate Count Bacteria Table (2.1).

Table (2.1): The analysis methods were used in evaluate water samples.

Parameters	Method of analysis
EC, and pH-values	Field multi-electrode meter (Jenway model 3305)
Ca^{+2}	Titration with Na_2-EDTA using Murexide indicator, titration carried out rapidly until color change from red to blue.
Mg^{+2}	Titration withNa_2-EDTA using Eriochrome black T indicator, titration carried out rapidly until color change from red to blue.
Na^{+1}, K^{+1}	Flame photometer
SO_4^{-2}	Gravimetric method hydrochloric acid was added to water samples then the mixture was boiled then barium chloride was added and the mixture left over night then filtering through filter paper, the filter paper was transferred to a constant weight porcelain cruciblein dried using Muffel furnace.
NO_3^{-1}	Spectrophotometer method (λ=420nm): sodium salicylate was added to water samples and the mixture was evaporated to dryness then concentrated sulfuric acid, water and tartate solution were added finally the solution was placed into agraduated flask which was filledwith water, then photometric determination was made.
Cl^{-1}	Titration with $AgNO_3$ using Potassium Chromate as indicators, titration carried out rapidly until color change from greenish yellow to reddish-brown.
$HCO3^{-1}$	Titration with H_2SO_4 using Bromocresol green and phenolphthalein indicators
NH_4^{+1}	Spectrophotometer method (λ=425nm) zinc sulphat was added to 100 ml water sample, then sodium hydroxide was added until pH reach 10.5, two drops and 2 ml of Rochell salt and Nessler reagent were added respictivly, finally the aabsorbance at 425 nm.
Total Plate Count Bacteria	Using Water Plate Count Agar with 0.5 ml water sample and incubate at 36°C ± 2°C for 44 ± 4 hours
Total Coliform Bacteria	Using Violet Red Bile Agar with 0.5 ml water sample and incubate for 24 ± 2hours at 30 ± 1 °C (APHA, 1998).
Fecal Coliform Bacteria	Using m-FC Agar with 0.5 ml water sample and incubate for 24 hours at 44.5 °C ± 0.2 °C.

2.3. International Scales

2.3.1. Chemical quality evaluation

The Palestinian water Authority (2004) and the WHO (2004) put the basis for the water quality evaluation, Table (2.2), used in Palestine.

Table (2.2): The Palestinian Standards and World Health Organization (WHO) guidelines for drinking water, 2004.

Parameters	Palestinian Standards (2004)		WHO (2004)	Parameters	Palestinian Standards (2004)		WHO (2004)
	Basic	Conditional			Basic	Conditional	
T° C	8-25		12-25	Cl^- (mg/L)	250	600	250
pH-value	6.5-8.5	9.5	6.5-8.5	SO_4^{-2}(mg/L)	200	400	250
Na^+(mg/L)	200	400	200	NO_3(mg/L)	50	70	50
Ca^{+2}(mg/L)	100	200	75	TDS(mg/L)	1000	1500	500-1000
Mg^{+2} (mg/L)	100	120	<125	Hardness(mg/L)	500	500	500
K^+ (mg/L)	10	12	12	TotalColiform	0	3	0
NH_4^+ (mg/L)			1.5	FaecalColiform	0	0	0
HCO_3^- (mg/L)	125-350	125-350	125-350				

The hardness of water is defined as its content of divalent metallic ions which react with sodium soaps to produce solid soaps or scummy residue and which react with negative ions when the water is heated in boilers to produce solid boiler scales (De Zuane, 1990)

Total hardness is expressed as CaCO3 in (mg/L), which could be calculated using the equation below (Todd, 1980)

Total Hardness ($CaCO_3$ mg/L) = 2.497 Ca^{+2} + 4.115 Mg^{+2}

The concentrations of the cations are in (mg/L).

According to its hardness, Sawyer and McCarty classified the water into soft, moderately hard, hard, and very hard waters, Table (2.3).

Table (2.3): Sawyer and McCarty (1967) classification of water, based on hardness.

Hardness as $CaCO_3$ (mg/L)	Water Type
0-75	Soft
75-150	Moderately Hard
150-300	Hard
>300	Very Hard

2.3.2. Water Quality for Agriculture Purposes

Water quality and quantity, the soil type, the area, the climate, the elevation and the type of crops together decide the suitability of water for irrigation. Salts in the irrigation water could negatively affect the growth of the plants by changing the osmotic pressure in the root zone. The sodium adsorption ratio (SAR), the sodium percentage, the total dissolved solids, and the electrical conductivity are used to evaluate the quality of water for irrigation.

2.3.2.1. Sodium Adsorption Ratio (SAR)

The expression of SAR was recommended by the United States Salinity Laboratory of the Department of Agriculture (Richrd, 1954). The SAR is considered to be in direct relationship with water adsorption by the soil. It is calculated according to the equation:

$$\mathbf{SAR = Na^{+} / ((Ca^{+2} + Mg^{+2})/2)^{0.5}}$$

Where:

The concentrations of the cations are in meq/L.

A classification of irrigation water based on SAR is shown in Table (2.4).

Table (2.4): Irrigation water classification, based on SAR values (Wilcox, 1955)

Classification	SAR Range	Comment
S1	<10	Low sodium water can be used for irrigation on almost all soils with little danger
S2	10-18	Medium sodium water will present an appreciable sodium hazard in fine textured soils having high cation exchange capacity
S3	18-26	High sodium water may produce harmful levels of exchangeable sodium in most soils
S4	>26	Very high sodium water is generally unsatisfactory purposes except at low and perhaps medium salinity.

The Wilcox classification is a modification of Richard (1954), which has the same ranges of SAR but divides water into four groups: excellent, good, fair and poor.

2.3.2.2. Soluble Sodium Percentage (SSP)

Sodium concentration is an important index in the evaluation of the irrigation water as it has the influence on soil permeability. Alkaline (Na^{+}-$CO3^{-2}$) and saline (Na^{+}-Cl^{-} or Na^{+}-SO_4^{-2}) soils are not suitable for the growth of plants. Using water with high sodium concentration and high sodium ratio increases the concentration of sodium in the soil and allows the sodium to exchange the other ions in the soil particles.

The sodium content is expressed in terms of SSP, which is defined as:

$$\mathbf{SSP = ((Na^{+} + K^{+}) / (Ca^{+2} + Mg^{+2} + Na^{+} + K^{+}))*100}$$

Classification of irrigation water based on SSP and EC is shown in Table (2.5).

Table (2.5): Quality classification of irrigation water, based on SSP (Todd, 1980)

Water Class	SSP Range	EC (µS/cm)
Excellent	<20	<250
Good	20-40	250-750
Permissible	40-60	750-2000
Doubtful	60-80	2000-3000
Unsuitable	>80	>3000

2.3.2.3. Total Dissolved Solids/ Electrical Conductivity

Osmotic pressure affected by the total dissolved solids which are a function of electrical conductivity. Any change in the osmotic pressure in the root zone changes the uptake rate of water into the plant. The USSL irrigation water in groups according to EC and total dissolved solids, Table (2.6).

Table (2.6): Grouping of irrigation water, based on EC and TDS (Richard, 1954)

TDS (mg/L)	EC (µS/cm)	Water Class	Remarks
<200	<250	C1	Low salinity: can be used for irrigation with most crops on most soils.
200-500	250-750	C2	Medium salinity: can be used to irrigate plants with moderate salt tolerance if moderate amount of leaching occurs.
500-1500	750-2250	C3	High salinity: not can be used on soils with restricted drainage. Can be used to irrigate plants with high salt tolerance.
1500-3000	2250-5000	C4	Very high salinity: not suitable for irrigation under ordinary conditions. Its can be used for irrigation occasionally under very especial circumstances.

The water samples can be classified to low, medium, hard and very hard salinity by using the EC-SAR classification show in Figure (2.1).

2.3.3. Suitability of Water for Domestic and Irrigation Purposes

Water from Dura springs is used mainly for domestic and irrigation purposes, some springs are used fully for irrigation, such as Bir Gannam, Bir Shaheen, Biaret Dodin and others, some springs are used partially for irrigation, such as Bir Yasser Al Drapi, Wad Al Shajneh, Al-Sa`pih and others.

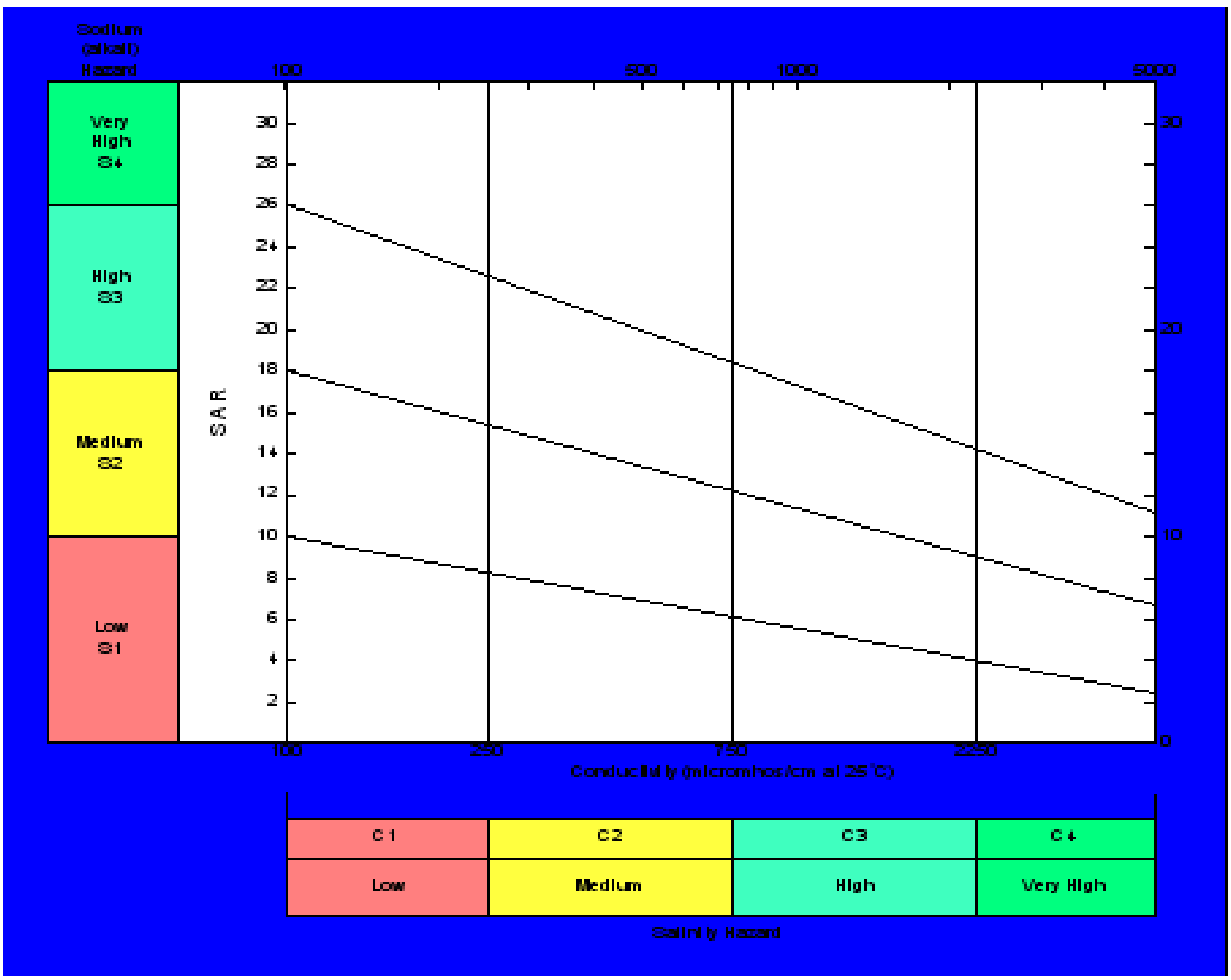


Fig. (2.1): The EC-SAR classification of water samples

2.4. Possible Sources of Contamination

Since springs or dug wells are draining water from the shallow water table aquifer, they are more susceptible of pollution. In the study area the aquifers are vulnerable to pollution due to their high porosity and permeability. Springs and dug wells in the study area are shallow and can be easily affected by pollutants.

The main possible sources of pollution presents in the area are:

1-Agriculture sources

Surface drainage from treated cultivated land and contamination from agriculture results from the heavy use of animal manure or various chemical fertilizers which are always rich in nitrate, potassium and sulfate, with excessive irrigation.

2-Wastewater collection

Wastewater collection is a growing priority in the study area. No sewage collection networks exist in Dura district. Cesspits are the traditional method for sewage disposal; cesspits were designed and constructed without a concrete lining in order to allow seepage into the ground.

2.5. Chemical Contamination

The composition and concentration of substances in ground and surface water is a resultant of anthropogenic activity associated with agriculture, industry and public utilities. As water travels through the soil's profile, various water-soluble substances are released (Pulikowski et al. 2006).

2.6. Data Presentation and classification

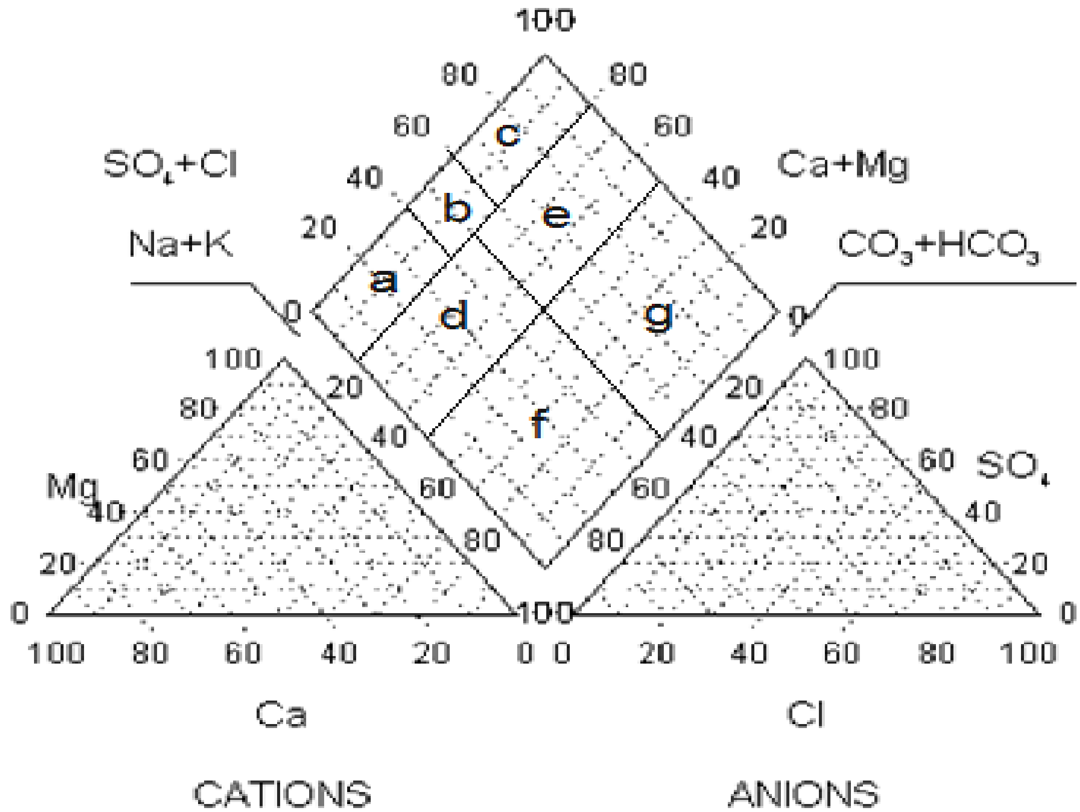
The water types in this study were identified using

1- A (Piper, 1944) diagram, which is a trilinear plot that permits the classification of water samples into seven water types according to (Langguth, 1966) Figure (2.2).

2- Wilcox diagram is to evaluate the suitability of water for irrigation and to calculate sodium adsorption ratio.

3- AquaChem is a fully-integrated software package developed specifically for graphical and numerical analysis of geochemical data sets. AquaChem covers a wide range of calculations frequently used for the analysis, interpretation and comparison of aqueous geochemical data.This software provide different plots foe water samples like; Piper diagram and Durov diagram as show in figure (3.6) and (4.7).

4- GWW is onother software has been used in this study; GWW was used to store data and create hydrographs like schoeller diagram as shown in figure (4.3).



Normal earth alkaline water with:

a- prevailing bicarbonate.

b- bicarbonate and sulphate (chloride).

c- prevailing sulphate or chloride.

Earth alkaline water with increased portion of alkalis with:

d- prevailing bicarbonate

e- prevailing sulphate and chloride

Alkaline water with:

f- prevailing bicarbonate

g-prevailing sulphate

Fig. (2.2):Piper diagram showing the water types according to Langguth (1966) classification

Chapter Three: Results

The water samples of 48 springs and dug wells were checked for the major cations and anions. The results showed a great diversity in the chemical and physical characteristics of the springs and dug wells. Biological water analysis has been done also including; Total plate count bacteria, total coliform bacteria and fecal coliform bacteria.

Tables (3.1) and (3.2) show the minimum, maximum and the average value for each parameter have been measured in the study.

3.1. Chemical Analyses

3.1.1. pH, EC and TDS

In this study the pH value for the first sampling (April, 2007) range between (6.5-8.2) and (6.8-9.1) for the second sampling (October, 2007), Bir Kazem Al Shrief was the dug well that exceeded WHO standard for the pH value of 9.1, the pH values for all the springs and dug wells were shown in Apendix (II)

In addition the EC values in both seasons varied in the most springs and dug wells, the EC (µs/cm) values for the first sampling in this study range between (170) µs/cm for Bir Hejh to the maximum value (2250) µs/cm for biaret Dodin other springs and dug wells have EC values exceeded (2000) µs/cm these were Bir Kursa Old, Al Hriebat (1), Al Hriebat (2), Al Garpy well, Hassan Khlil well, Abu Shrar (2).

For the second sampling the EC values range between (100) µs/cm for Bir Kazem Al Sharief to (2350) µs/cm for also Biaret Dodin, other wells exceeded (2000) µs/cm were Bir Kursa Old (2200) µs/cm. Apendix (II) show the EC values for the first and the second sampling to 48 springs and dug wells in the study.

The total dissolve solids were presented in Figure (3.1), the TDS value according to WHO range between (500-1000 mg/l), in this study the TDS values for the first sampling in April range between (108.8) mg/L in Bir Hejh to (1440) mg/L in Biaret Dodin. The same trend of results was observed in the second sampling in October, high difference was observed between the TDS values for the first and the second water sampling in Al Hriebat 1 and Abu Shrar 2 wells which were opened wells used for agricultural purposes, low TDS values on the second sampling mean that the water samples are not affected by the watershed. On the other hand somewhat the same TDS values were observed for the first and the second water sampling in Ain Abu Sief and Ain Fares which are considred as unpolluted wells.

3.1.2. Cations (Na^+, K^+, Ca^{+2}, $Mg^{+2}$and NH_4^+)

The value of sodium according to WHO standards is 200 (mg/L). In this study the [Na^+] for the first sampling were ranged from (6) mg/L in Bir Hejh to (97.6) mg/l in Al Garpy well. In the second sampling the sodium concentrations were ranged from (2.7) mg/L in Al Majnonh to (96.3) mg/L in Biaret Dodin. All the sodium values for the first and the second sampling were below the WHO standard, most of the sodium concentrations in both seasons varied significantly except some wells like Al Bir Al Shrqy and Bir Kazem Al Sharief as shown in Fig (3.2) and Apendix (III).

For potassium the WHO standard value was 12 mg/L, in this study in the first reading 64% of potassium values were exceeded the WHO standard, 13% of these polluted springs and dug wells and have potassium values more than 100 mg/L. 39% of these polluted wells had potassium values between (30-100 mg/L). 48% of these potassium values have potassium values between (12-29 mg/L). 36% of these wells were unpolluted with potassium for the first sampling. In the second sampling, the concentrations of potassium were remaining in the same trend for the most wells as in the same evaluation as shown in Fig (3.2) and Apendix (III). The figure also show that some springs and dug wells have very high potassium concntratios like Al sharqy well and Biaret Dodin which were affected by human activity and located in low land aera comparing to the study area.

The calcium WHO recommended limit value is (75 mg/L), in the first sampling of this study 42% of the springs and dug wells have calcium concentrations exceeded this standard value. For the second sampling only 15% of the springs and dug wells have calcium concentrations above the standard value. Apendix (III) shows the concentration for calcium in the first and the second sampling of the study.

The standard value of magnesium according to WHO is (125 mg/L), in this study the magnesium concentrations in the first sampling range between (19.3 mg/L) for in Bir Hejh to (84 mg/L) in Kursa old well, no spring or dug well exceeded the WHO standard for magnesium. Apendix (III) shows the magnesium concentration for the first and the second sampling in the study.

The standard value of ammonuim according to WHO is 1.5 mg/L, for this study the concentration of ammonia for the first sampling range between 0.4-0.9 mg/L for the first sampling in April and between 0.1-0.5 mg/L for the second sampling in October, so none of the springs and dug wells would considered polluted with ammonium. Apendix (III) shows the ammonium concentrations for the first and the second sampling on the atudy.

3.1.3. Anions (NO_3^- , Cl^-, HCO_3^- and SO_4^{-2})

The standard value of nitrate concentration according to WHO is (50 mg/L), in the frist sampling of this study the concentrations of nitrate range between (4.3) in Bir Ali Al Sharief to (145 mg/L) for Al Garpy well and Biaret Dodin. 63% of these springs and dug wells have nitrate values more than (50 mg/L), 50% of these polluted springs have nitrate concentration more than (100 mg/L), these springs were Al Alqa, Yasser Al Drapi, Wad Al Shajnh, WadSweety north, Ain Taha, Kanar, Bir Shaheen, Al Hriebat (2) , Drawiesh (1) , Drawiesh (2), Al Sabbar, Abu Al Glasy, Abu Shrar (1). 37% of the springs and dug wells were not polluted with nitrate and have nitrate concentration less than (50 mg/L).

In the second sampling the nitrate concentrations range between 5.7 mg/L in Bir Kazem Al Shrief to 134 mg/L in Bir Drawiesh (1), 60% of these springs and dug wells were polluted with nitrate. 40% of the springs and dug wells in the second sampling were safe of nitrate pollution. Figure (3.4) and Apendix (III) show the nitrate concentration for April and October samples in the study.

The standard value of chloride according to WHO is (250 mg/L), in this study the concentration of chloride for the first water samples analysis range between 35.3mg/L in Bir Musa Al Drapi to 352 mg/L in Al Garpy well, For the water samples collected in October 2007 the same trend of chloride concentrations were observed with some exceptions as shown in Fig (3.5) and Apendix (III).

According to WHO the standard value of bicarbonate is (125-350mg/L), in this study in the first sampling only Abu Al Glasy well And Abu Shrar (2) bicarbonate values exceeded 350 mg/L, with 378.7 mg/L and 360.7 mg/L respectively, And there was only one well below the standard values this well was Bir Hejh 49 mg/L, the rest of the wells have bicarbonate values between the standard condition. For the second sampling no was well exceeded (350 mg/L) in its bicarbonate value, the concentration of bicarbonate value range between 49mg/L in Bir Kazem Al Shrief to 269 mg/L in Al Hriebat (2) and Abu Mhna. Apendix (III) show the bicarbonate concentration for the first and the second samplings in the study.

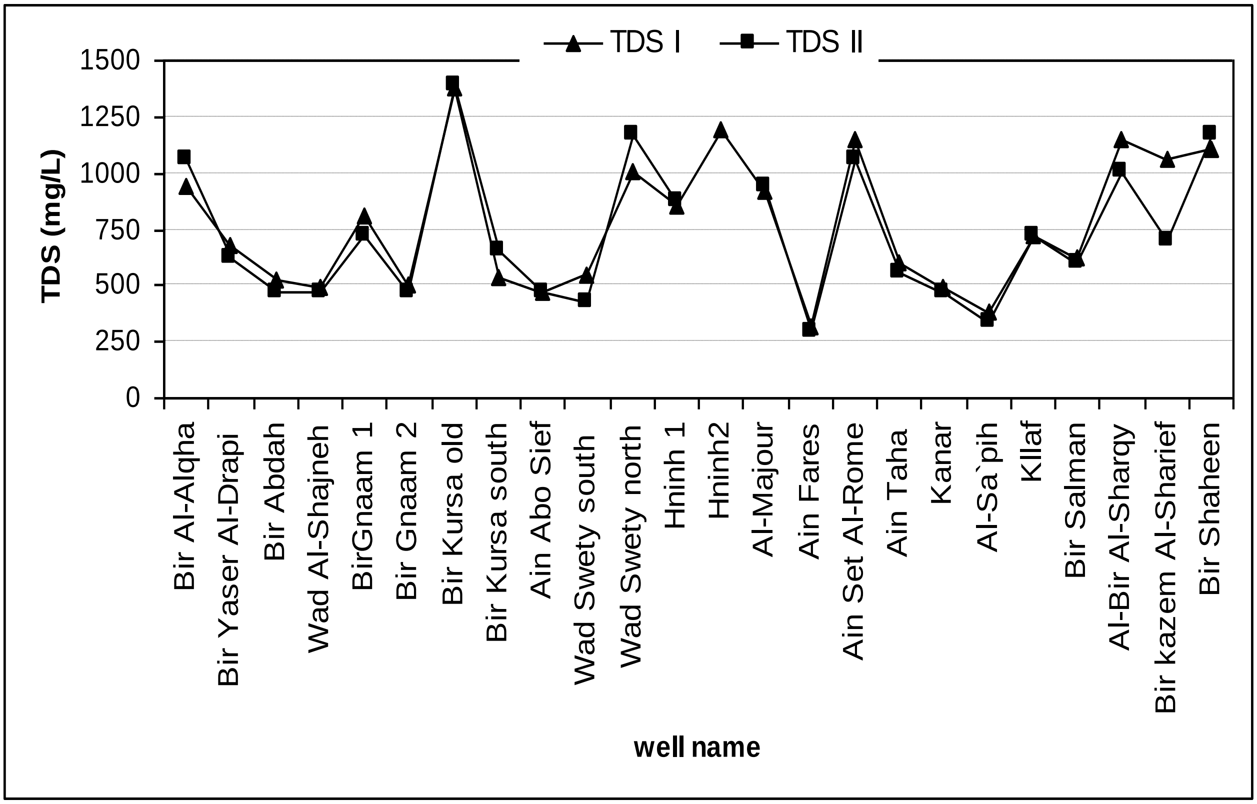
According to WHO the standard value of sulfate is (250 mg/L), the sulfate concentration of the first sampling of this study range between 11.7mg/L in Biaret Dodin to 76.3 mg/L in Abu Al Glasy well. Apendix (III) shows the sulfate concentration for the first and the second sampling in the study.

Table (3.1): Descriptive statistics of chemical, physical and biological parameters of the springs studied in Dura district in April 2007

	pH	EC	TDS	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	NH_4^{+}	HCO_3	Cl^{-}	SO_4^{-2}	NO_3^{-}	T.C	T.Col	F.Col
Unit		µS/cm	mg/L										col/100		
Minimum	6.5	170	108.8	32	19.3	6	8	0.4	49	35.3	11.7	4.3	19	0	0
Maximum	8.2	2250	1440	**167.7**	84	96.7	122	0.9	379	352	76.3	145	5333	593	536
Average	7.4	1265	810	74	45.4	49.2	33.2	0.56	205	146	30.8	72.3	1347	63	19

Table (3.2): Descriptive statistics of chemical, physical and biological parameters of the springs studied in Dura district in October 2007

Variable	pH	EC	TDS	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	NH_4^{+}	HCO_3	Cl^{-}	SO_4^{-2}	NO_3^{-}	T.C	T.Col	F.Col
Unit		µS/cm	mg/L										col/100		
Minimum	6.8	111	71	16	6.3	2.67	7	0.1	49	27.7	9	5.7	40	0	0
Maximum	9.1	2350	1504	120	62	96.3	96.3	0.5	269	214	61	134	4500	151	1200
Average	7.3	1090	698	52	27	42.8	28.2	0.26	173	105	24.8	64.5	1464	7	43



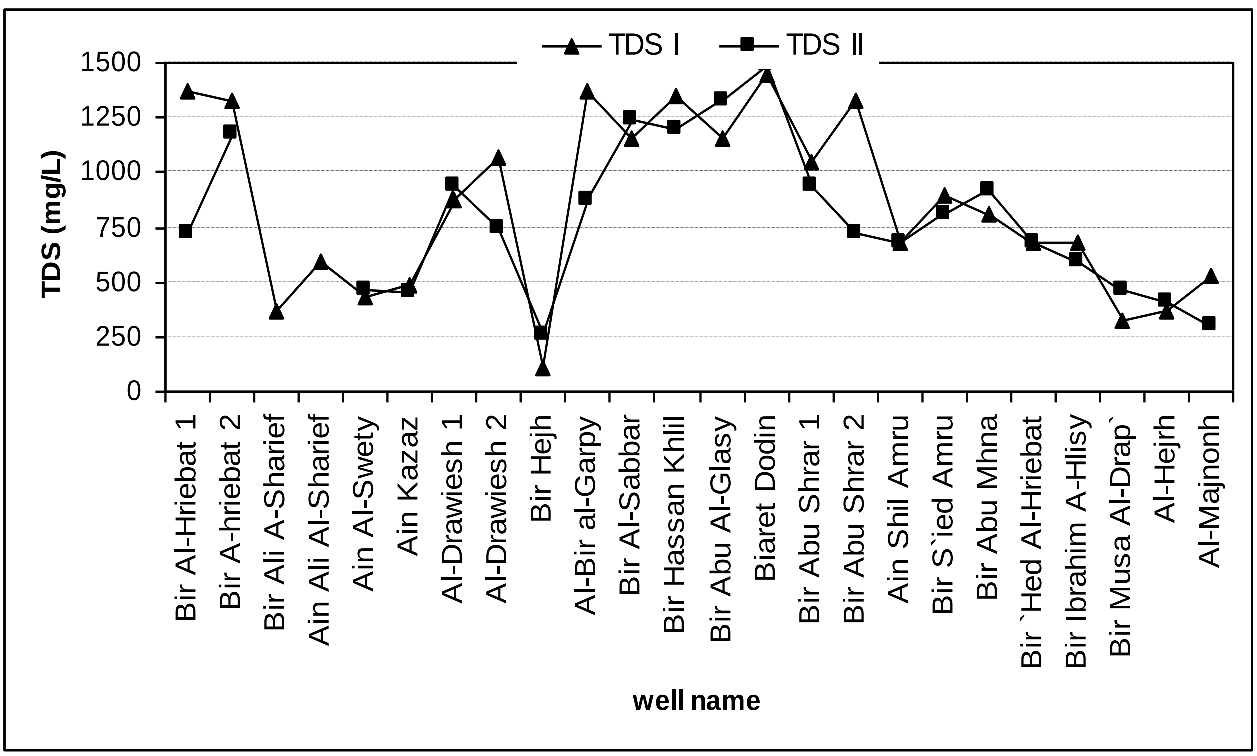
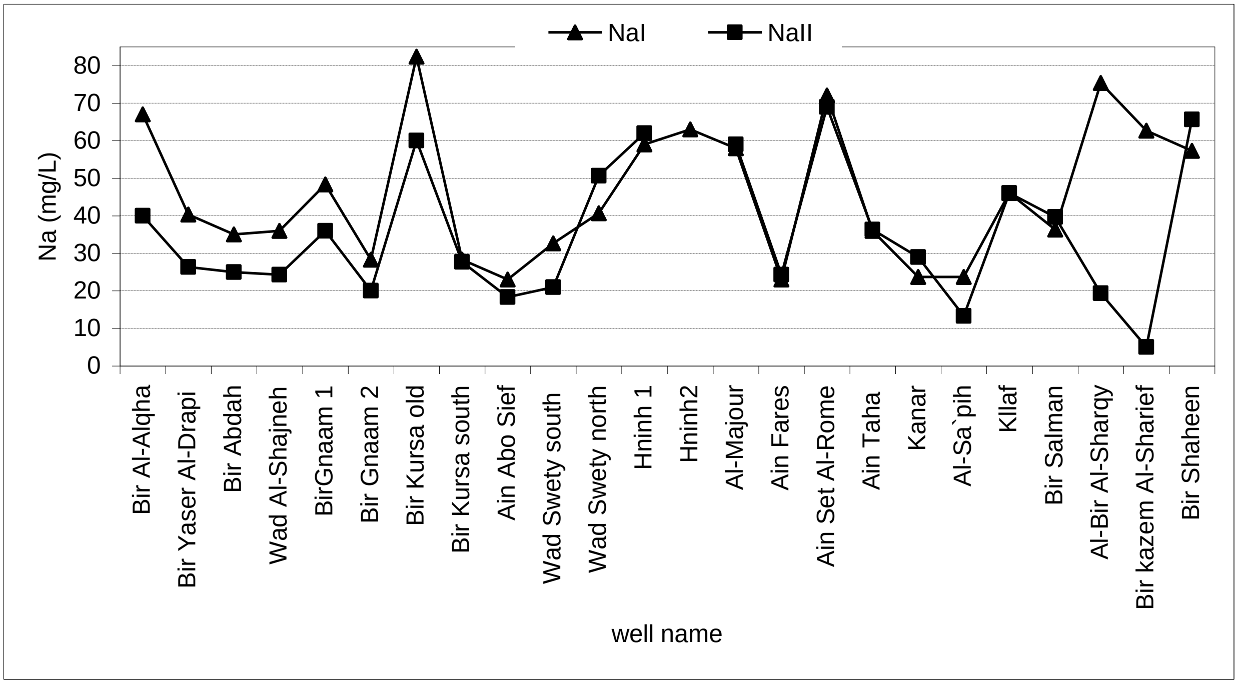


Fig.(3.1): TDS (mg.L^{-1}) values of water springs and dug wells in Dura district collected in two seasons (April and October, 2007)



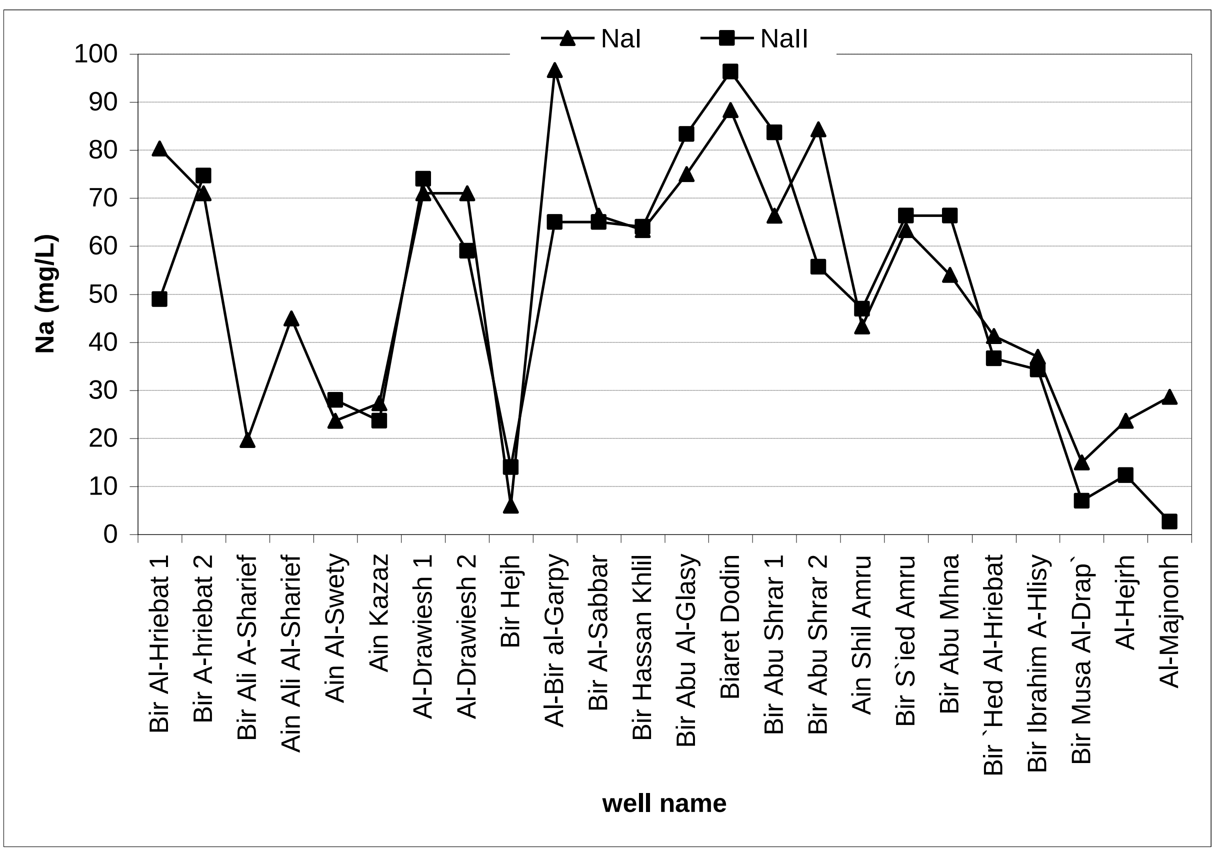
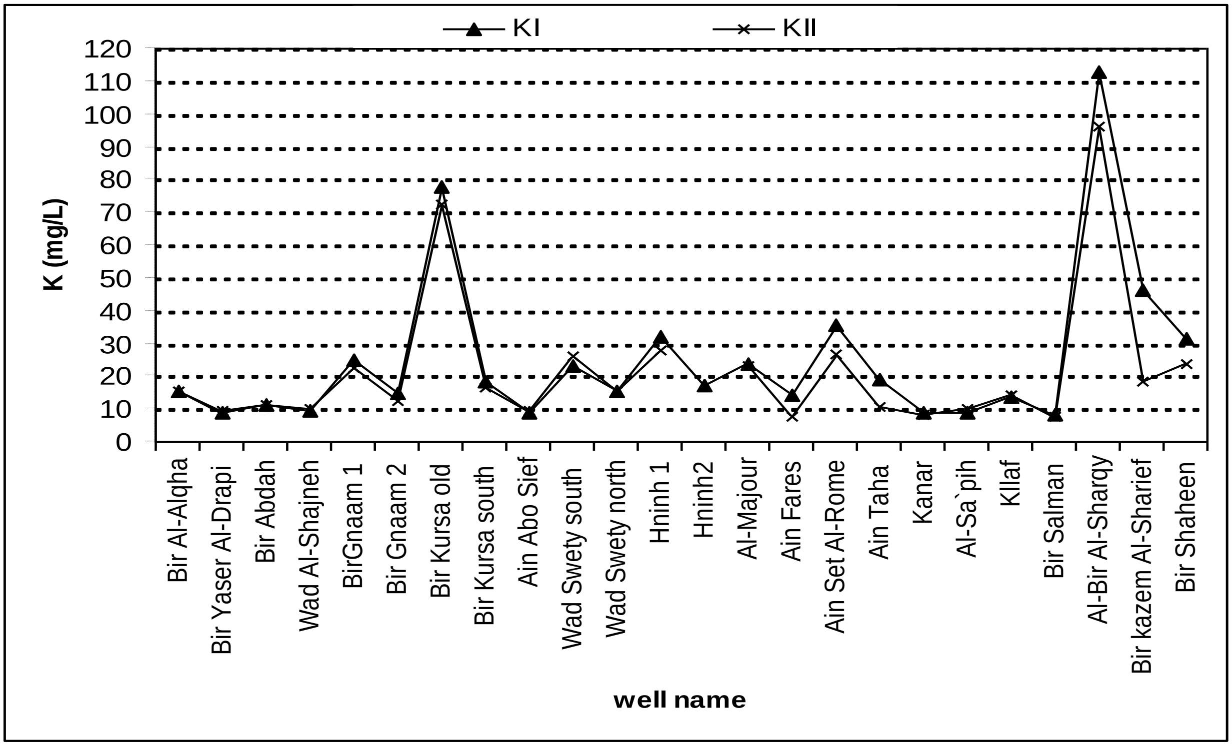


Fig. (3.2): Sodium concentrations values (mg L-1) of water springs and dug wells in Dura district collected in two seasons (April and October, 2007).



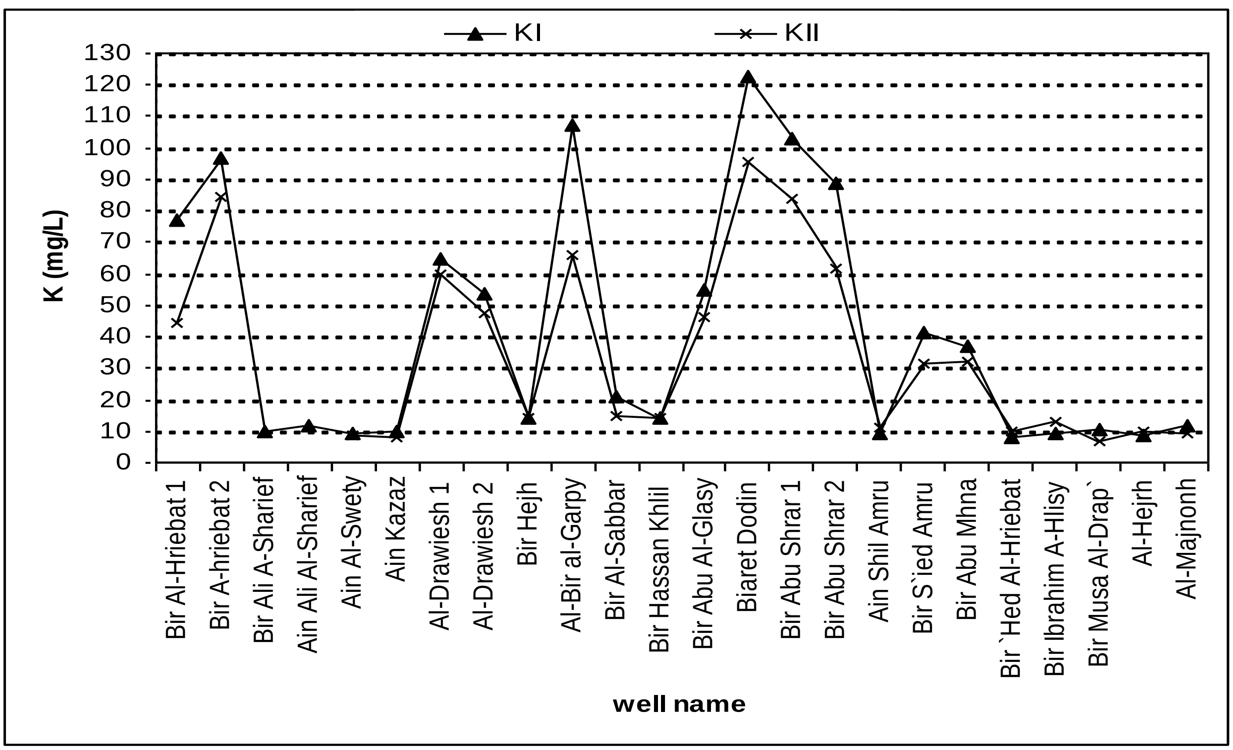
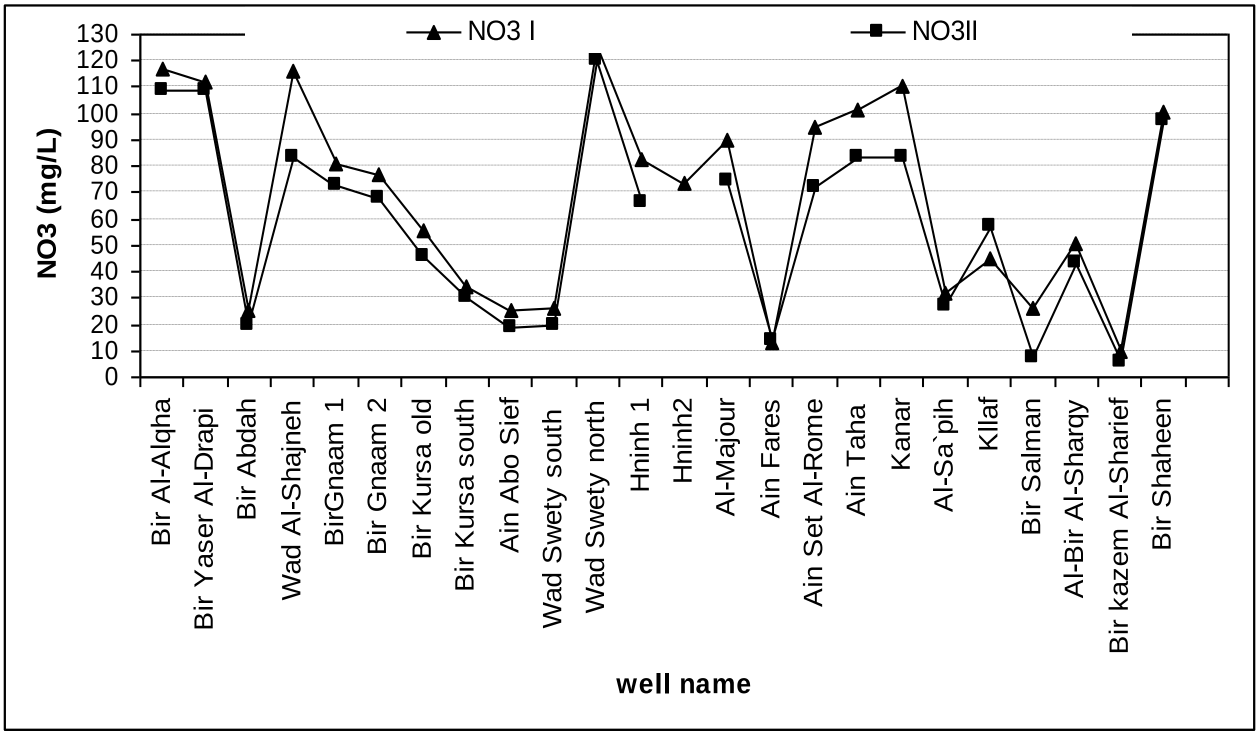


Fig (3.3): Potassium concentrations values (mg L-1) of water springs and dug wells in Dura district collected in two seasons (April and October, 2007).



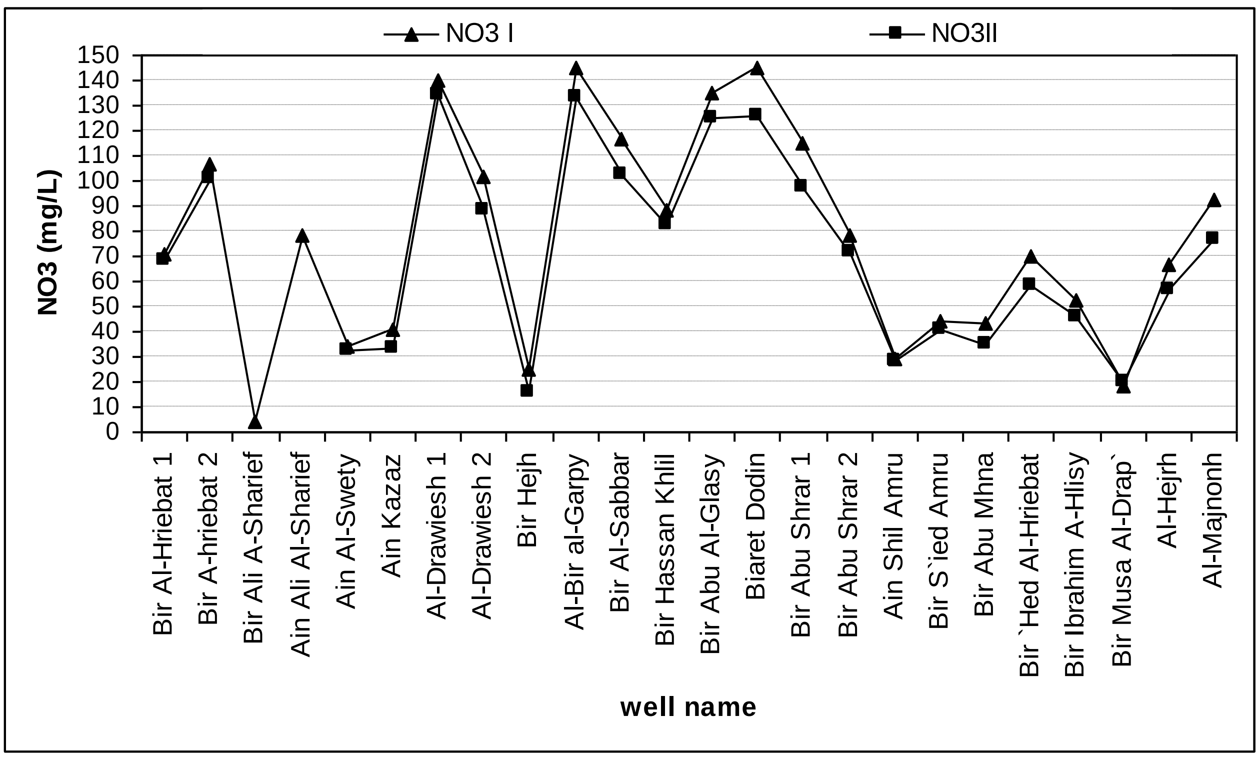
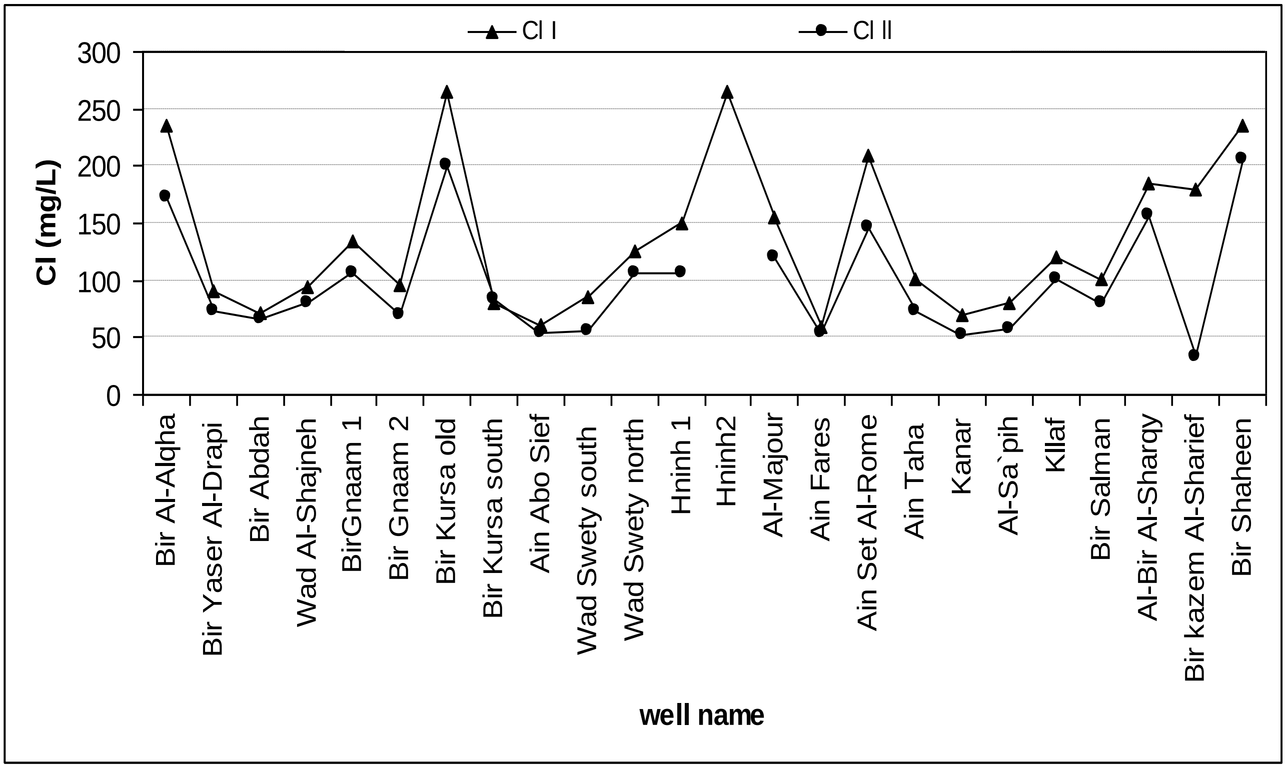


Fig. (3.4): Nitrate concentrations values ($mg.L^{-1}$) of water springs and dug wells in Dura district collected in two seasons (April and October, 2007).



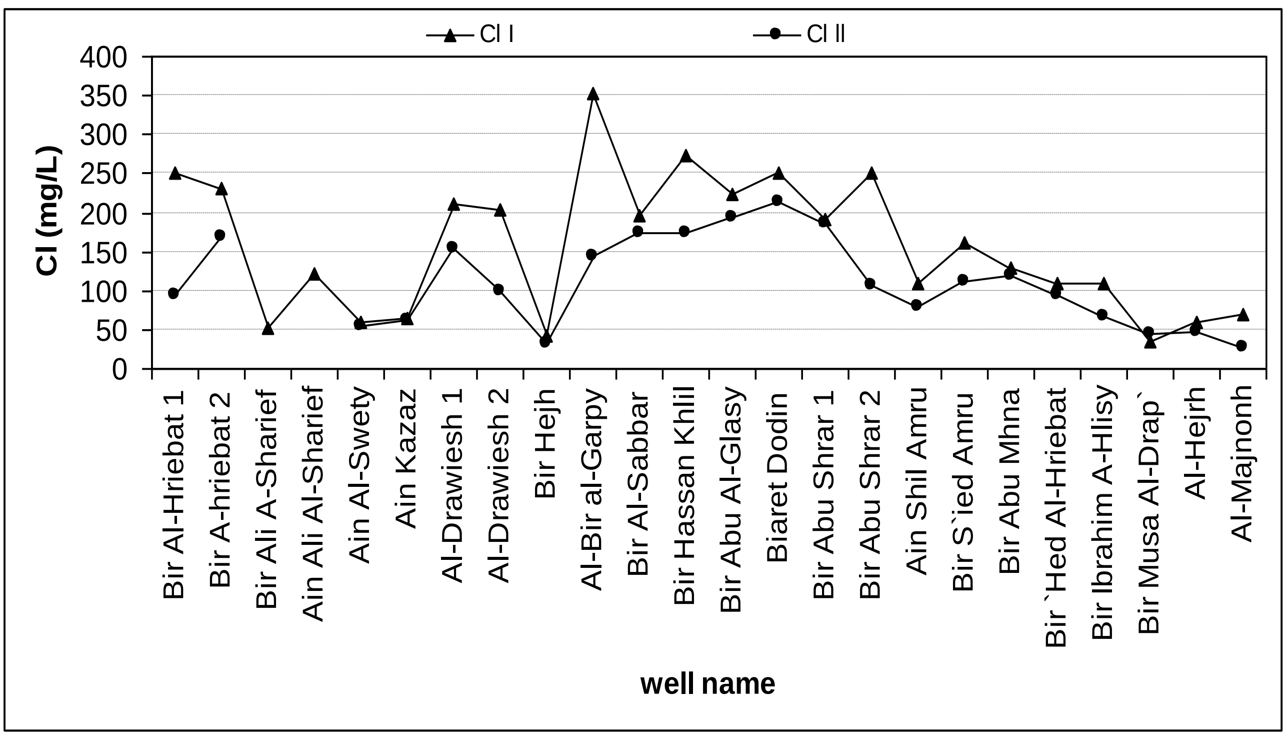


Fig. (3.5): Chloride concentrations values (mg L^{-1}) of water springs and dug wells in Dura district collected in two seasons (April and October, 2007)

3.2. Biological Analyses

3.2.1. Total Plate Count Bacteria (T.C)

In the first sampling five wells (Al Alqa, Gannam (1), Gannam (2), Bir Kursa Old and Ain Taha) had uncounted number of total count bacteria. Kallaf and Drawiesh (1) had total count bacteria of approximately 5000 col/100 ml water. Six wells (Bir Salman, Bir Hejh, Hassan Khlil, Al Garpy well, Al sabbar and Sied Amru) had total count bacteria of more than 2000 col/100 ml water. 31% of the springs and dug wells had total count bacteria between (1000-2000 col/100ml water). In the second reading three wells (Al Alqa, Wad Al Sweety south and north and Sied Amru) had uncounted total count bacteria. Five wells (Hninh (1), Ain Set Al Room, Kallaf, Al Hriebat and Ain Al Sweety) had total count bacteria between (4000-5000 col/100ml water). Seven wells (Al majour, Bir Salman, al Hriebat (2), Al Garpy well, Biaret Dodun, Abu Shrar (1) and Abu shrar (2)) had total count bacteria (2000-4000 col/100ml water). Apendix (IV) shows the values of Total plate count bacteria for the first and the second sampling in the study.

3.2.2. Total Coliform Bacteria (T.Col)

According to WHO, the standard value of total coliform bacteria is zero. In this study for the first sampling, six wells (Al Alqa, Yasser Al Drapi, Wad Al Shajnh, gannam (1), Ain Taha and Hninh (1)) had uncounted number of coliform bacteria. Also Four wells (Al Sapih, Al Sharqy well, Al Hriebat (2) and Ain Kazaz) had not any total coliform bacteria. 79% of the springs and dug wells had total coliform bacteria between 1-600 col/100ml water.

For the water samples analzed in Ocrober two wells (Al Alqa and Wad Al Shajnh) had uncounted total coliform bacteria. Seventy three percent of the springs and dug wells didn't have any total coliform bacteria.The rest of the springs have total count bacteria between 1-150 col/100ml water. Apendix (IV) shows the values of total coliform bacteria for the first and the second sampling in the study.

3.2.3. Fecal Coliform Bacteria (F.Col)

The standard value of fecal coliform bacteria accoriding to WHO is zero, in this study for the first sampling, only Al Alqa well had uncounted number of fecal coliform bacteria, fifty four percent of the springs and dug wells didn't have any fecal coliform in it .

The rest of the springs had fecal coliform bacteria between 1-550 col/100ml water these wells were Yasser Al Drapi, Wad al Shajnh, Gannam (1) and (2), Kursa Old, Ain Abu Sief, Wad Al sweety south and north, Hninh (1) and (2), Al Majour, Ain Taha,Kallaf, Bir Shheen, al Hriebat (1), bir Ali Al Sharief, ain Ali Al Sharief, Drawiesh (1), Abu Shrar(1) and (2) and Ain Suhil Amru.

In the second sampling Bir Alqa had uncounted number of fecal coliform bacteria and fifty one percent of the sprigs and dug wells didn't have any fecal coliform in it. Apendix (IV) shows the values of fecal coliform bacteria for the first and the second reading in the study.

3.3. Piper Diagram and Water type

According to Piper plot for the water samples collected in April 2007, Figure (3.6) and (3.7), the following results were obtained:

1-most of the springs and dug wells were located in the field of earth alkaline water with increased portion of alkais and this the major water type, they are categorized as follows:

- 8 with prevailing bicarbonate
- 26 with prevailing sulphate and chloride

2- 3 normal earth alkaline water with prevailing sulphate or (chloride)

3- 6 normal earth alkaline water with bicarbonate and sulphate or (chloride)

4- 3 normal earth alkaline water with prevailing bicarbonate

For the water samples collected in April 2007, Figure (3.8) and (3.9), the following results were obtained:

1-most of the springs and dug wells were located in the field of earth alkaline water with increased portion of alkalis and this the major water type, they are categorized as follows:

- 8 with prevailing bicarbonate
- 25 with prevailing sulphate and chloride

2- 1 spring normal earth alkaline water with prevailing sulphate or (chloride)

3- 5 normal earth alkaline water with bicarbonate and sulphate or (chloride)

4- 6 normal earth alkaline water with prevailing bicarbonate

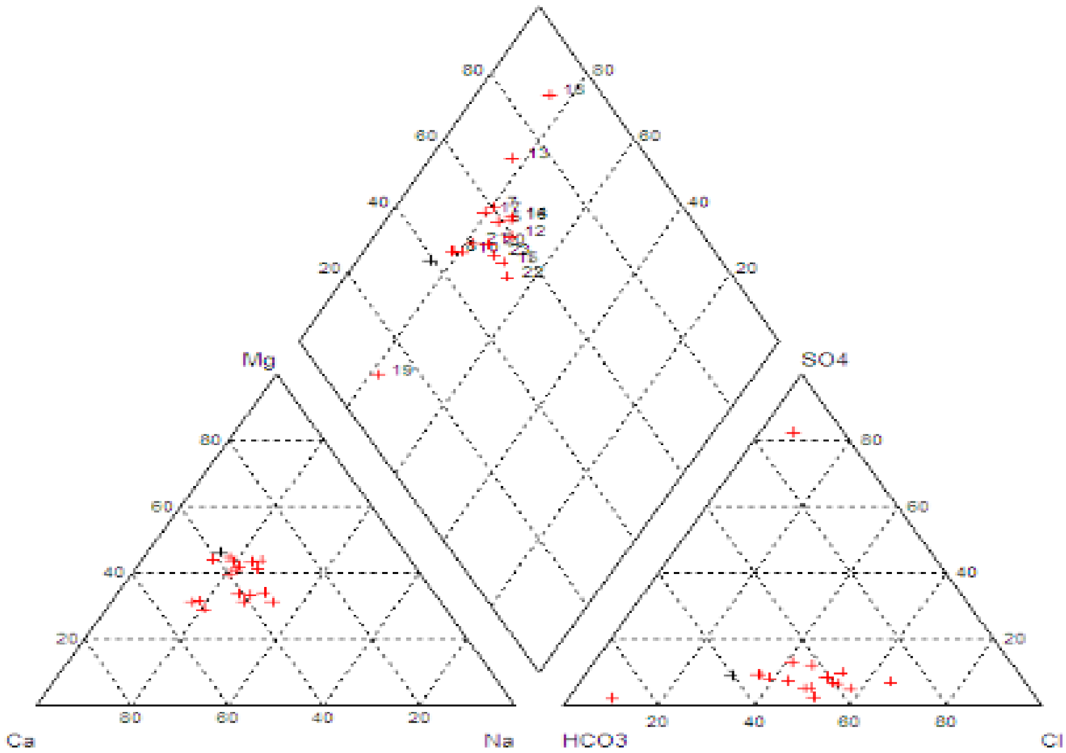


Fig. (3.6): Piper plot showing the first group of the springs collected in April 2007.

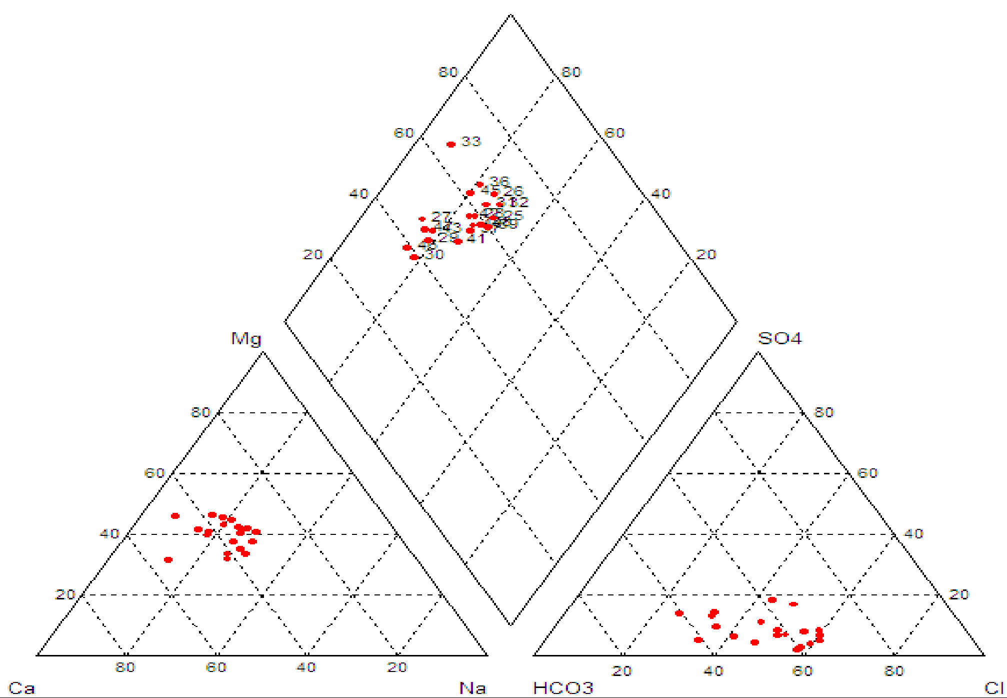


Fig. (3.7): Piper plot showing the second group of the springs collected in April 2007.

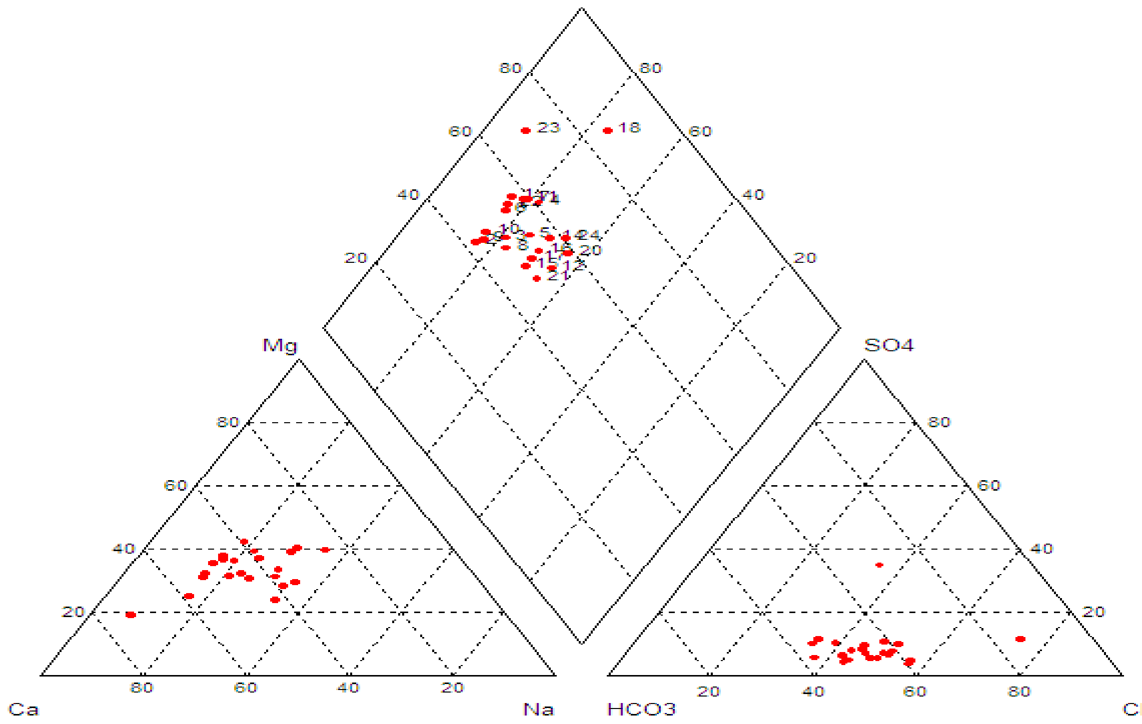


Fig. (3.8): Piper plot showing the first group of the springs collected in October 2007.

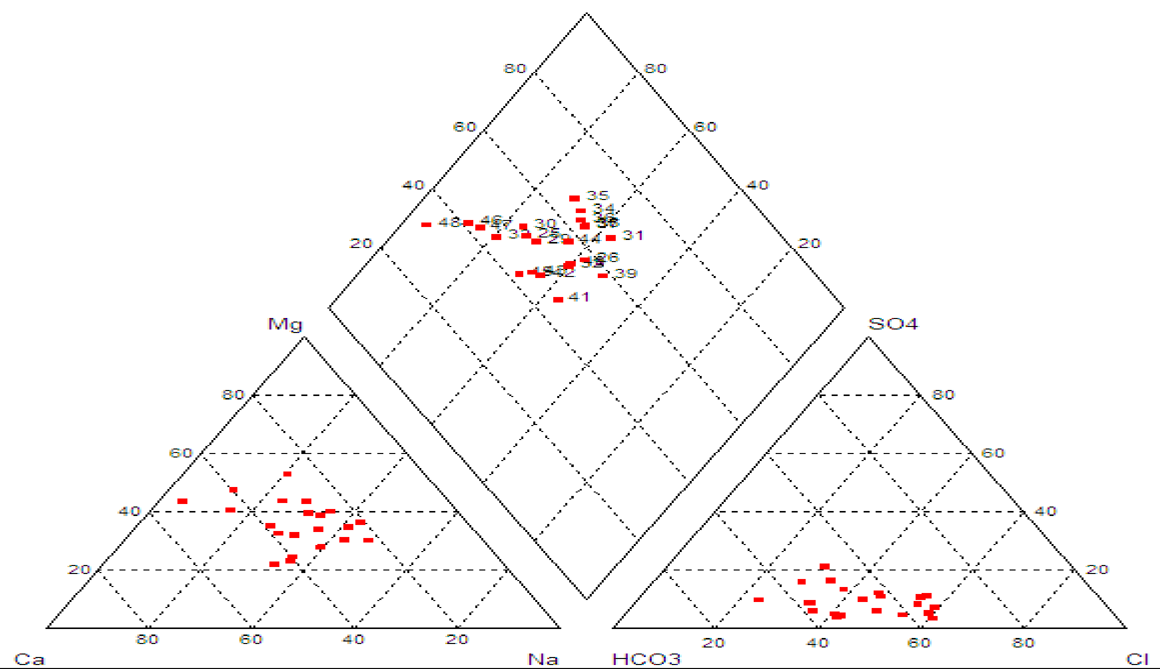


Fig. (3.9): Piper plot showing the second group of the springs collected in October 2007.

As we see from piper polts the major water type in the study area is earth alkaline water with increase portion of alkalis with prevailing sulphate and chloride. Contamination appears by shifting the results to the middle of piper polt. Figures 3.10, 3.11, 3.12 show the piper polt for three different groups of the springs in the study area, the first group in Figure (3.10) represnts springs that are located in a recharge watershed that is not affected by the activity of intensive agriculture or sewage. Abu Sief spring plot in the area of normal earth alkaline water with bicarbonate and sulphate (or chloride), Al Sapih, Abdah and Ain Fares plot in the earth alkaline water with increased portion of alkalis with prevailing sulphate and chloride and Musa Al Drapi in the earth alkaline water with increased portion of alkalis with prevailing bicarbonate. The second group in (Figure 3.11) represents springs located between houses and also intensive agriculture so the results were shifted to the area of earth alkaline water with increased portion of alkalis with prevailing sulphate and chloride except Bir Hejh that plots in the area of normal earth alkaline water with prevailing sulphate (or chloride), which mean that these springs were more contaminated by fertilizers and sewage than the first one in Figure (3.10). The third group (Figure 3.12) represnts springs located in an intensive agriculture area with high use of manure and fertilizers so most of the springs plot in the area of earth alkaline water with increased portion of alkalis with prevailing sulphate and chloride, which mean that these wells were contaminated by the feartilizers. Figure (3.13) represents the winter and the summer sampling for Al Sapih well and Hejh well, in Al Sapih well the winter and the summer sampling plot in the same area of earth alkaline water with increased portion of alkalis with prevailing sulphate and chloride, but for Hejh spring the winter sampling plots in the area of normal earth alkaline water with prevailing sulphate (or chloride) and the summer samplimg plots in the area of earth alkaline water with increase portion of alkalis with prevailing bicarbonate.

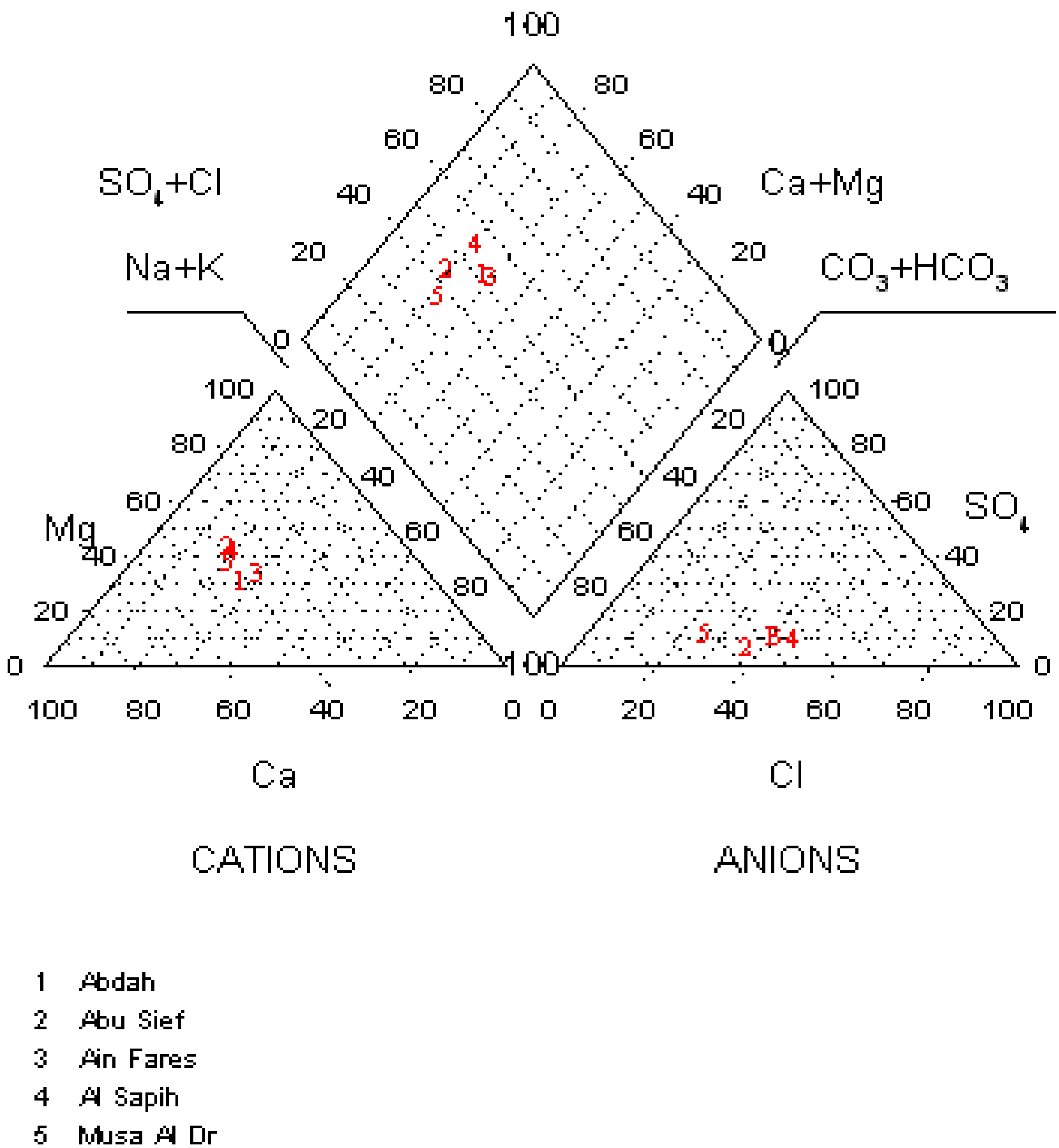


Fig. (3.10): Piper plot for the first group of water samples

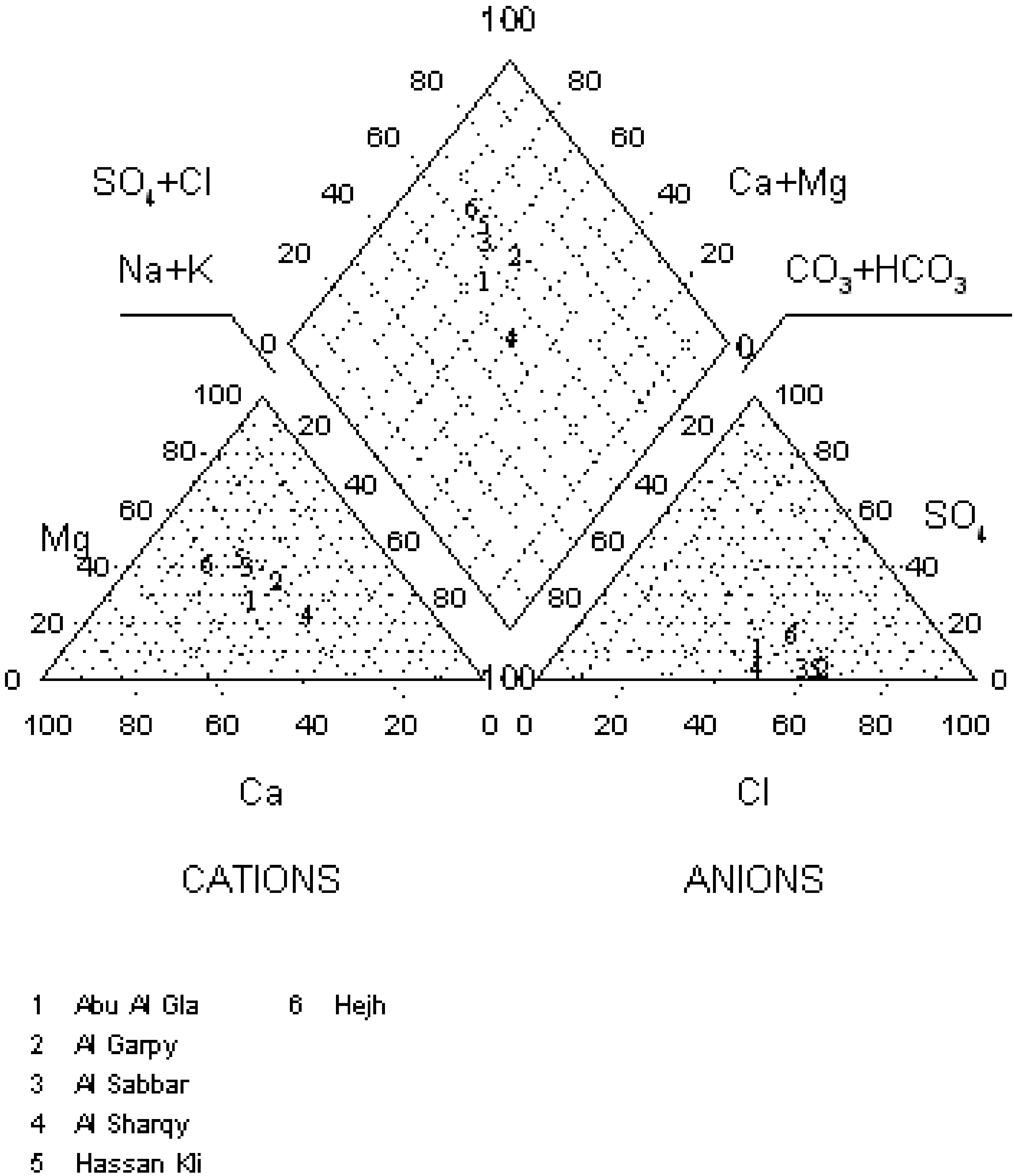


Fig. (3.11): Piper plot for the second group of water samples

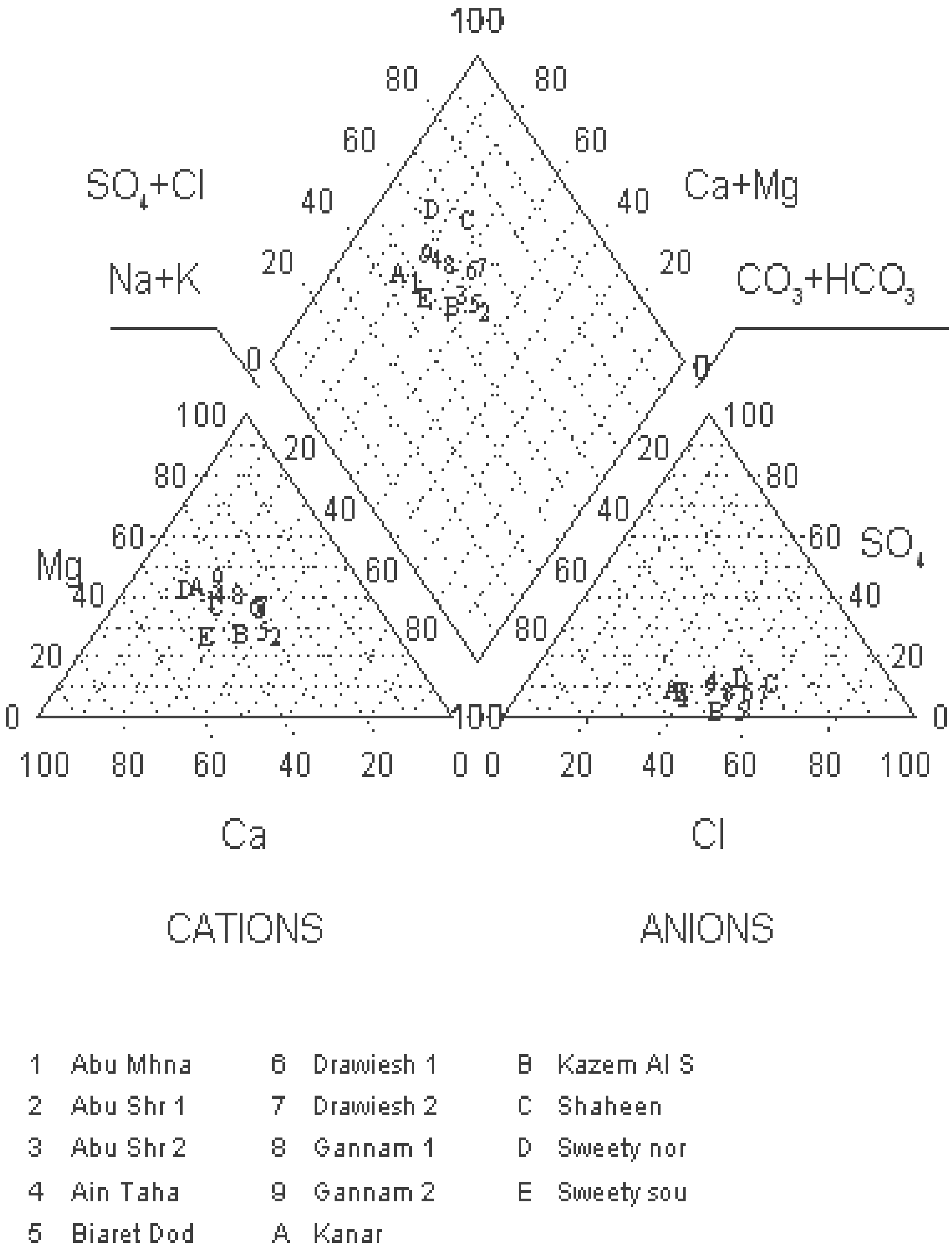


Fig. (3.12): Piper plot for the third group of water samples

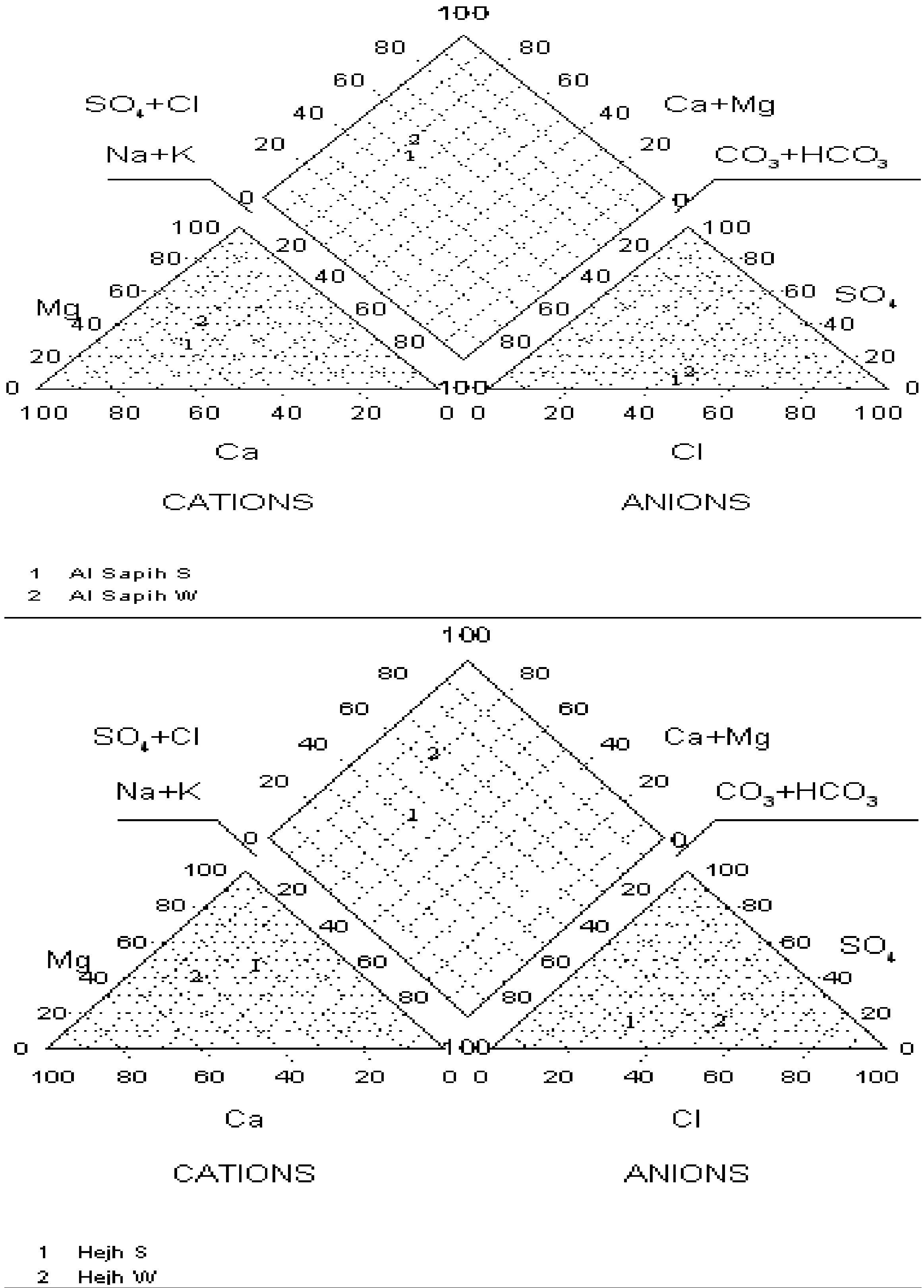


Fig. (3.13): Piper plot for Al Sapih and Hejh springs in summer and winter.

Chaper Four: Water Quality

4.1. Water quality

Water quality is a concept referring to the chemical, physical and biological characteristics of water. The required water quality is determined by the purpose for which the water is to be used (domestic, urban, agricultural or industrial). The water quality needs to satisfy the standards for each of these purposes in order to avoid any negative effects against the user. This means that the contents in water must fit the situations which never affect the health of the consumers over the life of consumption (WHO, 2004). If any of the water contents show short-term deviations from the standard for a specific purpose do not mean that the water is unsuitable for that purpose. Suitability here is judged by the amount and length of the deviation time as well as by the nature of the constituent involved.

4.1.1. Water quality for domestic purposes

Domestic water is defined as the water used for drinking, bathing, cooking, cleaning and for public buildings. The suitability of its quality as domestic water is judged on physical, chemical and microbiological characteristics (Abed Rabbo et. al., 1999).

The first concern in the elevation process is the physical characteristics, like total suspended solid, odor, taste and color. The second concern is the microbiological characteristics; the people are more familiar with waterborne-microbiological diseases than they are with waterborne-chemical diseases. Detection is easy and treatment costs are comparatively low. Waterborne-chemical diseases are less well-known and can not appreciate by the public, testing and treatment for the chemical parameters are difficult and require expensive high technology (Abed Rabbo et. al., 1999).

4.1.2. Microbiological quality evaluation

The biological characteristics of water are very important in the evaluation of its suitability for domestic purposes, as the infectious diseases caused by pathogenic bacteria, viruses, protozoa or parasites are the most common and widespread health risk associated with drinking water.

4.1.3. Total Hardness

Depending on Swayer and McCarty, 1967 classification of water hardness for the first sampling, 30 of the springs and dug wells considered very hard with a maximum value of 695 mg/L for Bir Kursa old. The rest of the springs and dug wells were considered hard.

For the water samples collected in October 2007, 11 of the springs and dug wells are considered, 25 springs and dug wells are considered hard and nine of the springs and dug wells were considered moderately hard. The values of total hardness for the first and the second sampling in the study were shown in Apendix (II).

Water hardness in most groundwater is naturally occurring from weathering of limestone and other calcium and magnesium bearing minerals and rocks (British Colombia Ministry of Health Servises, 2002).

4.2. Water quality for irrigation purposes

4.2.1. Soluble Sodium Percentage (SSP)

According to the classification of water quality based on SSP no well was considered unsuitable for irrigation purposes in the first sampling. Nine of the springs and dug wells were considered Excellent for irrigation purposes these wells were (Ain Abu Sief, Wad Al Sweety north, Hninh (2), Kanar, Ain Ali Al Sharief, Bir hejh, Musa Al Drapi, Al Hejrh and Al Majnonh).

36 of the sprigs were considered good for irrigation purposes depending on SSP evaluation and the last three wells (Al Sharqy well, Biaret Dodin and Abu Shrar (1)) considered permissible for irrigation purposes.

In the second sampling 5 of the springs and dug wells were considered excellent for irrigation purposes depending on SSP. 28 of the springs and dug wells were considered good for irrigation purposes. The rest of the springs were considered Permissible for irrigation purposes. The SSP values were shown in Apendix (II)

4.2.2. Sodium Adsorption Ratio (SAR)

Depending on the EC-SAR classification of water samples shown in Figure (3.6) all of the springs and dug wells had low sodium and SAR values were less than 10 in the first sampling 42% of the springs and dug well had SAR values less than 1. The rest of the springs and dug well had SAR values between (0.2- 1.8).

For the second sampling 47% of the springs and dug wells had SAR values less than one. The rest of the springs and dug wells have SAR values between (0.1- 2.6). Apendix (II) and Figres (4.1) and (4.2) show the EC-SAR classification for the springs and dug wells in the study area.

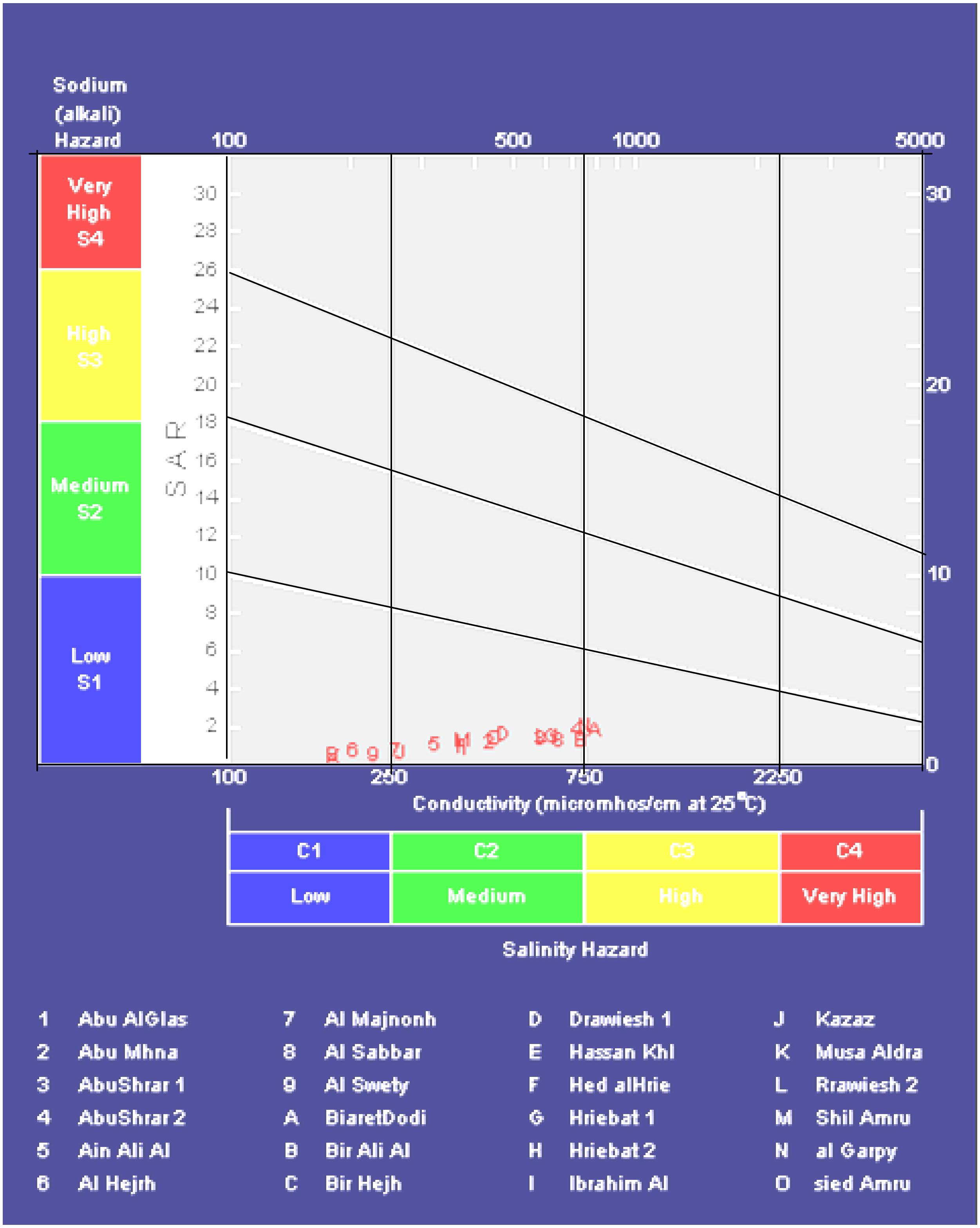


Fig. (4.1): EC-SAR classification of the water samples

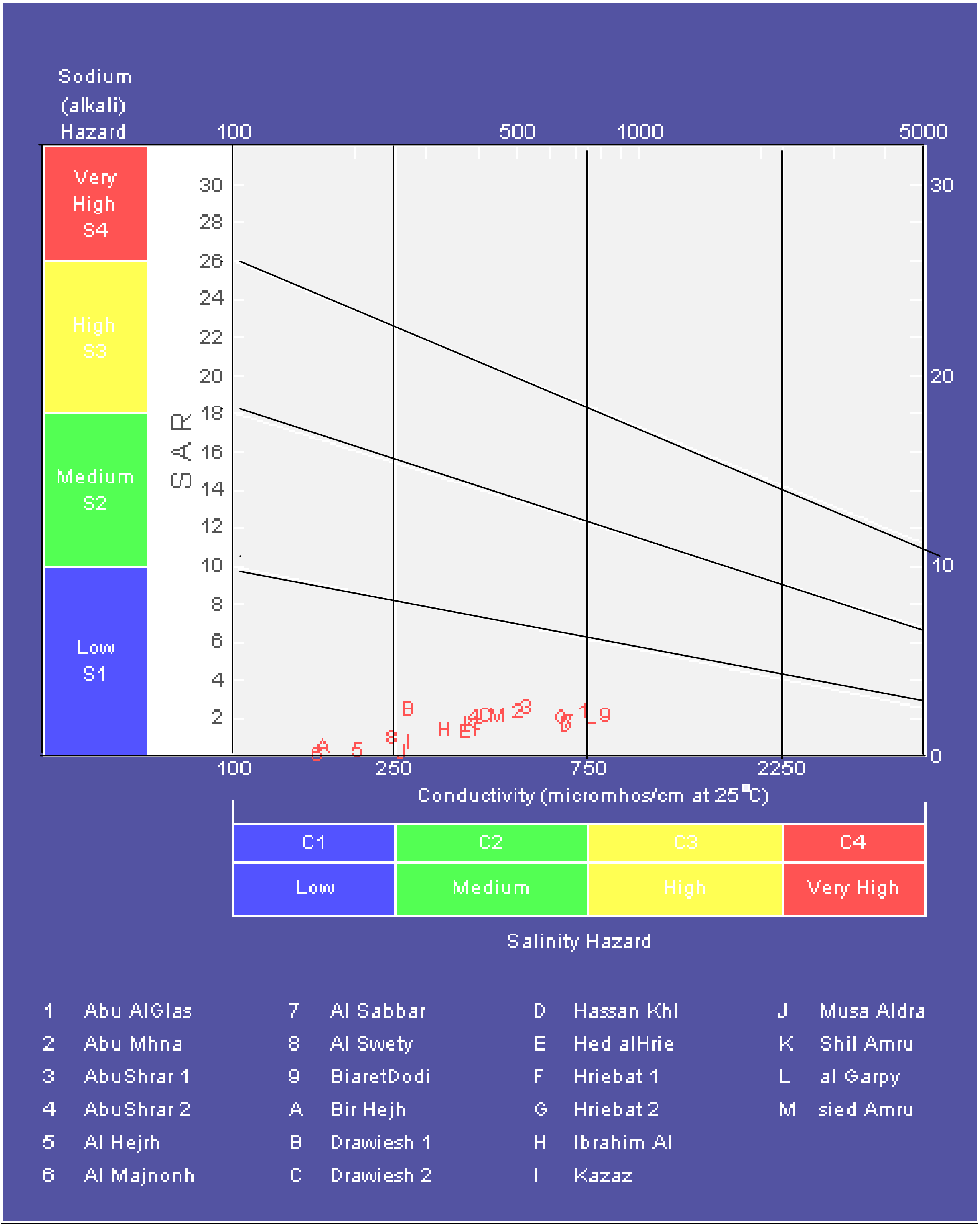


Fig. (4.2): EC-SAR classification of the water samples

Schoeller diagrame has the advantage that unlike the trilinear diagrams, actual sample concentrations are displayed and compared. Figure (4.3) represent the Schoeller plot for water samples collected from (Abdah, Ain Abu Sief, Ain Fares, Al Sapih and Bir Musa Al Drapi) these springs and dug wells are not affected by human activity have different range of cations and anions concentration from that of the springs and dug wells shown in figure (4.4) which were affected by human activity like agricultural purposes.

For example all the springs and dug wells in figure (4.3) have [Cl^-] range between (1-2.2 epm), but for the springs and dug wells shown in figure (4.4) that have [Cl^-] between (6-10epm).

Figure (4.5) show the shceoller diagrae for the springs and dug wells that located in Wad Abu al Qamra which affected by agricultural purposes and sewage flow.

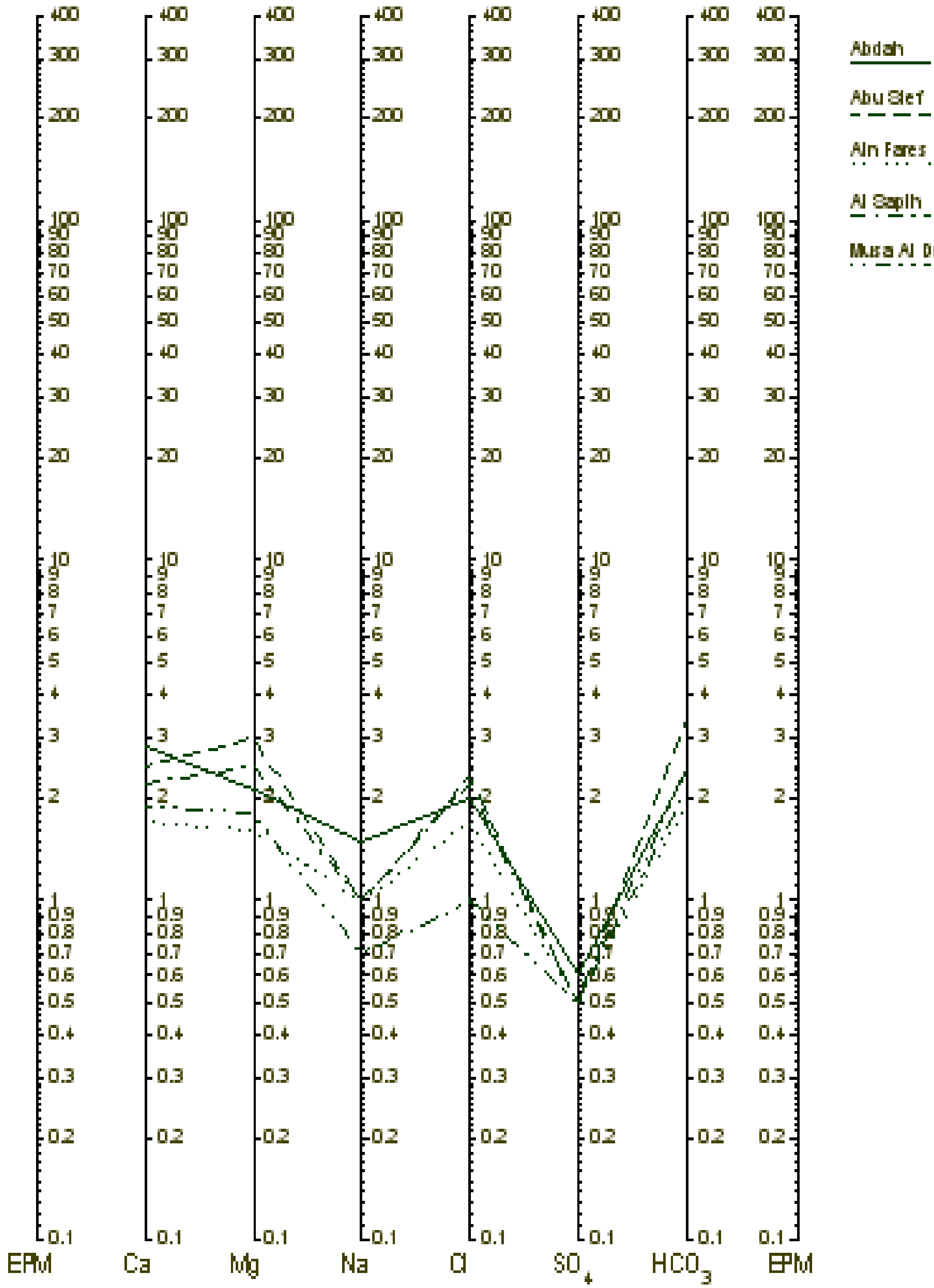


Fig. (4.3): Scholler digram plot for the samples of the first group

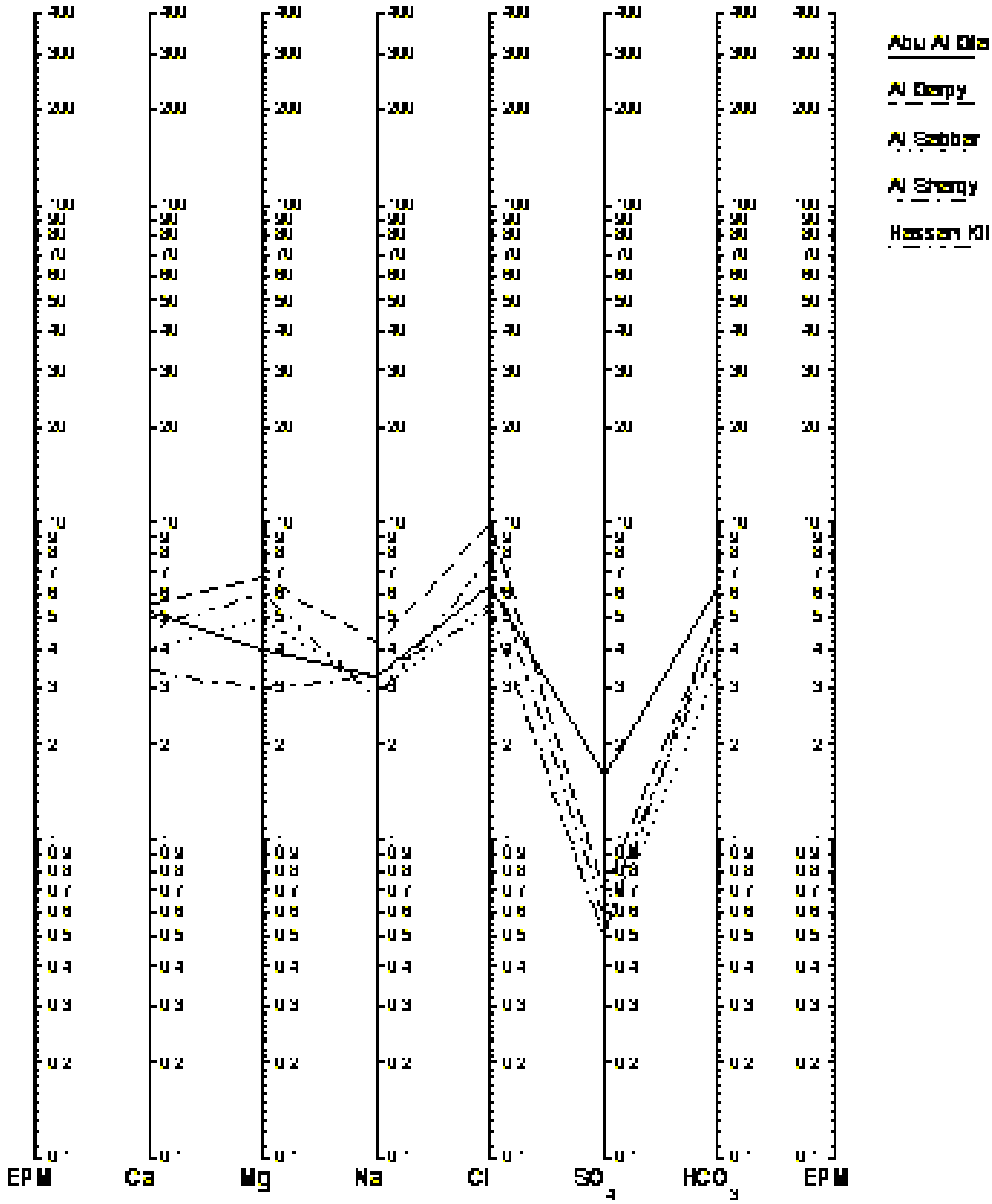


Fig. (4.4): Scholler digram plot for the samples of the second group

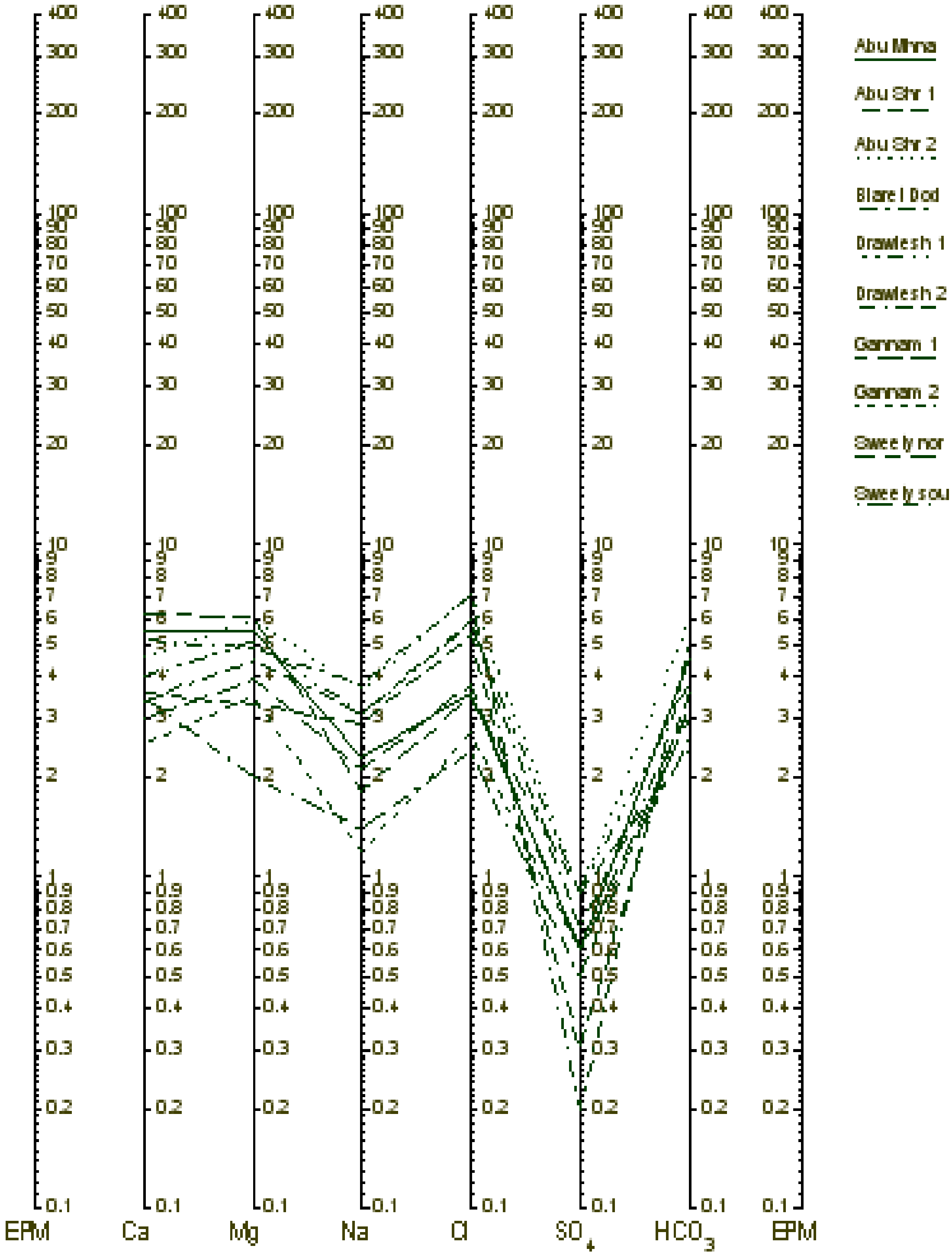


Fig. (4.5): Scholler digram plot for the samples of the third group

4.3. Water genesis

The most abundant water type in the study area is earth alkaline water with increase portion of alkalis with prevailing sulphate and chloride. According to Piper and Durov diagrams the water samples are mixed with wastewater and fertilizers. Other water type is normal earth alkainea water with bicarbonate and sulphate, which means that the water samples are not affected from wastewater or fertilizers.

4.3.1. Doruv Diagrame

The importance of this diagrame is that it diplays some possible geochemical processes that could take place. The fields and line on the diagram show the classifications LIoyd and Heathcote (1985). The fields as given in (LIoyd and Heathcote, 1985) Figure (4.6) are:

Field (1): HCO_3^- and Ca^{+2} dominant, frequently indicates recharging water in limestone, sandstones and other aquifers

Field (2): this type is dominant by Ca^{+2} and HCO_3^- ions, association with dolomite. If Na^+ is significant, an important ion exchange is presumed.

Field (3): HCO_3^- and Na^+ are dominated, indicates ion exchange water

Field (4): SO_4^{-2} is dominant, or anions discriminate and Ca^{+2} dominant, Ca^{+2} and So_4^{-2} dominant, frequently indicates a regharge water in lava and ,

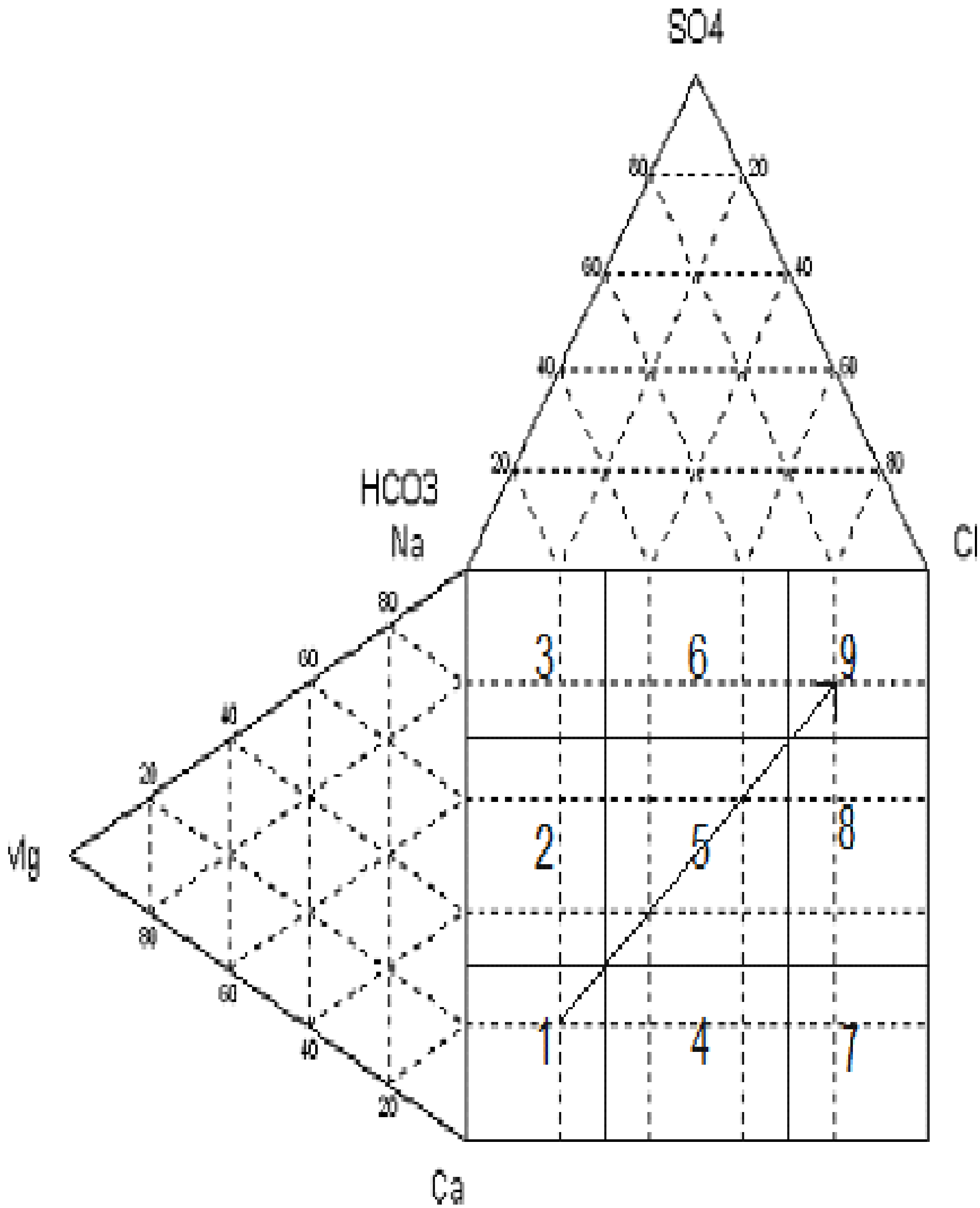


Fig. (4.6): Durov plot with water types classification according to LIoyd and Heathcoat, 1985

otherwise mixed water or water exhipiting simple dissolution may be indicated.

Field (5): no dominant anion or cation, indicates water exhibiting dissolution or mixing.

Field (6): SO_4^{-2} dominant or dicriminant and Na^+ dominant, water type is not frequently encountered and indicates probable mixing influence.

Field (7): Cl^- ad Na^+ dominant frequently encountered unless cement pollution is present. Otherwise the watewr may result from reverse ion exchangeof Na- Cl waters.

Field (8): Cl^- dominant anion and Na^+ dominant cation, indicate that the groundwatersbe related to reverse ion exchange of Na-Cl waters.

Field (9): Cl^- and Na^+ dominant frequently indicate end point waters.

For the water samples collected in April 2007 most of the springs plot in field 5 which indicates no domination of cation or anion they are located along the mixing line which indicates mixing the recharge groundwater with sewage and this agree with piper plot results which put them in the area of earth alkaline water with increased portion of alkalis and with prevailing sulphate and chloride. One well (Bir Kazem Al Sharief) plots in field 4 which indicates that SO_4 or Cl dominant, or anion discriminant and Ca dominant, Ca and SO_4 dominant, frequently indicates simple mixing with wastewater, on piper plot it plots in the area of earth alkaline water with increased portion of alkalis and with prevailing sulphate and chloride the water type is Ca-Na-Mg-K-Cl-HCO_3. Kanar plots in field 8 which indicates Cl dominant anion and Na dominant cation, so indicates that the water may be related to reverse ion exchange of Na-Cl water which comes from high sewage being mixed with the spring water. Al Mjnonh well plots in field 1 the water type is with HCO_3 and Ca dominant. This indicates recharging water in the limestone so this well is not polluted and represents the original water type in the study area. For the water samples collected in October 2007 most of them plot in field 5 as shown in Figures (4.7) and (4.8).

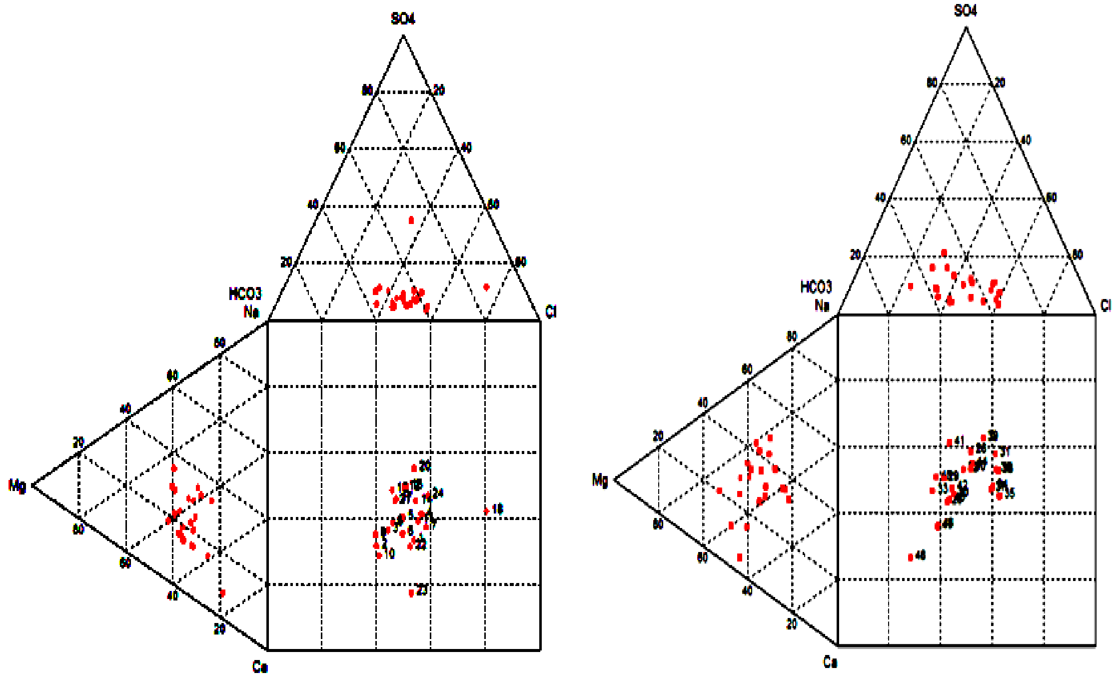


Fig. (4.7): Durov digrames for the samples collected in April, 2007.

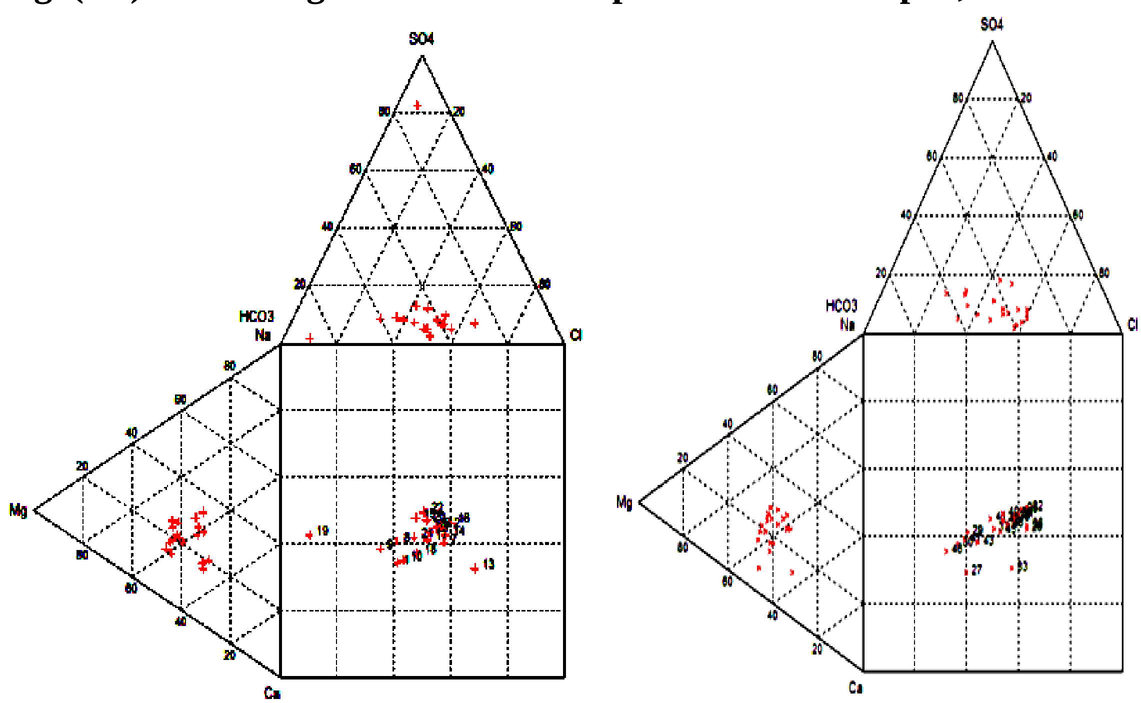


Fig. (4.8): Durov digrams for the samples collected in April, 2007.

4.3.2. Saturation Indices

Depending on the Aquachem soft-ware the Saturation Indices (SI) which is a method for expressing the extent of chemical equilibtium between the water and the mineral phases of the aquifer materials maks use of saturation indices. The equation that represnts the degree of water saturation with respect to a certain material is:

$$\mathbf{SI = log (K_{IAP}/K_{SP})}$$

Where

SI: the saturation index of a particular mineral

K_{IAp}: the ion activity product

K_{SP}: the solubility product

The importance of the saturation indices is to show the possible dissolution/precipitation processes during the water rock interaction.

If

SI value = 0: the water is in equilibrium with respect to the particular mineral.

SI value > 0: the water is over saturated with respect to that mineral, and thus tends towards its precipitation.

SI value < 0: the water is under saturated with respect to that mineral, and thus tends towards its dissolution.

Apendix (V) shows the saturation indices for five mineral phases for the water samples collected in April 2007. The calculations show that the water of most of the springs and dug wells is unsaturated with respect to the sulfate mineral phases (Gypsum and Anhydrite) and over saturated respect to Calcite, Aragonite and Dolomite.

4.4. The water parameters interrelationships

Using Microsoft Excel software different interrelationships appear between some parameters of the samples collected from the springs. Figures (4.9) and (4.10) show an increasing of [Cl^-] and [Na^+] with [TDS] indicating that the higher salinization is caused by the more soluble NaCl.

Figer (4.9) show high correlation between TDS and Na where the majority of the samples plot around the line with R-square of 0.9003.

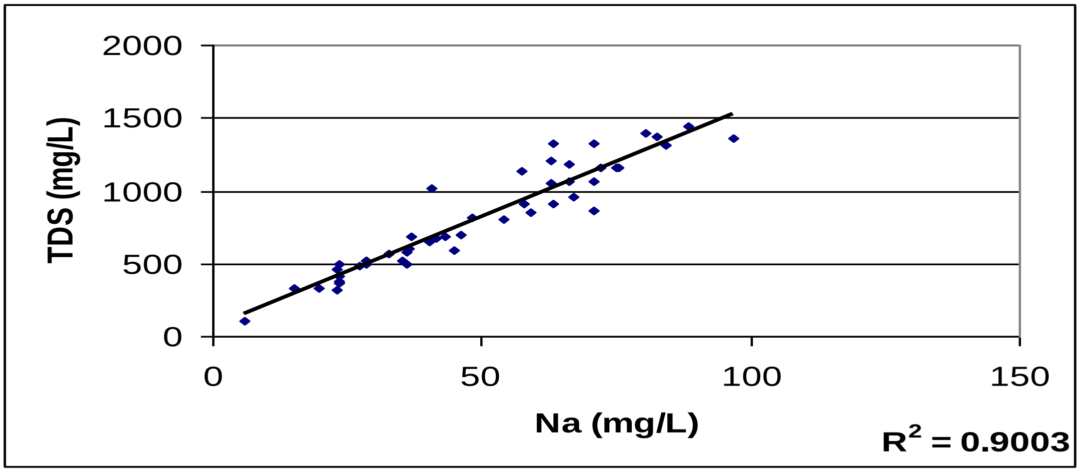


Fig. (4.9): relationship between TDS and Na of very high significant relationship.

Also high interrelationship appears between TDS and Cl with R-square of 0.892 as shown in figure (4.10) below.

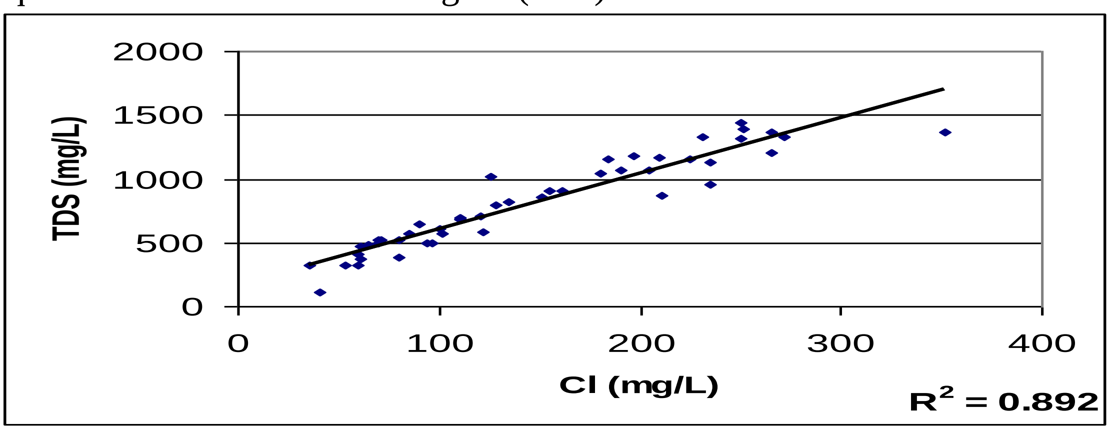


Fig. (4.10): relationship between TDS and Cl of good significant relationship.

Between Na and Cl appears high interrelationship with R-square of 0.89 as shown in Figre (4.11) below which mean that the water of most of the springs and dug wells are from the same water body.

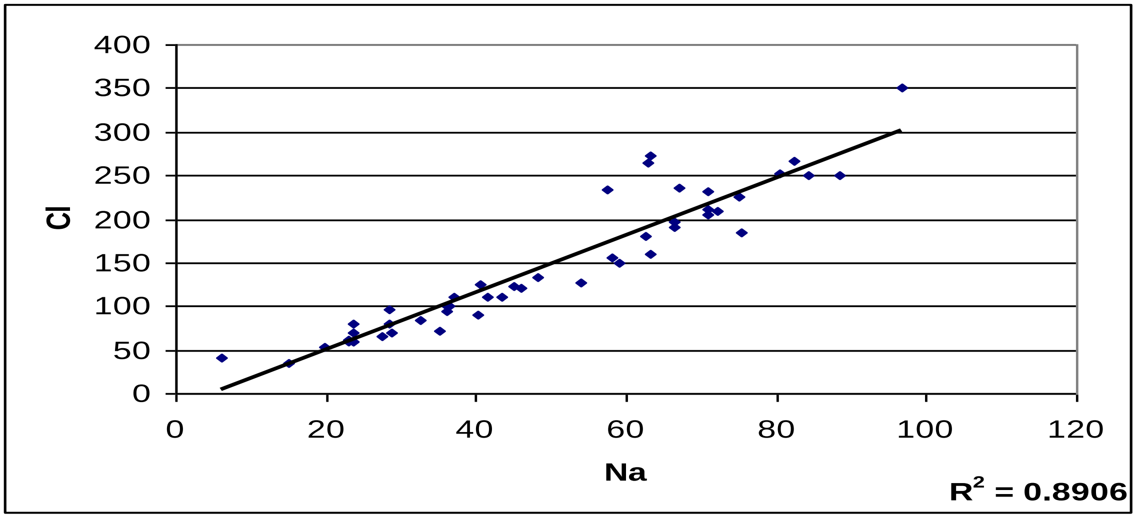


Fig. (4.11): relationship between Na and Cl of good significant relationship.

Chapter Five: Discussion

5.1. Evaluation of water quality for drinking

The results revealed that 43 wells and springs in the study area were polluted. While, five wells were unpolluted according the (WHO, 2004) standards. The EC and TDS values in the polluted wells and springs range from 800 µs/cm to 2300 µs/cm and from 512 mg/l to 1450 mg/l respectively, which were above the (WHO, 2004) standards (750 µs and 500 mg/l, respectively) to be suitable for drinking purpose. The exceeded values of TDS and EC were due to the high concentration of some cations and anions as shown in the interrelationship in the previous chapter. The high concentrions of cations and anions were due to the location of the wells and springs in agricultural fields, which are cultivated intensevly with drip fertigated vegetables. In those fields chemical fertilizers (urea, ammonium sulfate, potassium chloride, potassium nitrate and others) and manures are used. In addition, sixteen wells and springs are located in east the of study area lie within the area of uncollected wastewater. So contamination may occur from a variety of human activities such as agriculture, sanitation, traffic, or waste disposal practices. These may lead to contamination of groundwater both with pathogenic microorganisms and with hazardous chemicals such as nitrate.

5.1.1. The major cations in groundwater

Sodium is often naturally found in groundwater. It can be tasted by most people at concentrations of 200 mg/L or more. High concentrations of sodium in groundwater occur naturally in some areas. An increase in sodium in groundwater above ambient or natural levels may indicate pollution from point or non-point sources or salt water intrusion. As the result show 8% of the springs and dug wells have in the first sodium sampling between (80-90) mg/L and 19% have sodium sampling between (60-70) mg/L, some of these springs that have high concentrations of sodium were Bir Kursa Old that is located between houses in Kursa village. Other wells like Alhriebat (1), Abu Shrar (1) and (2), Biaret Dodin are located in Wad Abu Al Qamrah which is considered the first region in Dura area for cultivated agrigulture that is depending on the water of these springs and dug wells for the irrigation purposes.

The analyses of potassium showed that sixty four percent of the springs and dug wells of the first sampling and fifty eight percent for the second sampling exceed WHO standards. Some of these wells are located near and between houses like; Al Alqa, Kursa Old, Ain Set Al Room, Kallaf, Al Shareqy well, Bir Kazem Al Sharief, Bir Shaheen, Al Garpy well, Al Sabbar, Hassan Khlil and Abu Al Glasy. Other wells are located in cultivated areas between green houses like; Gannam (1) and (2), Kursa south, Wad Sweety south and north, Hninh, Al Majour, Bir Shaheen, Drawiesh (1) and (2), Biaret Dodin, Abbu Shrar (1) and (2), Bir Sied Amru and Bir Abu Mhna.

The analyses of calcium in groundwater showed that many of the springs and dug wells exceeded (WHO, 2004), these wells are located in different sites in the study area. For springs and dug wells that are located in places far away from houses and human activities the concentrations of this cation were below (WHO, 2004) standards like; Bir Abdah, Ain Abu Sief, Ain Fares, Al Sapih, Kanar, Bir Musa Al Drapi. Some of these springs and dug wells are located low and cultivated area like Wad Abu Alqamra, which is considered low land comparing to the study area and most of water running and infiltrating in it in the raining season, also it is considered a cultivated land that depended on the water of these springs and dug wells for cultivation.

The highly concentration of K in the wells and springs in the study area were due to leaching of fertilizers, diminerazation of K from manures, which is highly used by farmers in the well catchment. In additions, the potassium in organic wastes (manure and sewage sluge) occurs perdominantely as soluble inorganic K^+. The waste material can supply quantities of potassium depending on the rate applied, so these quantities can impacte the quality of surface and groundwater (Beaton, 1999).

5.1.2. The major anions in groundwater

The nitrate analyses showed that about 62% of the springs and dug wells were nitrate polluted. Half of the polluted springs had nitrate concentrations more than 100 mg/L, and for the second sampling 60% of the springs and dug wells were nitrate polluted 33% of these springs had nitrate concentrations more than 100 mg/L, high nitrate concentrations in many wells as a result of using manure for intensive agriculture, some of these springs and dug wells were Al Alqa, Wad Al Shajnh, Gannam (1) and (2), Wad Sweety north, Ain Taha, Kanar, Bir Shaheen, Al Hriebat (2), Drawiesh (1) and (2), Al Garpy well, Abu Al Glasy, Al Sabbar, Biaret Dodin, Abu Shrar (1). The rest of the springs are located near green houses and cultivated lands and between homes, so the result show that these springs and dug wells were highly affected by the fertilizers and sewage that inflitrate from the cesspits of the near houses. Similiary, common sources of nitrate include; fertilizers and manure, animal feedlots, municipal wastewater and sludge, septic systems and N-fixation from atmosphere by legumes, bacteria and lightning (Self and Waskom, 2005).

The chloride analyses show that 15% of the springs and dug wells exceeded the standard WHO for the first sampling. These springs and dug wells that have high chloride concentrations have also high concentration of nitrate and major cations. Some of these springs were Al Alqa, Kursa Old, Hninh (2), Bir Shaheen, Al Hriebat (1) and (2), Drawiesh (1) and (2), Abu Al Glasy, Hassan Khlil, Al garpy well, Biaret Dodin. So chloride shared with other cations and anions for the sources of pollutatnts.

Increase levels of chloride in groundwater can have unfavorable environmental and agricultural effects. High soil salinity creates a water concentration gradient between plant roots and their surroundings, decreasing osmotic pressure and drawing water out of the plants. This leads to poor germination, stunted growth, and smaller leaves and yellowing leaf tips, so high chloride concentrations in irrigation water can damage some plants. Measurement of ground water and wastewater chloride concentration is a good indicator of contamination from human sources. Soil carries a net negative charge, so cations adsorb tightly to soil particles and become immobile. Conversely, anionic chloride does not bind to soil particles and remains mobile in ground water. Thus, it acts as an excellent tracer of contaminant sources (Man- Tech, 2000). Chloride may enter fresh water systems naturally from erosion, or due to human intervention via field irrigation return flows, runoff and inorganic chemical industrial waste disposal.

The sulfate analysis values revealed that no well contaminated according to the (WHO, 2004) standard. Sulfates occur naturally in numerous minerals and are used commercially, principally in the chemical industry. Finally the bicarbonate analyses showed that only Abu Al Glasy and Abu Shrar (2) were the only wells that exceeded (WHO, 2004) standards in the study, bicarbonate concentrations depending on the soil layers that water move through it befor reaching groundwater.

Finally only five of these springs and dug wells are considered suitable for drinking water depending on WHO standards these wells were Bir Abdah, Ain Abu Sief, Ain Fares, Al Sapih and Bir Musa Al Drapi, the first four wells are located in places far away from civilization and intensive agriculture, so the pollutant sources mentiniod in this this study would not affected these springs and dug wells, the fifth dug well bir Musa Al Drapi has water table of more than 30 m, which make it far away from the pollutants.

5.1.3. Bacterial Contamination

The water analyses showed that some of the springs and dug wells had uncounted number of total count bacteria these wells were Al Alqa, Gannam (1), Gannam (2), Bir Kursa Old and Ain Taha.for total coliform bacteria analyses also these wells Al Alqa, Yasser Al Drapi, Wad Al Shajnh, gannam (1), Ain Taha and Hninh (1) had uncounted number of total colifom bacteria. For fecal coliform water analyses only Al Alqa well had uncounted number of fecal coliform bacteria. 73% of the springs and dug wells were contaminated with total coliform bacteria for the first sampling and 27% were contaminated for the second sampling, some of these springs and dug wells were Gannam (2), Kursa Old, Kursa south, Ain Abu Sief, Wad Sweety south and north, Al Majour, Ain Fares, Ain Set Al Room, Ain Taha, Kallaf, Bir Salman, Kazem Al Sharief, Al Hriebat (1), Ain Al Sweety, Ain Kazaz, Bir Hejh, Al Garpy well, Al Sabbar, Hassan Khlil, Abu Al Glasy, Biaret

Dodin, Abu Shrar (1), Ain Suhil Amru, Abu Mhna, Hed Al hriebat, Ibrahim Al Hlisy, Musa al Drapi, Al hejrh and Al majnonh. These wells are located between homes and affected by the sewage that infiltrate form the cesspits or the animale manure that use for agriculture and some of these springs were opened and dead animals or wastes could fall through it and cause bacterial contamination.

Coliform bacteria are much more common in springs and shallow wells compared to deeper wells because bacteria are naturally filtered out by soil and rock as surface water infiltrates into the ground. Deeper wells (greater than 100 feet) can still be contaminated by coliform bacteria if they are improperly constructed by allowing surface water to flow along the well casing directly into the deep groundwater or if nearby land uses are causing contamination of deep groundwater.

The fecal coliform analyses showed that about 48% of the springs and dug wells were contaminated with fecal coliform bacteria some of these springs were Wad al Shajnh, Gannam (1) and (2), Kursa Old, Ain Abu Sief, Wad Al sweety south and north, Hninh (1) and (2), Al Majour, Ain Taha,Kallaf, Bir Shheen, al Hriebat (1), bir Ali Al Sharief, ain Ali Al Sharief, Drawiesh (1), Abu Shrar(1) and (2) and Ain Suhil Amru. These polluted springs may be opened like Al Alqa well, or may be located in low areas like Wad Abu Al Gamrah which was affected by all the water runoff form the study area, or these springs may ba located between homes and affected by sewage.

If the test shows the presence of coliform bacteria, your water has some degree of contamination. Most types of coliform bacteria are harmless to humans, but some can cause mild illnesses and a few can lead to serious waterborne diseases. Coliform bacteria are often referred to as “indicator organisms” because they indicate the potential presence of disease-causing bacteria in water (Penn State, 2007).

The occurrence of pathogens and indicator organisms in groundwater and surface water sources depends on a number of factors, including intrinsic physical and chemical characteristics of the catchment's area and the magnitude and range of human activities and animal sources that release pathogens to the environment. Groundwater is often less influence of contamination sources than surface water due to the barrier effects provided by the overlying soil and its unsaturated zone. Groundwater contamination is more frequent where these protective barriers are breached, allowing direct contamination. This may occur through contaminated or abandoned wells or underground pollution sources, such as latrines and sewer lines, 31 springs in the study are contaminated with Fecal coliform.

5.2. Evaluation the water for irrigation and other agricultural purpose

For the first sampling in the study no well was considered unsuitable for irrigation purposes, 58% of the springs and dug wells were considered Excellent for irrigation purposes. The rest of the sprigs were considered good for irrigation purposes depending on SSP evaluation.

For the second sampling 11% of the springs and dug wells were considered Excellent for irrigation purposes depending on SSP these wells were Al Alqa, Yasser Al Drapi, Gannam (2), Musa Al Drapi and Al Majnonh. 53% of the springs and dug wells were considered good for irrigation purposes. The rest of the springs were considered Permissible for irrigation purposes, these wells were Hninh (1), Al Sharqy well, Al Hriebat (2), Drawiesh (1) and (2), Al Garpy well, Abu Al Glasy, Biaret Dodin, Abu

Srar (1) and (2), Ain Suhil Amru, Bir Sied Amru, Bir Abu Mhna, Hed Al Hriebat and Ibrahim Al Hlisy. Note that the wells which were considered good depending on SSP located in the areas that have intensive agriculture where high use of animal manures and fertilizers.

Depending on Wilcox diagram all of the springs and dug wells have low sodium and SAR values less than ten, for the first reading 60% of the springs and dug well have SAR values less than one. The rest 40% of the springs and dug well have SAR values between 1- 1.60.

For the second sampling 47% of the springs and dug wells have SAR values less than one. The rest of the springs and dug wells have SAR values between (1-2.60).

They are classified into three water classes according to the EC-SAR relationship of low sodium-low salinity hazard (S1-C1) as Ain Fares and Al Sapih, and of low sodium-medium salinity hazard (S1-C2) as Al Sharqy and Kanar, and of low sodium- high salinity hazard (S1-C3) as Bir Shaheen.

5.3. Water type

Piper classification of water samples show five types, most of these samples plot in the area of earth alkaline water with increased portion of alkalis with prevailing sulphate and chloride, also Durov diagram show most of the water sample in the mixing field with no dominant anion or cation which mean that these water samples were polluted because of mixing with wastewater.

5.4. Variation in water quality from season to another

The samples collected in winter have a high concentration of the major and minor ions as a result of a dilution by the recharge water from precipitation. This appear in most of the springs and dug wells, here wastewater play a good rule by mixing with water recharging to the aquifer, and this mixing increase in winter as a result of continous flow of precipitation and continous recharging after along drought period in summer.

5.5. Conclusions

The spings and dug wells in Dura area were found to be discharging from Eocene-Alluvial Aquifer that consists of limestone, dolomite, marl, calcareous karstic limestone and chalk.

Five wells (Abdh, Ain Abu Sief, Ain Fares, Al Sapih and Bir Musa Al Drapi) were considered suitable for drinking purposes according to WHO from the fourty eight springs and dug wells that tested in this study, the rest fourty three springs and dug wells were unsuitable for drinking purposes.for irrigation purposes and depending on SSP and SAR classification of water all the springs and dug wells were suitable for irrigation purposes.

Most of the springs and dug wells were considered hard and very hard especially in the the first reading. Also the results show that most of samples were contaminated with fecal and total coliform. Some of the polluted springs and dug wells located in near houses where direct contamination from septage takes place.

The water type's classification using Piper plot indicates the following in the first reading, the prevailing general water type was the normal earth alkaline water and was demonstrated by 87% of the springs and dug wells. The second general water type is the earth alkaline water with increases portion of alkalis and is demonstrated by 13% of the springs and dug wells. In the second reading the prevailing general water type is the normal earth alkaline water and is demonstrated by 38% of the springs and dug wells. Distribution for subclasses is as follows, the second general water type is the earth alkaline water with increases portion of alkalis and is demonstrated by 62% of the springs and dug wells.

5.6. Recomendations

1-a comprehensive water and metrological database for Palestine is essential.

2-A detailed Palestinian topographic contour map, geologic map and watershed map for the West Bank and Gaza Strip.

3-A comprehensive hydrological and hydrogeological study to identify the water bearing formation, water budget, hydraulic characteristic of the Palestinian aquifer systems as well as to identify the ground water flow pattern and underground water catchments is needed.

4-More detailed from the municipality, the farmers and the citizens with the pollution sources like sewers, septic tanks and pastures and tried to keep them away from watershed of the springs and dug wells.

5-Construction of sewage network system in the study area to decrease the influence of the septic tanks on the groundwater.

6-mostly of the springs and dug wells should be treated to improve its microbiological quality to acceptable levels.

7-Public health concern especially those springs and dug wells which show high nitrate and salinity pollution should be abandoned from domestic use and transferred to irrigation use.

8-Water of high quality should be used for direct human consumption while low quality water can mostly be used in agriculture.

9- The watershed is recommended to be under control of the operator either by direct ownership or protective covenants.

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Appendix (I):The forty eight springs and dug wells in Dura area, its name, coordinate, property and location.

well no	well name	Coordinate X	Y	property	site	WT I	WT II	Current water use
●1	Bir Al-Alqha	151039	96594	public	Alaqa	13	15	Agriculture
●2	Bir Yaser Al-Drapi	151001	97025	private	Imreesh	7	9	Domestic/agriculture
●3	Bir Abdah	151880	97266	private	Abdh	5.5	7	Agriculture
●4	Wad Al-Shajneh	152347	97868	private	Wad Al Shajna	8	9	Domestic/agriculture
●5	Bir Gnaam 1	152218	98733	private	Tarrama	6	5	Agriculture
●6	Bir Gnaam 2	152218	98733	private	Tarrama	7	6.5	Agriculture
●7	Bir Kursa old	151628	99111	public	Kursa	10.5	10.5	Domestic
●8	Bir Kursa south	151907	99661	private	Kursa	5.5	8	Domestic/agriculture
●9	Ain Abo Sief	151391	99874	private	Abu Sief	3	5	Agriculture
10	Wad Swety south	152456	100023	private	Wad Swety	11	12	Domestic/agriculture
11	Wad Swety north	152414	99907	private	Wad Swety	12	15	Domestic/agriculture
12	Hninh 1	152923	100234	private	Hninh	4.5	6	Domestic/agriculture
13	Hninh2	152966	100231	private	Hninh	4		Domestic/agriculture
●14	Al-Majour	153116	99798	private	Al Majoor	6.5	8	Domestic/agriculture
●15	Ain Fares	151142	104799	private	Kreesah	3	5	Domestic
16	Ain Set Al-Rome	152320	102625	private	Kreesah	spring		Domestic/agriculture
17	Ain Taha	152019	102586	private	Kreesah	spring		Domestic/agriculture
18	Kanar	154870	101569	private	Kanar	spring		Agriculture
●19	Al-Sa`pih	153372	104220	private	Wad Shqaq	spring		Domestic/agriculture
20	Kllaf	151783	103057	private	Kreesah	3	6	Agriculture
21	Bir Salman	152729	100708	private	Al Apher	3.5	6	Agriculture
22	Al-Bir Al-Sharqy	152965	101505	public	center	11	13	Agriculture
23	Bir kazem Al-Sharief	153103	101350	private	Wad Abu Qamra	6	8	Domestic/agriculture
24	Bir Shaheen	153231	101225	private	Wad Abu Qamra	12	14	Agriculture

Continue

well no	well name	Coordinate X.........................Y		property	site	WT I	WT II	Current water use
25	Bir Al-Hriebat 1	153403	101204	private	Wad Abu Qamra	7	9	Domestic/agriculture
26	Bir A-Hriebat 2	153413	101233	private	Wad Abu Qamra	12	15	agriculture
27	Bir Ali A-Sharief	154742	100433	Private	Wad Abu Qamra	6		Agriculture
28	Ain Ali Al-Sharief	100773	100773	private	Wad Abu Qamra	spring		Agriculture
29	Ain Al Sweety	154445	100774	private	Wad Abu Qamra	4	7	Domestic/agriculture
30	Ain Kazaz	154491	100764	private	Wad Abu Qamra	6	8	Domestic/agriculture
31	Al-Drawiesh 1	153985	101107	private	Wad Abu Qamra	6	8	Agriculture
32	Al-Drawiesh 2	154012	101143	private	Wad Abu Qamra	2	6	Agriculture
33	Bir Hejh	152400	101989	private	center	10	12	Domestic/agriculture
34	Al-Bir al-Garpy	152695	101936	public	center	9	13	
35	Bir Al-Sabbar	152337	101987	private	center	10	12	Domestic/agriculture
36	Bir Hassan Khlil	152410	101961	private	center	11	14	Domestic/agriculture
37	Bir Abu Al-Glasy	152642	101946	private	center	9	12	Domestic/agriculture
38	Biaret Dodin	152435	101381	private	Wad Abu Qamra	6	11	Agriculture
39	Bir Abu Shrar 1	153321	101351	private	Wad Abu Qamra	6	10	Agriculture
40	Bir Abu Shrar 2	153334	101283	private	Wad Abu Qamra	7	9	Agriculture
41	Ain Shil Amru	154213	101232	private	Wad Abu Qamra	spring		Agriculture
42	Bir S`ied Amru	153837	101414	private	Wad Abu Qamra	6	9	Domestic/agriculture
43	Bir Abu Mhna	153187	104209	private	Serta	4	6	Agriculture
44	Bir `Hed Al-Hriebat	153832	101570	private	Serta	4	9	Agriculture
45	Bir Ibrahim A-Hlisy	153803	101585	private	Serta	9	11	Domestic/agriculture
46	Musa Al-Drap`	152926	101276	private	Wad Abu Qamra	31	32	Agriculture
●47	Al-Hejrh	155606	99644	private	Fawwar camp	7	9	Agriculture
●48	Al-Majnonh	154372	99158	private	Al majnoneh	8	10	Domestic/agriculture

(Note ●: wells out of municipality boarder)

Appendix (II): Measured and calculated parameters for the water samples colleted in April and October, 2007

	well name	pH I	pH II	EC I µS/cm	EC II µS/cm	TDS I mg/L	TDS II mg/L	TH I mg/L	TH II mg/L	SSP I %	SSP II %	SAR I	SAR II
1	Bir Al-Alqha	7.5	7.4	1490	1650	939	1067	560.7	467.2	22.8	18.6	1.23	0.81
2	Bir Yaser Al-Drapi	7.1	7.4	1010	980	683	619	390.4	307.7	20.3	18.4	0.89	0.65
3	Bir Abdah	7.4	7.6	810	743	521	469	243.0	227.1	27.2	23.3	0.98	0.72
4	Wad Al-Shajneh	7.3	7.7	770	741	497	469	283.5	190.9	24.2	25.6	0.93	0.77
5	BirGnaam 1	7.5	7.6	1280	1160	811	725	344.8	327.4	28.5	24.7	1.13	0.87
6	Bir Gnaam 2	7.9	7.8	770	720	499	469	300.4	256.6	21.1	18.8	0.71	0.54
7	Bir Kursa old	8.2	7.2	2140	2180	1376	1387	695.2	544.5	28.6	29.1	1.36	1.12
8	Bir Kursa south	7.5	7.4	820	1020	531	661	275.3	244.6	23.7	25.0	0.74	0.77
9	Ain Abo Sief	7.5	7.1	730	710	469	469	275.3	195.5	18.2	21.0	0.60	0.57
10	Wad Swety south	7.5	7.5	890	695	553	427	274.8	236.1	26.8	25.1	0.86	0.59
11	Wad Swety north	7.0	7.1	1590	1840	1003	1173	613.8	493.2	15.0	20.8	0.71	0.99
12	Hninh 1	7.8	7.2	1330	1370	853	875	325.2	255.1	34.3	40.0	1.42	1.69
13	Hninh2	7.7		1890		1195		668.9		19.2		1.06	
14	Al-Majour	7.5	7.2	1420	1470	917	939	364.9	316.3	30.1	33.3	1.32	1.44
15	Ain Fares	7.3	7.3	500	451	320	299	167.4	128.8	29.0	32.9	0.77	0.93
16	Ain Set Al-Rome	7.6	7.6	1820	1650	1152	1067	450.5	358.9	31.0	33.9	1.48	1.58
17	Ain Taha	7.6	7.4	900	872	597	555	325.4	192.1	24.0	32.6	0.87	1.14
18	Kanar	7.6	7.1	780	739	491	469	290.3	202.8	17.8	26.7	0.60	0.89
19	Al-Sa`pih	7.5	7.4	600	510	384	341	235.2	139.8	21.1	23.0	0.67	0.49
20	Kllaf	7.7	7.5	1100	1140	725	725	300.4	182.4	28.1	39.3	1.15	1.48
21	Bir Salman	7.1	7.3	950	900	619	597	290.3	171.6	23.6	36.0	0.93	1.32
22	Al-Bir Al-Sharqy	7.6	7.4	1810	1570	1152	1003	320.2	221.3	49.0	42.8	1.83	0.57
23	Bir kazem Al-Sharief	7.7	9.1	1640	111	1067	704	352.5	125.1	35.7	21.5	1.45	0.19
24	Bir Shaheen	7.6	6.9	1770	1850	1109	1173	497.1	293.2	25.0	37.2	1.12	1.67

	well name	pH I	pH II	EC I µS/cm	EC II µS/cm	TDS I Mg/L	TDS II mg/L	TH I mg/L	TH II Mg/L	SSP I %	SSPII %	SAR I	SAR II
25	Bir Al-Hriebat 1	7.2	7.0	2180	1140	1365	725	426.6	303.8	39.1	35.0	1.69	1.22
26	Bir A-hriebat 2	7.0	7.7	2080	1830	1323	1173	455.9	231.2	37.9	54.0	1.45	2.14
27	Bir Ali A-Sharief	6.8		510		363		274.8		16.8		0.52	
28	Ain Ali Al-Sharief	7.8		920		597		300.3		27.3		1.13	
29	Ain Al-Swety	7.4	7.4	650	708	427	467	227.7	150.2	21.7	32.4	0.68	0.99
30	Ain Kazaz	7.5	7.2	760	762	491	448	271.8	164.6	21.0	27.3	0.72	0.80
31	Al-Drawiesh 1	7.2	7.4	1350	1470	875	939	455.4	216.8	34.3	52.3	1.45	2.19
32	Al-Drawiesh 2	7.4	7.2	1670	1180	1067	747	393.9	197.9	36.2	48.9	1.56	1.83
33	Bir Hejh	6.5	7.7	170	472	107	256	159.5	119.5	16.3	29.0	0.21	0.56
34	Al-Bir al-Garpy	7.5	7.2	2130	1300	1365	875	609.9	258.3	36.3	46.6	1.70	1.76
35	Bir Al-Sabbar	7.2	7.0	1840	1920	1152	1237	450.5	347.2	27.5	31.6	1.36	1.52
36	Bir Hassan Khlil	7.1	7.1	2080	1870	1344	1195	530.2	272.3	22.7	36.6	1.20	1.69
37	Bir Abu Al-Glasy	7.5	6.9	1810	2070	1152	1323	460.2	325.2	33.7	42.5	1.52	2.01
38	Biaret Dodin	7.1	7.0	2250	2350	1451	1493	507.1	377.6	40.8	46.8	1.71	2.16
39	Bir Abu Shrar 1	7.5	7.0	1660	1500	1045	939	344.6	200.1	44.5	59.1	1.55	2.57
40	Bir Abu Shrar 2	7.4	7.2	2060	1110	1323	725	530.6	186.3	35.9	51.7	1.59	1.77
41	Ain Shil Amru	7.5	7.1	1070	1080	683	683	282.3	135.5	27.3	46.2	1.12	1.76
42	Bir S`ied Amru	7.0	7.4	1420	1270	896	811	450.0	263.3	29.8	41.2	1.30	1.78
43	Bir Abu Mhna	7.2	7.3	1250	1430	811	917	547.6	287.7	23.1	39.2	1.00	1.70
44	Bir `Hed Al-Hriebat	7.4	7.1	1060	1050	683	683	281.7	148.5	26.2	38.3	1.07	1.31
45	Bir Ibrahim A-Hlisy	7.4	6.8	1080	940	683	597	325.4	164.6	22.1	35.6	0.89	1.16
46	Bir Musa Al-Drap`	7.4	7.7	510	740	320	469	185.7	105.9	19.8	18.6	0.48	0.30
47	Al-Hejrh	7.9	7.3	580	620	363	405	278.7	145.7	18.2	21.4	0.62	0.44
48	Al-Majnonh	7.0	7.6	810	460	533	299	329.4	119.8	19.0	12.9	0.69	0.11

Appendix (III): Chemical parameters values ($mg.L^{-1}$) of water springs and dug wells in Dura district collected in two seasons (April and October, 2007)

	well name	Ca^{+2} I mg/L	Ca^{+2} II mg/L	Mg^{+2} I mg/L	Mg^{+2} II mg/L	Na^{+} I mg/L	Na+ II mg/L	K^{+} I mg/L	K^{+} II mg/L	NH_4^{+} I mg/L	NH_4^{+} II mg/L	HCO^{-}_3 I mg/L	HCO^{-}_3 II mg/L	Cl^{-} I mg/L	Cl^{-} II mg/L	SO_4^{-2} I mg/L	SO_4^{-2} II mg/L	NO_3^{-} I mg/L	NO_3^{-} II mg/L
	Standard (WHO)	75		125		200		12		1.5		125-350		250		250		50	
1	Bir Al-Alqa	124.3	108.2	60.8	48.4	67.1	40.6	15.4	15.0	0.53	0.23	256.2	207.4	235.3	173.5	29.0	34.7	117.6	109.2
2	Bir Yasser Al-Drapi	96.2	76.2	36.5	28.6	41.0	26.5	9.3	9.1	0.57	0.20	231.8	195.2	90.1	73.4	30.3	15.3	110.2	109.4
3	Bir Abdah	56.1	58.1	25.0	20.1	36.7	25.5	11.8	11.1	0.46	0.27	148.8	170.8	72.1	66.7	28.3	24.4	25.6	20.4
4	Wad Al-Shajneh	64.1	38.1	30.0	23.6	36.7	24.6	9.9	9.9	0.55	0.21	144.0	102.5	94.1	80.1	29.1	21.5	116.6	82.9
5	Bir Gnaam 1	60.1	92.2	47.3	23.6	49.7	36.8	25.7	23.9	0.58	0.22	183.0	183.0	134.1	106.8	29.3	30.6	80.5	72.7
6	Bir Gnaam 2	50.1	62.1	42.6	24.9	28.0	20.8	14.2	13.0	0.57	0.21	158.6	122.0	96.1	70.1	30.8	17.4	76.4	68.6
7	Bir Kursa old	140.0	120.2	84.0	59.5	80.1	59.5	78.4	73.6	0.68	0.14	200.1	244.0	265.3	200.2	34.7	18.3	55.9	46.2
8	Bir Kursa south	50.1	64.1	36.5	21.0	28.0	27.4	19.0	17.8	0.66	0.25	207.4	170.8	80.1	83.4	27.7	11.8	34.1	29.8
9	Ain Abu Sief	50.1	42.1	36.5	21.4	23.6	18.0	9.3	9.5	0.51	0.23	205.0	146.4	61.1	53.4	23.9	21.3	25.3	19.4
10	Wad Sweety south	70.0	66.1	24.3	17.9	32.3	21.7	23.9	26.9	0.58	0.23	195.2	146.4	85.1	56.7	24.8	25.3	26.6	20.6
11	Wad Sweety north	123.3	96.2	74.3	62.6	41.0	50.0	16.6	16.0	0.61	0.23	148.8	146.4	125.1	106.8	41.0	22.5	125.9	120.3
12	Hninh 1	70.1	56.1	36.5	28.0	58.4	61.4	31.1	28.9	0.55	0.26	195.2	183.0	151.2	106.8	25.6	22.7	82.6	66.4
13	Hninh2	167.7		60.8		62.7		17.2		0.92		195.2		265.3		38.0		74.0	
14	Al-Majour	80.2	68.1	40.0	36.8	58.4	59.5	24.5	23.9	0.69	0.24	183.0	170.8	155.2	120.1	38.4	22.0	89.2	74.4
15	Ain Fares	34.1	24.8	20.0	17.5	23.6	24.6	15.4	8.1	0.55	0.29	114.7	109.8	60.1	53.4	25.7	11.5	13.5	13.2
16	Ain Set Al-Rome	80.2	61.3	60.8	50.8	71.4	69.8	36.0	27.7	0.81	0.16	234.2	244.0	210.2	146.8	24.5	23.7	94.2	72.4
17	Ain Taha	60.1	40.5	42.6	22.1	36.7	36.8	19.6	10.9	0.51	0.29	158.6	141.5	100.1	73.4	36.2	18.6	101.1	84.3
18	Kanar	56.1	42.5	36.5	24.5	23.6	28.3	8.7	8.1	0.56	0.30	178.1	170.8	70.1	53.4	22.5	11.0	110.8	84.8
19	Al-Sa`pih	44.1	36.1	30.4	12.5	23.6	13.2	9.3	10.5	0.47	0.34	131.8	109.8	79.1	58.1	23.5	8.8	31.8	27.4
20	Kllaf	50.1	28.1	42.6	28.0	45.3	47.2	14.2	14.2	0.67	0.30	195.2	146.4	121.1	100.1	17	30.8	45.2	57.0
21	Bir Salman	56.1	44.1	36.5	15.9	36.7	39.7	8.1	8.1	0.39	0.25	195.2	158.6	100.1	80.1	23.6	12.6	26.2	7.8
22	Al-Bir Al-Sharqy	68.1	56.9	36.5	20.1	75.8	19.9	114.8	96.6	0.62	0.51	307.4	246.4	185.2	157.2	26.7	24.7	51.3	43.9
23	Bir kazem Al-Sharief	80.2	40.1	37.0	6.1	62.7	4.8	46.3	18.8	0.41	0.24	278.2	48.8	180.2	33.4	11.1	45.6	10.2	5.3
24	Bir Shaheen	100.2	68.1	60.0	30.6	58.4	65.1	31.8	24.9	0.51	0.18	195.2	244.0	235.3	206.9	60.4	24.8	100.2	97.5

Continue

	well name	Ca^{+2} I mg/L	Ca^{+2} II mg/L	Mg^{+2} I mg/L	Mg^{+2} II mg/L	Na^{+} I mg/L	Na+ II mg/L	K^{+} I mg/L	K^{+} II mg/L	NH_4^{+} I mg/L	NH_4^{+} II mg/L	HCO_3^{-} I mg/L	HCO_3^{-} II mg/L	Cl^{-} I mg/L	Cl^{-} II mg/L	SO_4^{-2} I mg/L	SO_4^{-2} II mg/L	NO_3^{-} I mg/L	NO_3^{-} II mg/L
	Standard (WHO)	75		125		200		12		1.5		125-350		250		250		50	
25	Bir Al-Hriebat 1	80.2	64.1	55.0	35.9	80.1	49.1	78.4	43.1	0.62	0.16	268.4	231.8	250.3	93.4	22.6	60.7	70.3	68.5
26	Bir A-Hriebat 2	100.2	38.1	50.0	34.1	71.4	74.6	96.6	84.5	0.59	0.17	219.6	268.4	230.3	166.9	44.8	61.2	107.0	100.9
27	Bir Ali A-Sharief	70.0		24.3		19.3		9.9		0.48		146.4		54.1		32.5		4.1	
28	Ain Ali Al-Sharief	60.1		36.5		45.3		12.4		0.47		163.5		122.1		22.2		78.4	
29	Ain Al-Swety	40.1	24.0	31.0	22.8	23.6	28.3	8.7	9.1	0.44	0.30	158.6	146.4	60.1	53.4	22.6	50.6	34.1	32.5
30	Ain Kazaz	56.1	28.1	32.0	23.6	28.0	23.6	9.9	8.7	0.46	0.32	200.1	134.2	65.1	60.1	13.7	29.7	40.6	33.2
31	Al-Drawiesh 1	80.2	40.1	62.0	28.0	71.4	73.6	65.1	60.2	0.52	0.17	234.2	158.6	210.2	153.5	41.1	42.6	140.9	134.0
32	Al-Drawiesh 2	68.1	44.1	54.4	22.3	71.4	59.5	53.6	48.1	0.70	0.25	195.2	183.0	205.2	100.1	31.4	31.9	101.6	88.4
33	Bir Hejh	32.0	16.0	19.3	19.7	6.2	14.2	13.6	14.4	0.64	0.28	48.8	109.8	40.0	33.4	19.2	25.6	25.6	15.9
34	Al-Bir al-Garpy	110.2	64.1	81.3	24.9	97.5	65.1	107.5	66.9	0.65	0.25	305.0	158.6	352.4	146.8	34.6	38.6	145.6	133.5
35	Bir Al-Sabbar	80.2	76.2	60.8	39.4	67.1	65.1	20.8	15.6	0.58	0.23	207.4	170.8	197.2	173.5	24.4	29.5	116.6	102.3
36	Bir Hassan Khlil	92.2	46.1	72.9	39.4	62.7	64.2	14.8	14.4	0.65	0.23	263.5	183.0	273.3	173.5	30.5	20.6	88.8	82.5
37	Bir Abu Al-Glasy	104.2	83.0	48.6	28.9	75.8	82.1	54.8	46.3	0.75	0.30	378.2	219.6	225.2	193.5	76.5	39.6	135.4	125.2
38	Biaret Dodin	104.2	71.3	60.0	49.0	88.8	96.3	123.9	96.6	0.47	0.22	305.0	219.6	250.3	213.6	11.5	16.1	145.6	125.5
39	Bir Abu Shrar 1	72.1	34.1	40.0	28.0	67.1	83.1	102.1	84.5	0.54	0.19	224.5	195.2	190.2	186.9	12.6	21.3	114.6	97.6
40	Bir Abu Shrar 2	92.2	40.5	73.0	21.0	84.5	54.8	89.9	61.2	0.73	0.25	361.1	170.8	250.3	106.8	45.5	17.9	78.8	71.4
41	Ain Shil Amru	52.1	19.2	37.0	21.0	45.3	47.2	9.3	11.3	0.56	0.23	195.2	183.0	110.1	80.1	14.2	13.2	29.0	28.9
42	Bir S`ied Amru	80.2	66.5	60.7	24.5	62.7	66.1	41.4	31.8	0.47	0.24	231.8	244.0	160.2	113.5	37.2	16.1	44.2	41.2
43	Bir Abu Mhna	110.0	77.0	66.3	23.2	54.0	66.1	37.8	33.0	0.38	0.22	280.6	268.4	128.1	120.1	27.6	16.1	43.6	35.6
44	Bir `Hed Al-Hriebat	60.1	21.2	32.0	22.3	41.0	37.8	8.1	10.5	0.71	0.27	134.2	146.4	110.1	93.4	58.7	30.9	69.1	58.1
45	Bir Ibrahim A-Hlisy	60.1	28.1	42.6	23.6	36.7	34.0	9.9	13.0	0.38	0.44	163.5	195.2	100.1	66.7	62.2	24.3	52.8	46.3
46	Bir Musa Al-Drap`	38.1	20.0	22.0	14.1	14.9	7.6	10.5	7.7	0.46	0.43	146.4	122.0	35.0	43.4	26.8	10.6	18.4	19.5
47	Al-Hejrh	50.1	30.1	37.3	17.7	23.6	12.3	8.7	10.5	0.40	0.34	170.8	131.8	60.1	46.7	33.1	15.1	67.3	56.2
48	Al-Majnonh	66.0	26.1	40.0	13.6	28.0	2.9	12.4	9.3	0.40	0.35	195.2	136.6	70.1	28.0	35.5	15.3	92.7	76.6

Appendix (IV): The number of Total Count Bacteria, Total Coliform Bacteria and Fecal Coliform for the water samples collectd in April and October, 2007.

Well	well name	TC I	TC II	T.Col I	T.Col II	F.Col I	F.Col II	Well no	well name	TC I	TC II	T.Col I	T.Col II	F.Col I	F.Col II
1	Bir Al-Alqha	un	un	un	un	un	un	25	Bir Al-Hriebat 1	395	4120	188	0	101	0
2	Bir Yaser Al-Drapi	1179	127	un	0	1	0	26	Bir A-hriebat 2	152	2967	0	69	0	1200
3	Bir Abdah	1672	1224	19	0	0	1	27	Bir Ali A-Sharief	1947		593		537	
4	Wad Al-Shajneh	1669	60	un	un	1	0	28	Ain Ali Al-Sharief	94		20		7	
5	BirGnaam 1	un	800	un	77	5	395	29	Ain Al-Swety	1261	4227	25	0	0	0
6	Bir Gnaam 2	un	108	56	0	1	1	30	Ain Kazaz	800	173	0	0	0	0
7	Bir Kursa old	un	310	17	0	0	4	31	Al-Drawiesh 1	5333	90	133	3	6	0
8	Bir Kursa south	872	un	70	0	1	1	32	Al-Drawiesh 2	973	1554	103	1	0	3
9	Ain Abo Sief	1091	800	141	4	2	23	33	Bir Hejh	2773	183	1	0	0	0
10	Wad Swety south	1733	un	57	0	1	0	34	Al-Bir al-Garpy	2800	2560	1	0	0	0
11	Wad Swety north	1333	un	4	0	1	5	35	Bir Al-Sabbar	2453	153	16	0	0	19
12	Hninh 1	1035	4100	un	3	30	19	36	Bir Hassan Khlil	2880	783	3	0	0	0
13	Hninh2	1621		104		1		37	Bir Abu Al-Glasy	1520	415	16	0	0	0
14	Al-Majour	352	3717	39	0	3	43	38	Biaret Dodin	580	3000	24	0	0	1
15	Ain Fares	403	580	67	0	0	0	39	Bir Abu Shrar 1	1893	3133	89	0	7	1
16	Ain Set Al-Rome	1184	4387	100	0	0	0	40	Bir Abu Shrar 2	773	3833	68	1	9	55
17	Ain Taha	un	178	un	0	4	0	41	Ain Shil Amru	1000	118	265	0	2	0
18	Kanar	544	573	13	0	0	0	42	Bir S`ied Amru	2453	un	3	4	0	4
19	Al-Sa`pih	151	140	0	0	0	0	43	Bir Abu Mhna	600	540	67	0	0	2
20	Kllaf	5067	4500	118	0	16	0	44	Bir `Hed Al-Hriebat	373	667	33	0	0	2
21	Bir Salman	2005	3717	65	0	0	3	45	Bir Ibrahim A-Hlisy	83	63	1	0	0	0
22	Al-Bir Al-Sharqy	239	200	0	1	0	un	46	Bir Musa Al-Drap`	1973	1970	25	0	0	0
23	Bir kazem Al-Sharief	19	41	2	0	0	0	47	Al-Hejrh	1733	1563	3	0	0	0
24	Bir Shaheen	215	240	107	151	61	85	48	Al-Majnonh	680	650	11	0	0	0

Note (un): uncounted number of bacteria

Appendix (V): Saturation Indices values for the water samples collected in April, 2007.

	Well name	Calcite	Aragonite	Dolomite	Gypsum	Anhidrite		Well name	Calcite	Aragonite	Dolomite	Gypsum	Anhidrite
1	Bir Al-Alqha	0.11	-0.05	0.04	-2.2	-2.1	25	Bir Al-Hriebat 1	0.52	0.38	1.06	-2.557	-2.79
2	Bir Yaser Al-Drapi	-0.07	-2.29	-0.21-	-2.07	-0.21	26	Bir A-hriebat 2	0.42	0.3	0.99	-1.83	-2.05
3	Bir Abdah	-0.22	-0.36	-0.5	-2.41	-2.63	27	Bir Ali A-Sharief	-0.1	-0.16	0.16	-2.34	-2.56
4	Wad Al-Shajneh	-0.19	-0.33	-0.42	-2.33	-2.55	28	Ain Ali Al-Sharief	-0.21	-0.35	-0.37	-1.96	-2.18
5	BirGnaam 1	-0.16	-0.3	-0.18	-2.5	-2.72	29	Ain Al-Swety	-0.65	-0.8	-1.42	-2.1	-2.32
6	Bir Gnaam 2	0.03	-0.11	0.31	-2.27	-2.49	30	Ain Kazaz	0.29	0.15	0.72	-2.37	-2.59
7	Bir Kursa old	0.11	-0.04	0.27	-2.5	-2.72	31	Al-Drawiesh 1	-0.26	-0.4	-0.28	-2.48	-2.7
8	Bir Kursa south	1.05	0.91	2.24	-2.09	-2.31	32	Al-Drawiesh 2	0.07	-0.07	0.25	-2.59	-2.81
9	Ain Abo Sief	0.34	0.2	0.9	-2.25	-2.47	33	Bir Hejh	-0.08	-0.22	0.09	-2.08	-2.3
10	Wad Swety south	0.03	0.12	0.27	-2.34	-2.56	34	Al-Bir al-Garpy	-0.01	-0.15	0.23	-2.24	-2.46
11	Wad Swety north	0.03	-0.11	0.28	-2.4	-2.62	35	Bir Al-Sabbar	-1.72	-1.86	-3.31	-2.56	-2.78
12	Hninh 1	0.15	0.01	0.19	-2.24	-2.46	36	Bir Hassan Khlil	-0.06	-0.11	0.11	-2.1	-2.32
13	Hninh2	-0.28	-0.42	-0.51	-2.38	-2.6	37	Bir Abu Al-Glasy	-0.07	-0.22	0.11	-2.18	-2.4
14	Al-Majour	0.42	0.27	0.9	-2.26	-2.48	38	Biaret Dodin	-0.07	-0.22	0.11	-2.18	-2.4
15	Ain Fares	0.63	0.49	1.18	-1.86	-2.08	39	Bir Abu Shrar 1	0.52	0.37	1.06	-1.72	-1.94
16	Ain Set Al-Rome	0.15	0.0	0.35	-2.05	-2.27	40	Bir Abu Shrar 2	0.04	-0.11	0.19	-2.55	-2.77
17	Ain Taha	0.55	-0.7	-0.99	-2.45	-2.67	41	Ain Shil Amru	0.18	0.04	0.46	-2.59	-2.81
18	Kanar	0.33	0.18	0.89	-2.3	-2.52	42	Bir S`ied Amru	0.34	0.2	0.94	-2.03	-2.25
19	Al-Sa`pih	0.07	-0.07	0.35	-2.17	-2.39	43	Bir Abu Mhna	0.02	-0.12	0.25	-2.6	-2.82
20	Kllaf	-0.18	-0.33	-0.23	-1	-1.22	44	Bir `Hed Al-Hriebat	-0.27	-0.41	-0.3	-2.11	-2.33
21	Bir Salman	0.66	0.52	1.52	-2.58	-2.8	45	Bir Ibrahim A-Hlisy	0.14	0.0	0.41	-2.14	-2.36
22	Al-Bir Al-Sharqy	0.19	0.05	0.66	-2.56	-2.78	46	Bir Musa Al-Drap`	0.1	0.14	0.5	-1.94	-2.16
23	Bir kazem Al-Sharief	0.35	-0.49	-0.53	-2.37	-2.59	47	Al-Hejrh	-0.12	-0.26	-0.03	-1.94	-2.16
24	Bir Shaheen	0.39	0.24	0.85	-2.3	-2.52	48	Al-Majnonh	-0.3	-0.44	-.49	-2.39	-2.61

Abstract (Arabic)

الخلاصة

تعتبر مدينة دورا الواقعة على بعد 10 كم جنوب مدينة الخليل هي منطقة دراسة هذا البحث، حيث تبلغ مساحتها حوالي 112.1 كم^2 ويبلغ عدد السكان 30000 حسب الإحصاء المركزي الفلسطيني 2007.

تم من خلال هذه الدراسة توفير قاعدة بيانات عن الينابيع الموجودة في المنطقة، والتعرف على تركيز الايونات السالبة والموجبة، ومحاولة تحديد مسبب التلوث الذي يؤدي إلى زيادة تركيز هذه الايونات عن الحد المسموح به.

جيولوجية المنطقة تتكون من الصخور الرسوبية الجيرية، والتي تعود إلى العصر الألبي حتى الهيلوسين. وتتكون صخور تلك المنطقة من حجر الجير والمارل والدولومايت والطباشير.

تقع منطقة الدراسة اعتمادا على معدل سقوط الأمطار ضمن المنطقة شبه الجافة تقريبا، حيث تشكل مياه الأمطار المصدر الأساسي والرئيس للمياه الجوفية.

جمعت عينات المياه من ثمانية واربعين عين ماء خاص وعام حيث تم اختيار عيون الماء اعتمادا على توزيعها في منطقة الدراسة. حيث تم فحص العينات باستخدام تحاليل مختلفة مثل تحليل (الصوديوم، البوتاسيوم، الكالسيوم، المغنيسيوم، الكلور، البايكربونات، الكبريتات، النترات وأيضا التحاليل البيولوجية).لقد تم جمع عينات الماء على مرحلتين؛ المرحلة الأولى كانت في شهر نيسان 2007 حيث يكون تدفق الماء في الينابيع أعلى ما يمكن بعد موسم الشتاء؛ أما المرحلة الثانية فكانت في شهر تشرين أول من نفس العام في آخر موسم الصيف.اظهرت الدراسة انه يوجد فقط خمسة ابار صالحة للشرب وفقا لمعايير منظمة الصحة العالمية من ضمن الثمانية والاربعين بئرا، اما بقية الابار فلا تصلح للشرب بسبب زيادة تركيزاحد الملوثات فيها. كما اظهرت الدراسة ايضا ان جميع الابار صالحة للاستخدام الزراعي.