Spatial and Temporal Variation in the Hydrochemistry and Isotopic Composition of the Groundwater in the Jordan in Jordan Rift Valley.

(Case Study for Ramallah-Jerusalem Sub-basin, Palestine)

By

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بسم الله الرحمن الرحيم

"الله الذي يرسل الرياح فتثير سحابا فيبسطه في السماء كيف يشاء
ويجعله كسفا فترى الودق يخرج من خلاله
فإذا أصاب به من يشاء من عباده اذا هم يستبشرون"

"It is Allah who sends the winds so that they raise a cloud.
Then he spreads it in the sky as he pleases and places it layer upon layer
and thou seest the rain issuing forth from its midst.
And when He causes it to servants. Behold! They rejoice"

صدق الله العظيم

Al Rum- 48-الروم

Dedication

I Dedicate My Work

To Whom I Belong;

To My Parents,

To My Brothers & Sisters,

To All My Friends,

For Their Help, Support & Encouragement

All the Way Long.

Acknowledgments

I would like to express my special deepest thanks and gratitude to **Dr. Saed Khayat**, for his support, continuous care. It was my pleaser that I had such a supervisor in this work, and such a friend in my life.

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Abstract

The interpretation of monitoring of Groundwater from the springs along Wadi Al-Qilt stream in the Jerusalem–Ramallah Mountain slope area and in the Jericho Plain, West Bank, Palestine, and for the precipitation in the Jerusalem Ramallah sub-basin during the hydrological year 2006-2007 has been carried out. Intended for the anthropogenic nitrate and dissolved organic carbon in the springs and precipitation, along with spatially and temporally variations of other geogenic (natural) and anthropogenic chemical composition of the groundwater as will as stable isotopes $\delta^{18}O$ and $\delta^{2}H$.

A detailed analysis of dissolved species reveals that besides dissolution of carbonates, also nitrate, chloride, and sulfate are leached from soil and the aquifer rocks together with small amounts of Mg. Thus, Mg not only originates from carbonates but also from Mg-Cl saline waters included in the rocks. The Mg-Cl saline water problem should be handled in proper way as a potential source for freshwater deterioration that is drained from the upper mountain and deteriorate as soon approach further to the east near Jericho boarder.

The spatial temporal changes in the hydrochemistry of the aquifer reveals that the problem of freshwater deterioration complicated as a function of groundwater residence time and it's long contact with the aquifer matrix and saline bodies. The main factors affected the groundwater residence time and flow rate are the geological structure of the aquifer, the amount of active recharge to the aquifer, and the recharge mechanism. The residence time as well as the intensity of recharge (precipitation) plays the important role and found to be responsible in controlling the changes in the chemical composition of spring water which is mainly affected by the distance from the main recharge area. It was found that the groundwater in the springs near Jericho boarders, namely Sulatn and Dyouk springs have long residence time and older age than those springs in the upper part of Wadi Qilt. This was indicated by the relatively higher Mg/Ca molar ratio as well as more enriched ^{2}H isotopic signature.

A very important indicator is the oxidation of organics derived from sewage and garbage resulting in variable dissolved CO_2. High CO_2 yields lower pH values and thus under saturation with respect to calcite (and dolomite). Low CO_2 concentrations result in over saturation, witch means that calcite saturation accrues at the end of the rainy season. This observation was clear at the beginning of the winter season effect is particularly high at the beginning of the winter season and lowest at its end. While the springs water show a

shock in the NO_3 and DOC values several weeks after a significant storm event. The values of DOC in groundwater reach over than 12 mg/L in Qilt and Dyouk springs in values which might consists a potential health risk if the water was chlorinated for drinking purposes.

The rainwater samples show a high nitrate values after the first rain event and directly after dry period between storms. These values tend to get lower as the winter season proceeds under the washout effect for the atmospheric pollutants. The response of the karstic systems to the precipitations and the nitrate content are quite heterogeneous and depend on the hydrological state of the system as well as the time and the intensity of the storm events. The effluent of different anthropogenic pollutants from sewage water of the settlements, Bedoins, and animals surrounding the wadi was varied also depending on the storm intensity and the length of dry period between each rain event. The degradation of dissolved organic matter is a major source for increase the water hardness and mineralization

The isotopic signatures for the rain events along the rainy season found varied depending on the weather conditions, Orographic effects (altitude effect). The local meteoric water line (LMWL) was**: $\delta^2H = 7.95\ \delta^{18}O + 19.75$ ‰ SMOW**.

Two zones of recharge are distinguishable. Zone 1 represented by Ein Fara and Ein Qilt, witch is fed directly through the infiltration of meteoric water and surface runoff from the mountains along the eastern mountain slopes with less groundwater residence time and high flow rate. Zone 2 appears near the western border of Jericho at the foothills, which is mainly fed by the underground water flow from the eastern slopes with low surface infiltration rate. But it shows higher groundwater residence time and slow flow rate than zone 1. Both zones have varied isotopic signatures where the later zone shows more enriched deuterium values in the early season which confirmed the long residence of the groundwater that flushed out later and replaced by the new replenished groundwater with more depleted values. The main factors affected the groundwater residence time and flow rate are the geological structure of the aquifer, the amount of active recharge to the aquifer, and the recharge mechanism.

The results thus might be very useful for more efficient freshwater exploitation in the region, therefore pre-cautions should take place for the replenished water. The runoff water should not be freely infiltrated along the Wadi since it has a bad infiltration zone in one of its parts (zone 2) and thus much more water could be lost by evaporation.

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1. Introduction

1.1 Introduction

The availability and accessibility for water resources is considered being the core of civilization structural human colonies in the humanity history, and with no doubt in the future. Ground water in the mountain aquifer is concluded to be one of the major fresh portable water sources in the Middle East. Fresh water in this region is tapped from the aquifer system of shallow Plio-plesocene and deep Cenomounous (Eastern Mountain) aquifers.

Groundwater is desired in appropriate quantity to serve the demand of different uses. Though groundwater quality is elemental and essential; water quality in the West Bank aquifers is generally good. Nevertheless the increases in the salinity from west to east, as its shown in Jericho area hydrochemistry where Cl reaches high value, due to three possible major pollution sources: anthropogenic effect, agricultural back flow and deep brine water and dissolution of salts from Lisan layers. However, taking into account the karstic nature of these aquifers, the sources of pollution will eventually cause extensive pollution to these aquifers. *(Aliewi et.al., 2005)*.

Characterizing groundwater with the same mineralogy might have an exceptional and unique chemical composition due to soluble minerals in saturated zone, numerous lithology controlled factors such as dissolution rates, and cation exchange capacity, fluid mobility and reaction kinetics at mineral surfaces determine together the net solute inventory added to an evolving water parcel along a flow path *(Bullen et al. 1996*).

The effects of urbanization on the natural resources are still the main issue in most of the environmental studies all over the world. Elevated concentrations of pollutants in drinking water are a concern to rural communities as nitrate and dissolved organics in excess amounts can cause environmental and health problems. Rural areas, where livestock and drinking water supplies are found in common locations, are particularly at risk as animal manure contains high levels of nitrogen and organics. More over, many adjacent communities discharge wastewater freely to the water streams in some area in a way that caused the higher risk to groundwater resources.

Water-rock interaction alters the solute inventory in addition to the flow path lithology variation and mixed infiltrated water with saline formation water enclosed in sedimentary rock. As a consequence it's not necessary that groundwater composition matches that of infiltrated water, variation of both meteoric precipitation (recharge) and the rate of water/rock interaction yield time-dependent variable hydrochemical compositions of groundwater .as will as the in chemical composition between dry and wet season sand from one spring to another *(Shalash, 2007).*

These effects are important in semi-arid to arid areas with their seasonal rainfalls and where the amount and mechanism of recharge of aquifers control the quality of groundwater *(Khayat, 2005).* These influences have been studied in the upper aquifer of the Jerusalem-Ramallah sub-basin, Palestine. Because it is a karstic aquifer with absence of major lithologic variability but of very discontinuous structure we only discuss the results on Wadi Qilt and the adjacent area of the Jericho Plain.

The entry of pollutants such as nitrate (NO_3) and Dissolved Oxygen Carbon (DOC) into groundwater can often be reduced or even eliminated by the use of best management practices for agriculture and wastewater disposal system. Still, these pollutants are a big threatens to the groundwater resources. For example, when nitrogen in the form of nitrate (NO_3) reaches groundwater it becomes very mobile and can migrate long distances from the area of input, leading to the contamination of groundwater supplies. Furthermore, the dissolved organics (DOC) can also transfer and react with other natural or additive elements forming side hazardous products in groundwater and drinking water distribution systems.

Hydrochemical and isotopic methods are considered as a popular tool for groundwater research all over the world. And have been successful as economical way to determine the groundwater type, to identify the source of groundwater and its flow, as will as to evaluate the quantity of groundwater recharge and replenishment. *(Vuataz, 2000; Li, et al., 2006).* In particular, under arid and semiarid environmental conditions, the isotope techniques represent virtually the only approach for identification and quantification of Groundwater recharge. *(Aggarwal, 2006).*

For this reason, the hydrochemical and isotopic analyses from the winter season of 2006/2007 of springs in the Wadi Qilt and of the Jericho Plain discharging from the calcareous mountain karstic aquifer of the Eastern Slopes of the Jerusalem-Ramallah Mts., Palestine, are used to specifically resolve the spatial and temporal variations of water quality and its relation to mechanisms of recharge, runoff formation, flow conditions, infiltration zones, movement and residence time of groundwater in the Mountain aquifer. A better understanding about the sources, destiny, as well as the variation in concentration for these pollutants in the mean of time and place, extensive hydro-geological studies to identify the true potential, safe yield and quality of groundwater of this aquifer are still needed. Coming up to expected result providing information for protecting local Groundwater.

1.2 Aim and Scope

This work aims at assessing the spatial and temporal changes in the hydrochemistry and isotopic constituents as a result of the impact of anthropogenic and geogenic effluent in the area of Wadi Qilt-Jericho (Jerusalem Ramallah sub-basin). To achieve this, overall assessment for the groundwater from this aquifer to the pollution contributes from the natural influences as well as man-made influence; dumping sites, wastewater streams and industries, were carried out, and was accomplished by sampling and monitoring the main constituents and corresponding concentrations in surface and groundwater spatially and temporarily, starting by monitoring the precipitation on the recharge point at the upper mountains, surface water runoff through the wadis springs, at locations that are at risk of being impacted by polluted effluent, and through simple quantification of potential leaching to groundwater resources.

The goal is to develop spatial and computational capabilities in this work for data processing, evaluations, and assessments in particular for temporal and spatial trends and behavior of pollution indicators and polluted water loading and constituent concentration.

Few periodical measurements for surface and groundwater quality are available for the springs along the stream in this area. Most of quality measurements conducted in the area never deals with the variation of natural, organics and nitrate pollutants in term of time and distance. A few visual observations to the stream and the wastewater entering it give an indication to a high deterioration in its quality. However, measurements are not available to trace the variation of these pollutants spatially with distance from the main recharge point in the upper mountain, as well as temporally depending on the time and magnitude of different storm event within the season on such deterioration. In this study we try to trace the major changes in the natural and anthropogenic contribution of major and minor hydrochemical traces as well as Nitrate and dissolved organic Carbon (DOC) in the groundwater along the path of the Wadi Qilt area, in term of variation in distance along Wadi and time of the year, beside the effect of different storm events throughout the winter season 2006/2007.

This study should give a better understanding about the mechanism of water pollution from its recharge point to the point of percolation in the aquifer and which processes might affect on the distribution and amount of these pollutants, spatial and temporal variations of water quality and its relation to mechanisms of recharge, runoff formation, flow conditions, infiltration zones, movement and residence time of groundwater in the Mountain aquifer. More better understanding about the sources, destiny, as well as the variation in concentration for these pollutants in the mean of time and place, coming up to expected result providing information for protecting local Groundwater in this semi-arid area.

2. Study area (Wadi Qilt)

2.1 introduction

The water resources in the study area (Fig.1) consist of water from precipitation, groundwater, and surface water *(Rofe & Raffety, 1963).*

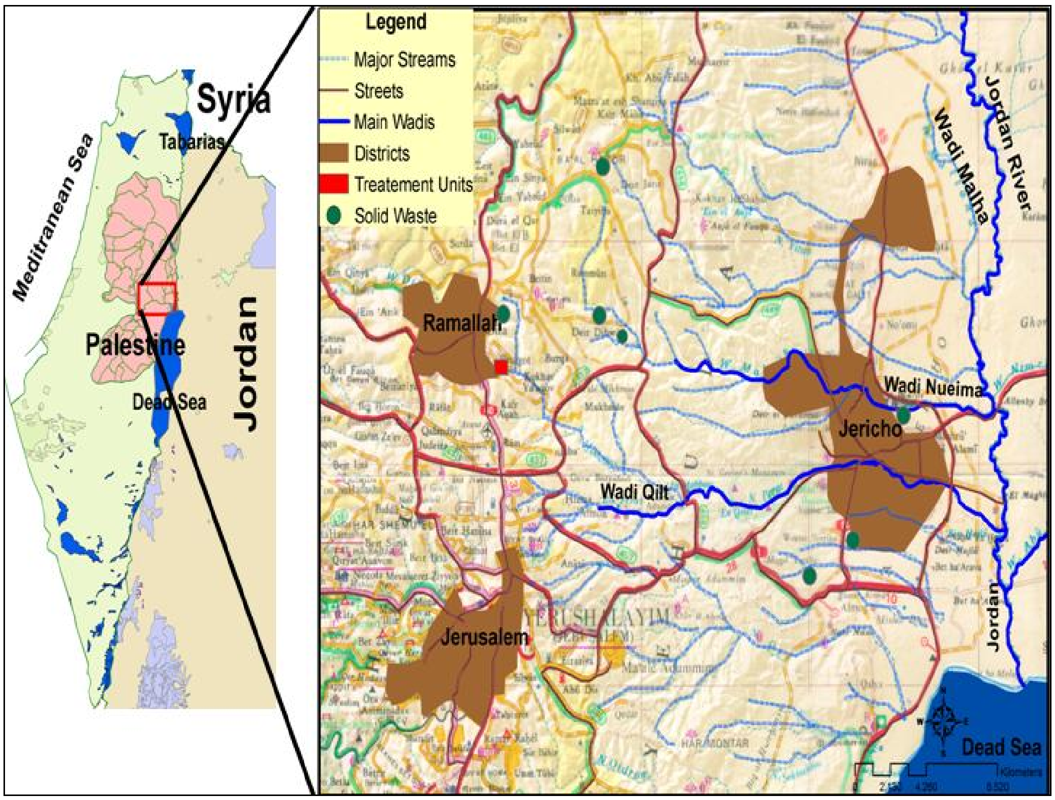


Fig. 1: Study Area including potential hazardous points to the water streams.

Two major possible pollutants in the area; the first is the natural sources that mainly come from atmospheric deposition and the rock water interaction along the flow pathway and water infiltration, the effect of the unique lithological structure (karstic) of the area on the salinity raising, as addressed in many earlier researches and the increase of water deterioration by evaporation and salty rocks dissolution through water runoff *(Rosenthal and Vengosh, 1994; Khayat et al, 2006a; Marie and Vengosh, 2000).*That contains organic and inorganic wastes. Most of the organic part is composed of raw domestic and industrial wastewater (organic dyes) while the inorganic one composed of heavy metals and hazardous nutrients.

Due to the absence of efficient treatment plants and control of wastewater in the West Bank and some Israeli settlements along the Wadis path, this sewage flows into the natural streams surrounding the basin, which drains directly into the Wadis runoff, and percolating to the groundwater *(ARIJ, 1997)*.

Such pollutants sources comes via Jerusalem- Ramallah (west) toward the eastern basin influences ground and springs water and make it deteriorated and unsuitable for different uses and applications in the Jordan rift valley, which in tern can influence the economic, social and political situation in the study area. Additional contamination of the spring water from other sources has occurred, e.g., Bedouins living at the down stream dumping their wastewater into the stream, leaching from stone quarries and the municipal and other industrial wastewater that discharging from the eastern side of the city of Al-Bireh polluting surface and groundwater resources across water path. 78 % of the waste water disposing method in Ramallah area (main recharge point) is using Cesspits and Open Channels where this percentage is higher in Jerusalem area where it reaches 84 %.

Vacuum tanker normally empty the sewage and the content is disposed off in the nearby area where the wastewater drained freely through natural streams to adjacent Wadis *(ARIJ, 1995)*. This situation is improper, unhealthy and cause several environmental hazards, mainly for the groundwater in the karstic mountain and shallow Jordan rift aquifers. (Pic.1). Israel occupation adds to the wastewater problem significantly as the thousands of settlers living in scattered settlements the West Bank and in East Jerusalem (Fig.2) generates waste that is disposed to the Wadis without proper treatment.

Pic. 1: Vacuum tanker dumping raw wastewater directly to the wadi.

As the use of water for Israelis is significantly higher than for Palestinians, so is the amount of waste that they generate. This amount of water which is used by the 306,806 settlers in the West Bank, including the 170, 00 in East Jerusalem, may generate 30 MCM of wastewater per year *(ARIJ, 1997).*

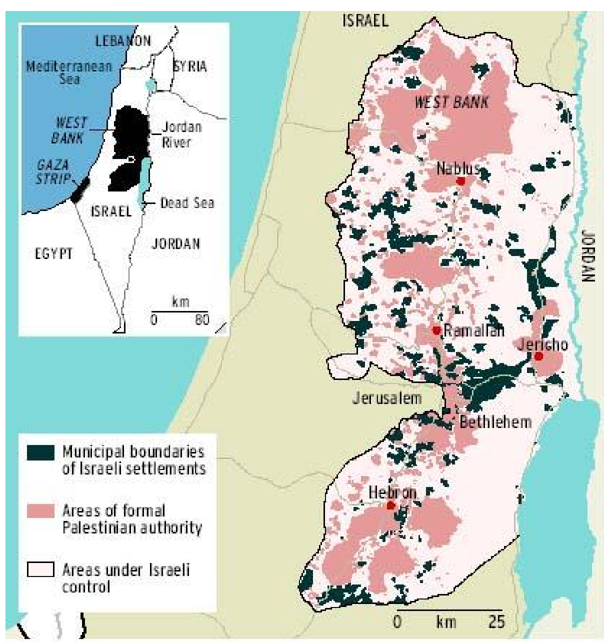


Fig.2: Scattered settlements the West Bank and in East Jerusalem *(ARIJ 1997).*

2.2 Water in the West Bank

The water resources in Palestine are mainly the Jordan River, Wadi flows and groundwater (utilized mainly through wells and springs). The main source of domestic water in the entire West Bank is groundwater, derived from the shallow and deep water bearing formations of the Mountain Aquifer. Based on the direction of hydraulic drainage of the Mountain Aquifer, it was divided and named to three main ground water basins; Western, Northeastern and Eastern Basin (Fig.3) *(Rofe & Raffety, 1963;Qannam 2000;PWA, 2005 and Guttman 2005).* The West Bank aquifer system discharges approximately 600-660 mcm/yr. *(Aliewi et al, 2005).*

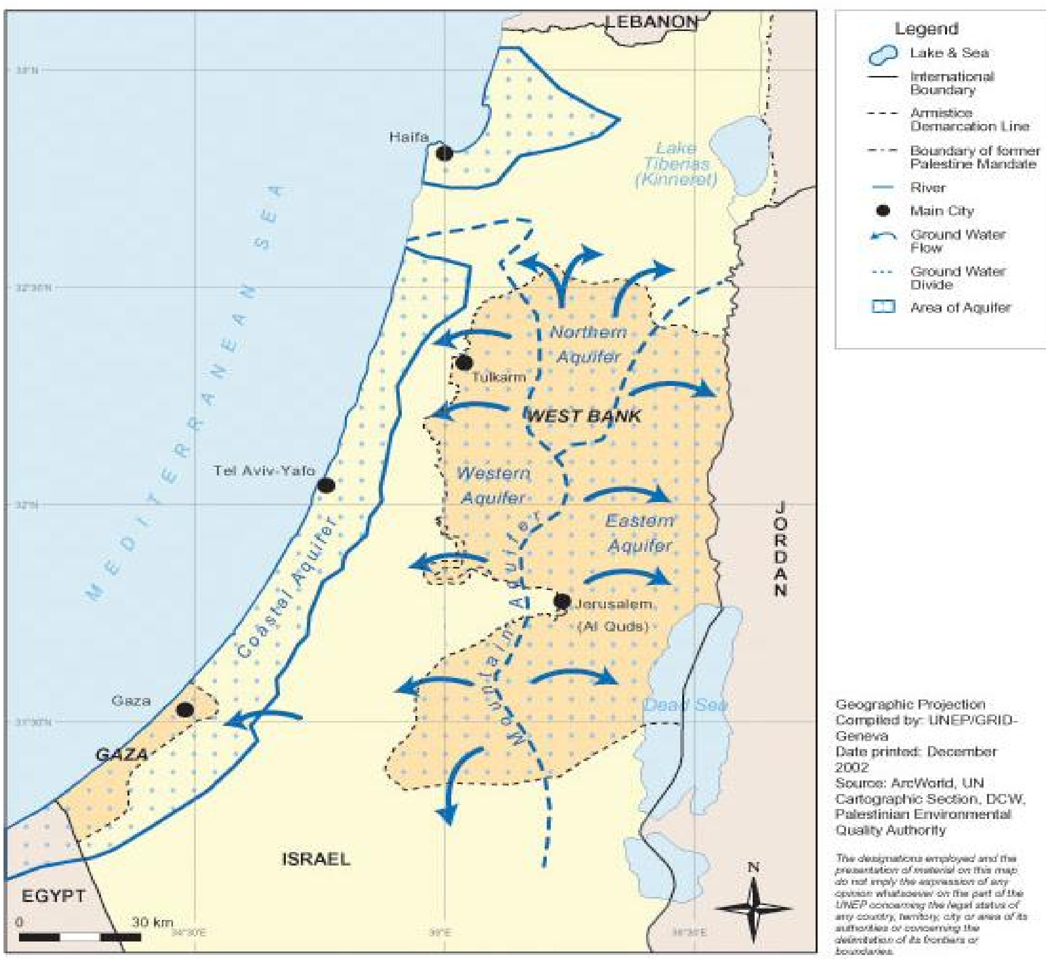


Fig. 3: Groundwater basins in the West Bank and the Gaza Strip *(ArcWorld, UN, 2002).*

Only the Eastern Basin lies entirely in the West Bank while the other two basins are shared with Israel. About 80-90 % of the recharge areas for the Northeastern and Western basins lie within the West Bank *(Libiszewski, 1995 and WWS, 2002),* but the ground water flow westwards towards the Mediterranean and northwards towards Bisan and Marj Ibn Amer. .

Israel controls all aquifers in Palestine; although the major part of fresh water supply in Palestine originates from the three aquifers of the West Bank. In the West Bank, the aquifer system is comprised of several rock formations that are recharged from rainfall. In years of normal rainfall, some 600-650 Mcm/ yr of rain infiltrate the soil and replenish the ground aquifers *(PWA, 2005).* There are a number of minor parallel or sub-parallel folds so that the structure can be considered as an anticlinorium's (Fig.4). The Jerusalem Anticline is asymmetrical, with a steeply dipping west limb (mean 30°) and a more gently dipping east limb (mean 15°), *(Rofe & Raffety 1963).* The following table is a summary of the available water from these resources.

Table 1: Available resources in Palestine (Aliewi.et al.2006)

Source of water	Natural flow or Recharge (Mcm/yr)
Jordan River	1485-1671
Wadi f low	110-120
West Bank Groundwater Aquifers Basins	
Eastern	100-172
Northeastern	130-200
Western	335-450
Coastal	55-65
Total	2,215 – 2,678

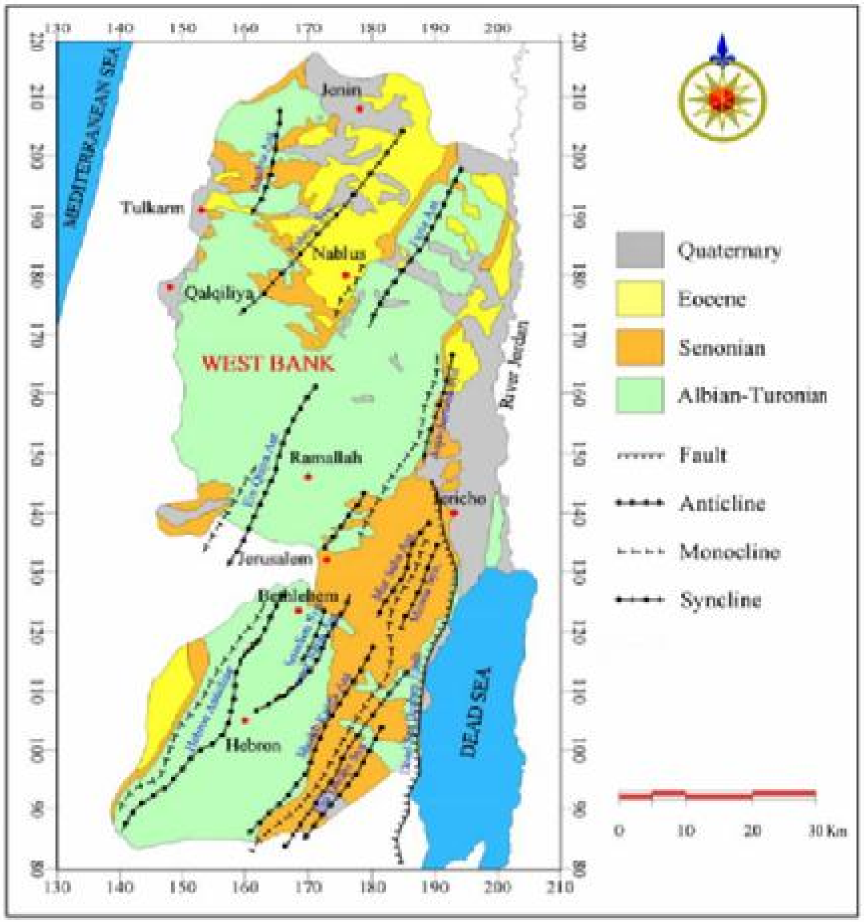


Fig. 4: General geological and structural map of the West Bank (modified after Abed Rabbo et al. 1999, Guttman & Zuckerman 1995, and Qannam 2000).

Existing peace agreements between Israel and the PLO on the WB and GS water resources do not go beyond temporary solutions for emerging crises nor do they create a sustainable and permanent solution. Further, these agreements were concluded in an unjust and inequitable manner. The existing agreements are merely a temporary solution for solving only the immediate domestic needs of the Palestinians for the transitional five years of the interim period, which expired in September 1998 (Oslo 2 Accords 1995).

2.3 Study area location and Features

The study area (Wadi Al-Qilt) is located in the eastern part of the West Bank, including part of Ramallah, Al Bireh and Jerusalem and part of Jericho bounded from east by the Jordan River, and Wadi Fassayil from north, Wadi Qilt from south and hills of Ramallah (Kofr Malik and Taybe hills) from the west boundary. As its considered the major drainage system in the area between Jerusalem and Ramallah Mountains downwards to the Jordan River in the east, with area of 174 Km^2 (Fig .5). *(ARIJ, 2005)*. The drainage basin of wadi Al-Qilt is located in the well-known Dead Sea Rift Valley. In the Ramallah and Jerusalem the mountains rise up to elevation over than 700 m above msl. , and decline to range of 200 – 250 m below msl. in the east west of Jericho.

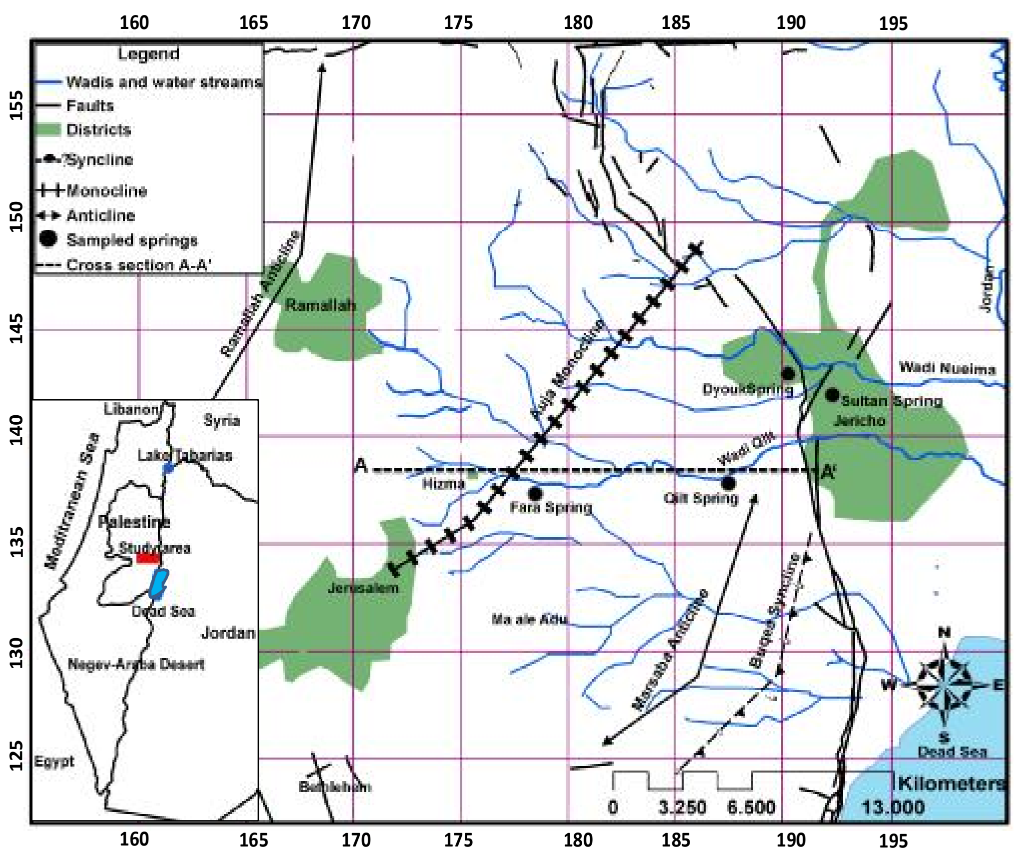


Fig .5: Study Area of the Eastern slope of Jerusalem-Ramallah sub-basin, localizing

Jericho located at the southern border of the study area, the main town, and known as the oldest urban settlement yet to be discovered for human civilization, with significant archaeological remains dating back as to the seventh millennium B.C. The site of ancient Jericho is half a kilometer away from modern Jericho at a level of 250 meters below msl. It lies at latitude 31 52 degrees north and longitude 35 39 degrees east. From 1967-1996 Jericho was occupied and administered by Israelis. Since 1996 Jericho become under the civil administration of the Palestinian, but kept under the military control of the Israel.

2.4 Populations and Land Use

In the drainage of Wadi Al-Qilt, there are several Palestinian Communities; city, refuge camps and villages, estimated to be around 100 thousands capita. While the six Israeli Settlements was estimated to be around 30 thousands capita. Palestinian and Israeli built up areas occupy approximately 1.7% and 1.5% respectively. Still lots of data are still unknown and missing particularly that concern about Israeli military bases and industrial zones. *(PBS. 1994).*

As its located in the rain shadow with less than 150 mm/y, most of the land is range land with dessert appearance that palm trees are major plants, except that where groundwater is available we find intensive agricultural activity with crops like bananas, citrus and tomato.

2.5 Topography and Soil

The topography is unique, with the lowest ground level in the world. That starts at the eastern slopes from Ramallah hills, decreasing from west toward the east, elevations range between 750-800 m above msl. Where the highest point is 1022 m above msl. at

Tal-A'sur. And at Jericho reaches the lowest elevation of 24 m below msl. at the southeast (Dead Sea) goes to 240 m below msl.

Different topographic circumstances, and Climate, arid in the east and wet in the mountainous ridge; variable geology; sedimentary rocks, sand dunes, alluvium, etc. In addition to the physical weathering from both water and wind modifies the soils. Due to these extreme conditions that causes this varieties, that's responsible of forming these soils.

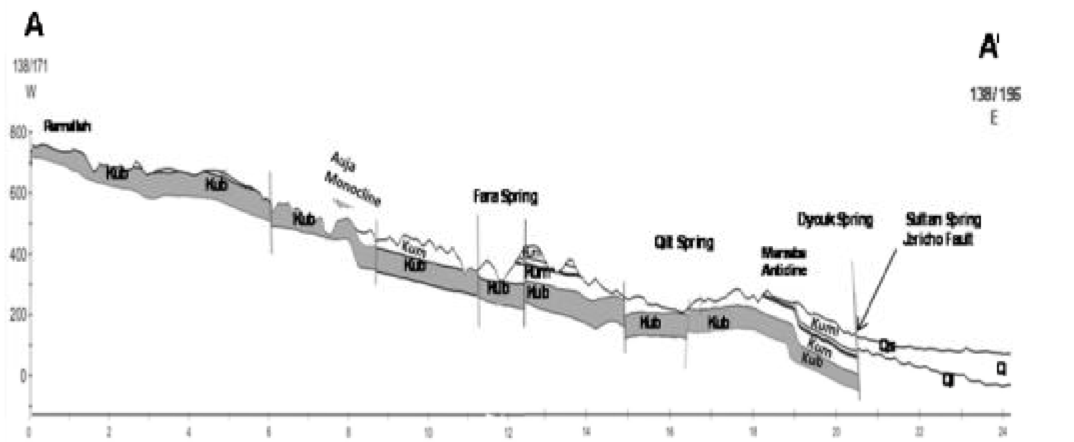


Fig. 6: W-E Cross section A-A' (Fig.5) showing the aquifer and aquiclude layers, (modified after Toll, 2001)

Despite the small size of West Bank, a variety of soils can be found. The main soil association that covers Jericho area is alluvial arid brown soil, which is, covers an area of about 6,470 hectares. It is exists of alluvial fans and plains, formed as a result of erosion of calcareous silty and clayey materials. *(ARIJ, 1995).*

2.6 Climate and Metrological Data

The climate of the study area is semi-arid, although, however, several surface-water flows originating from the Jerusalem-Ramallah Mts. pass the basin through Wadi Nwe'meh and Wadi Qilt (Fig. 5).

In the West Bank the Temperature varies between 20 to 23 ˚C in the summer, getting a maximum of 43 ˚C. The average in winter reaches 10 ˚C. This is due to the differences in position, elevation, and distance from the cost and environment around the station *(Ghanem, 1999)*. And it's found that Temperature decreases from south to north .as will as from east to west on the opposite to the altitude.

The annual precipitation in the main recharge zone of the aquifer in the Jerusalem-Ramallah Mountains is about 540 mm (Marie, 2001). Annual precipitation for the last 26 years (since 1974) shown in Fig.7, and Table.1/Appx. for Ramallah station. Noted there are strong variations in monthly and even daily rainfalls.

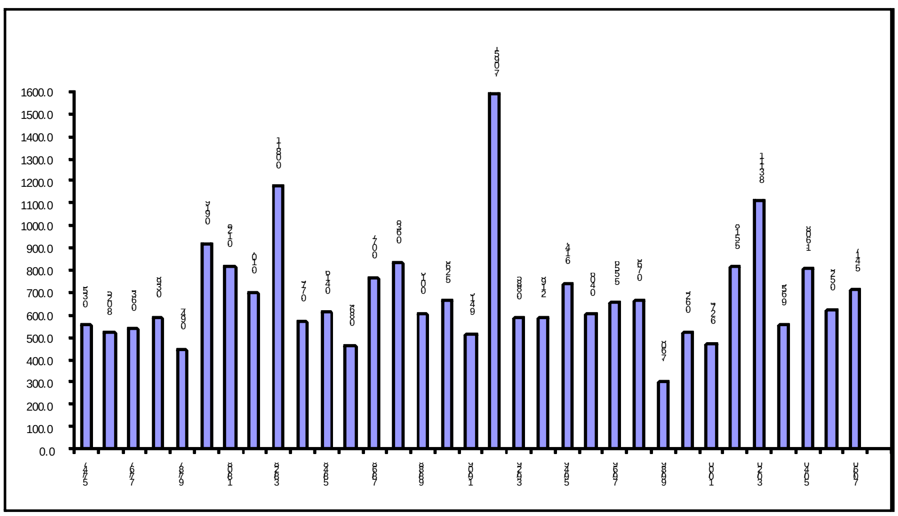


Fig.7: Annual precipitation since 1974 (from JWU, Ramallah station)

Individual strong storm events control recharge of the mountain aquifer. And almost 95% of the annual rainfall occurs between December and March and more than 65% in the 3 months between December and February. The dry period extends from May to end of September. *(ARIJ, 1997).*

During the wet season in the area that starts by the end of October reaching its climax in January and February, the precipitation in the area is characterized by the short duration and the lower amount. Precipitation ranges from 5 to 100 mm in each storm event. Spatial distribution of rainfall also varies strongly. In the Jerusalem and Ramallah Mts. precipitation ranges from 400 to 650 mm/yr, whereas according to the Jericho weather station, the mean annual precipitation in the study area is approximately 120- 180 mm/yr, of which approximately 60% falls in the three months of December, January and February (Fig. 8). In general, the Jericho district has the lowest rain in the region and short rainy season ranging between 20-25 rainy days per year (*ARIJ, 1997;PWA, 2003).*

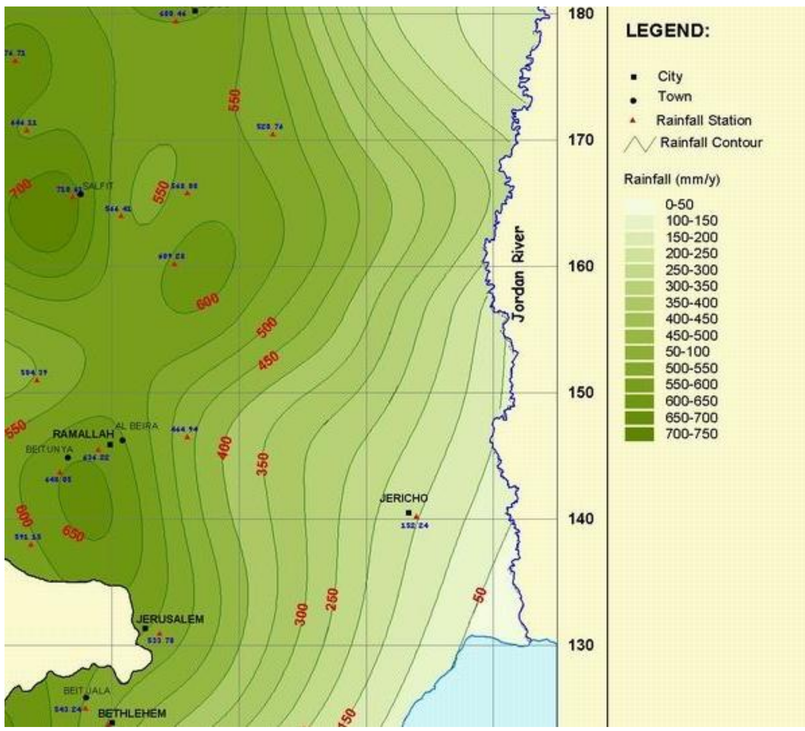


Fig. 8: Average annual precipitation rate in mm in the Jordan valley Area *(After PHG, 2002).*

The relative humidity (RH %) represent the atmospheric moisture content, which is controlled by the temperature, elevation and distance from coast. The mean annual relative humidity reaches about 50%, with the highest rates in winter time that reach 75% and the lowest rate in summer that reaches 5% when the temperature is very high. The solar radiation reaches its highest point in July, consequently, the evaporation rate in the area is very high that reaches 298 mm. Normally, this high evaporation exceeds the precipitation during the year, while with the increases in humidity in winter period the evaporation rate come to lower value that reaches 50 mm (Fig. 9), thus the agriculture in the area is totally depending on the irrigation *(ARIJ, 1995)*.

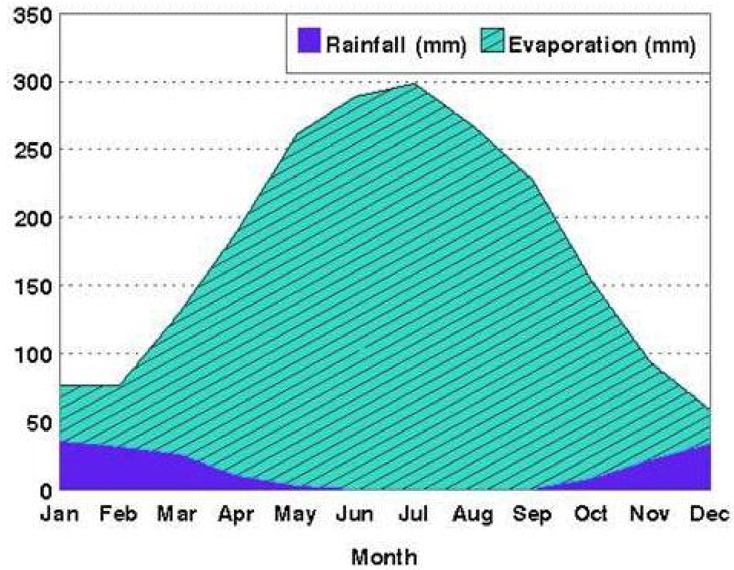


Fig. 9: Monthly rainfall and evaporation in the Jericho for 1969-1992. (ARIJ, 1995)

Due to the deficient and incomplete records in the Palestinian meteorological stations in Ramallah and Jericho, for the hydrological year 2006-2007,that we need to use to clarify the pattern of winter season in this region, induction for the available data records for the previous hydrological year 2005-2006 were investigated as a substitute, then deducted to derive the relation between rain parameters and other meteorological data in the study area. In (Fig.10), correlation for the meteorological data for the hydrological year 2005-2006 of sampling of daily precipitation and mean air temperature, whereas (Fig.11), illustrates the relation for the meteorological parameters (Amount of Precipitation, Temperature, RH, Evaporation. etc) for one selected month (January 2006).

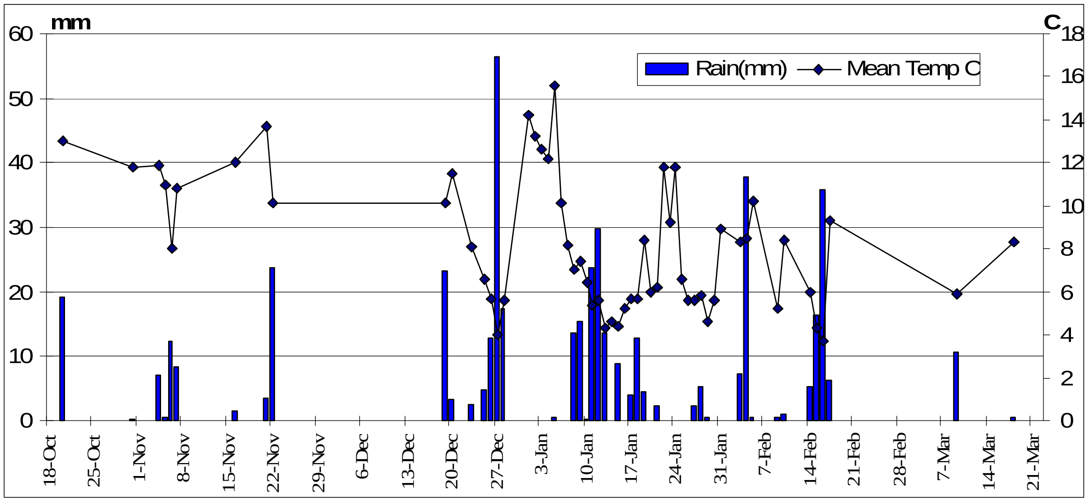


Fig.10: Daily amount of precipitation (Rain mm) and mean air temperature (C) for the hydrological year 2005-06. (Table. 2/Appx)

In general, winter season (hydrological year) and as it was clearly observed, shows Non-regular rain events, that varies in the amount, distribution and concentration as will as deviation in the correlation with other meteorological parameters, Temperature, RH. etc..

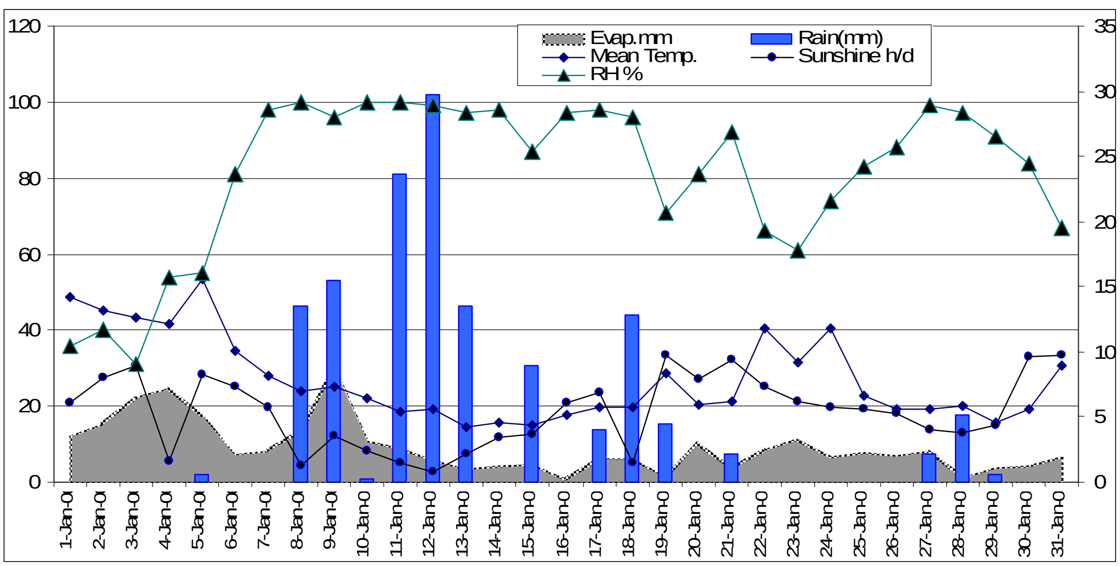


Fig. 11: Daily amount of meteorological parameters for January 2006. *(Table. 3/Appx)*

From the rainfall records for the period from 1990 to 2007, (Table 1/ Appx), as will as the averages mean values for the meteorological parameters for the last 25 year (Fig. 12, Table. 4/Appx.). The hydrological year in the study starts in October and lasts cousinly till April, and divided into two periods, as for the first one, Autumn; that have less rainfall, higher temperate. While for the second period, winter in witch the rainfall concentrated in the four months (December – March), as 70% from the Average precipitation in this period, combined with lower Temperature.

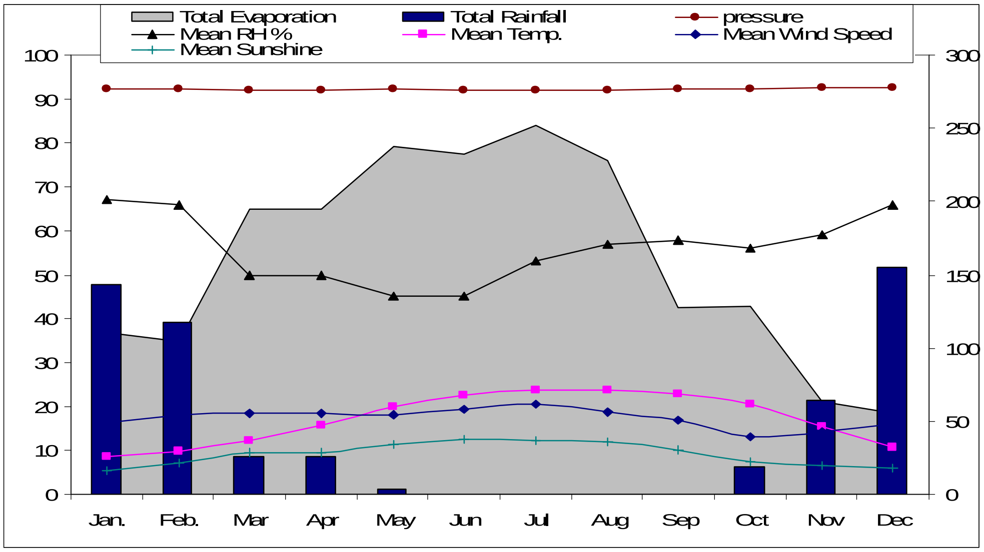


Fig. 12: Averages mean values for the meteorological parameters for the last 25-year,

2.7 Geology

The geology and hydrology of the entire Rift Valley mainly affected by The Rift Valley faults structure. The stratigraphy consists of carbonates, chert, chalk, gravels, and sandstones and evaporates which range in age from the Triassic to Holocene age in the east near the rift. The youngest formations are of Pleistocene to Neogene Holocene age. The ancient Jurassic and Lower Cretaceous formations are composed mainly of limestone, sandstones, and marl layers *(ARIJ, 1997)*. The following is a description of the stratigraphy and the characteristics of the geological formations exposed in the study area, is based mainly on the studies of the Guttman (2005,2000), Qannam (2000), and Braun & Hirsch (1994) as well as the generalized stratigraphic sequence of the West Bank that is shown in Table.1 and the geological map of the Geological Survey of Israel in (Fig.13).

2.7.1 Stratigraphy and Lithology of study area

2.7.1.1 West Bank mountains formation

The Upper Cenomanian Turanian extends along eastern slops from Ramallah toward Jericho border covers most of the study area. While the Samara and Lisan deposits covers small part in of the study area. The following text was modified after *(Khayat, 2005).* Predominantly carbonate sediments and rocks of Tertiary and Cretaceous ages are the outcrops Within the West Bank. Older rocks are known from the boreholes as they are not found at the surface. The oldest exposed rocks belong to the Albian, overlain by younger strata of the Cenomanian, Turanian, Senonian, and Eocene, exposed on both flanks of the anticlinal axis in the West Bank. The general stratigraphy of the West Bank and the Israeli and the Palestinian names of the different geological formations in the West Bank as well as their lithology, thickness and aquifer potentiality are described and illustrated in Table 2. The exposed rocks of the West Bank are (Fig. 13, Table. 2 and Table. 5/Appx.):

1. Albian - Lower Cretaceous formations include the regional West Bank groundwater system (Beit Kahil, Yatta formations). The depth of the ground water system in this formation ranges from 970 to 500 meters.
2. Upper Cretaceous formations comprising the regional West Bank groundwater system (Hebron, Bethlehem and Jerusalem formations). Covers most of the study area with a depth of the ground water system in this formation ranges from 490 to 190 meters.
3. Senonian age rocks (Abu Dis formation) are composed mainly of chalks and marls. Occupied small part to the west of Jericho fault in the study area The depth of the ground water system in this formation ranges from the ground surface 0 to 450 meters.

4. Pleistocene to Eocene age rocks overlay the Senonian age rocks in the Northern and Northeastern area of the West Bank, the rocks are composed mainly of limestone, chalky limestone, chalks, marls, and siltstone, which are of partial limited coverage and depth Unconsolidated, as Quaternary alluvial sediments overlie the major rock formations. Occupied a small part in the east of study area, near Jericho Sultan spring.

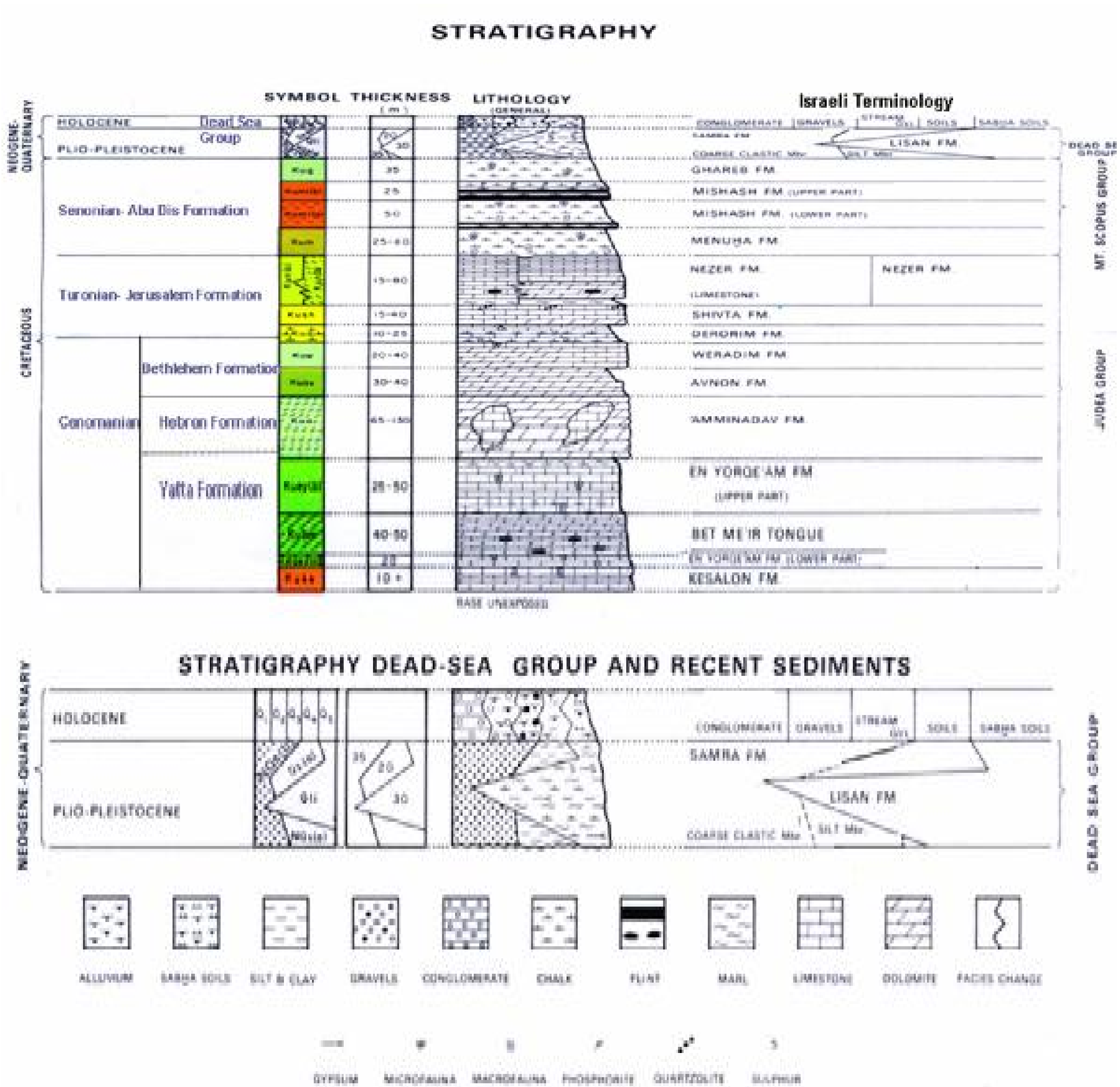


Fig.13: Generalized columnar geological Section indicating various formations in the study area. *(Modified from Geological Survey of Isreal, 1973)*

Table.2: Stratigraphic table of rock units in the study area. The study area formation dominate by the outcrop of Upper Cenomanian (Turanian), which later on covered in the eastern part of the study area near Jericho with Campanian Abu Dis Formation (modified after Begin, 1974).

Period	Epoch	Group (Israeli terminology)	Formation (Israeli terminology)			Formation (Palestinian terminology)	Hydrogeological Unit		Thickness [m]
Quaternary	Holocene Pleistocene	Dead Sea	Alluvium		Q	Lisan			Base unexposed
			Lisan		Qli				
Teritary	Pliocene		Samra		Qs(a)				
Upper Cretaceous	Campanian	Mt. Scopus	Mishash		Kumi	Abu Dis	Aquiclude		100- 400
	Santonian-Campanian		Menuha		Kum				
	Turonian	Judea	Bina	Nezer	Kub	Jerusalem	Aquifer	Aquifer	90-100
				Shivta				Aquifer	
				Derorim				Aquiclude	
	Upper Cenomanian		Weradim		Kuw	Upper Bethlehem	Aquifer		90-100
			Kefar Shaul		Kuks	Lower Bethlehem	Aquitard		30-40
	Lower Cenomanian		Aminadav		Kua	Hebron	Aquifer		110-140
			Moza	Ein Yorqe'am	Kuey	Yatta	Aquiclude	Aquitard	10
			Beit Meir				Aquitard		120-140
Lower Cretaceous	Albian		Kesalon		Kuke	Upper Beit Kahil	Aquifer		30
			Soreq		Kus		Aquitard		110-170
			Givat Yearim		Kugy	Lower Beit Kahil	Aquifer		20-40
			Kefira		Kk		Aquifer		160-180

2.7.1.2 The Jordan Valley deposits (Dead Sea Group)

The Jordan Valley deposits (the Dead Sea Group) consist of two formations, the Lisan Samra Formation, and the Alluvial Formation. There was no difference made between this Quaternary deposits, Samra, Lisan, and Alluvial deposits as it is extremely hard mapping these Formations, when they can be only seen in wadis which cut deeply into these sediments. Otherwise they are over laid by younger alluvium and soils. Geological formation in the study area and other formation of Palestine are shown in the Table.2.

1. Alluvial deposits

Alluvial deposits or the Holocene or sub-recent Alluvial aquifer. These deposits cover the area adjacent the Jordan valley by 1 km in the north and 5 km in the south as two parallel lines, witch is small part in east of the study area. It's of the Pleistocene to recent in the age, bordered structurally by the Jordan rift regional fault in the east and another fault of 12 km length in the west *(GMOI, 1974)*.

Alluvial deposits is built up of sub-recent terrigenous deposits formed along the outlets of major Wadis. Permeable horizons alternate with impermeable lithologies within the deposits. These alluvial fans are still under accumulation after large floods and consist of debris from all neighboring lithologies and are deposited according to their transport energy. The transport normally takes place along alternating channels. The alluvial aquifer often directly overlies the Pleistocene gravel aquifer and by that is hydraulically interconnected with this aquifer. The total depth is maximum near the rift margins can reach up to high values, dropping to minimum depths towards the center of the rift basin.

The alluvial deposits consisting of talus stream gravels, soils and Sabha soils occur as loose sediments, several meters thick, mainly in the Jordan valley. The geomorphologic position for the talus and stream gravels distinction. The soils were differentiated from the silt of the Samra formation according to the same criterion. While the soils, which are of the Erarosa type, restricted to the recent stream beds (Jordan River and Wadi Mafjar) or to mountain valley, mainly along the Samra fault strip.

The Saha soils are salty soils, exposed over the Lisan formation in the Jordan valley southeast of Fassayil, for that the silt covers extensive area outside of recent streams, *(The Geological Map of Israel, 1974).*

2. Pleistocene Lisan Samra formation

This includes three members; Samra coarse clastic, Samra silt, and Lisan, of the Pleistocene Samra aquifer are a lateral facies succession from terrestrial/fluvial, to deltaic/limnic and limnic/brackish lake environments. They reflect the PlioPleistocene depositional conditions of the Lisan Lake. Lisan, the marl, gypsum, and silt lacustrine unit is generally considered an aquiclude, void of exploitable water. It is distributed mainly towards the middle of the graben. Samra formation consists of two members; A silt member underlying or interfingering with Lisan and a coarse clastic member further to the West that predominantly consists of gravel, interbedded with clay, sand and marl horizons *(The Geological Map of Israel, 1974)*.

The natural recharge by rain is almost negligible. Therefore, the aquifer is mainly fed by inflows of excess water from neighboring aquifers, namely the lower Cretaceous Kurnub sandstone aquifer and the Albian to Turanian limestone and dolomite aquifer, also know as the lower and upper aquifer and from runoff in the wadis on the Eastern slopes of the West Bank. The aquifer supplies agriculture in the Jordan Valley between Jericho and Fari’a Graben.

Samra Formation is Clastic fan sediments build up the Samra formation that dominates with possible occurrence of Lisan formation at the east margin. Samra formation consists of conglomerates, sand, and silts. More or less it’s weathered on the surface of the Jordan valley and crops out along Wadi Qilt where it enters the Jordan valley. The silts that this formation consists of consider being the parent material of the rich soil of Jericho *(Begin, 1975)*. These Clastic sediments are highly variable in the texture, as will as the particle size that varies from fine silt to boulders of 30 cm in diameter. Furthermore it's observed that the particles can be rounded and angular and the sediments also poor to well sorted.

Lisan formation consists of laminated chalk, gypsum, marl, and clay layers reaching a maximum thickness of 35 m at the Jordan River. The sediments ranging from the hyperersaline to fresh deposited in a lake environment. It comes at the lower portion of the Jordan valley occurring up to a maximum elevation of 180 m below msl, however the common level in Jericho area is 240 m below msl. *(Begin, 1974)*.

2.8 Hydrology of study area

2.8.1 Eastern Aquifer Basin (EAB)

This basin lies almost entirely in the West Bank. (Fig.14). Estimates of the safe yield (Extraction Potential) of this basin are not well determined; 100 Mill. m^3/yr (Elmusa, 1996 and Gvirtzman, 1994), 125 Mill. m^3/yr *(Wolf 1995)* and 172 Mill. m^3/yr (Oslo 2 Accords 1995). According to Oslo 2 Accords (1995), the 172 Mill. m^3/yr is shared as follows: 24 Mill. m^3/yr utilized by the Palestinians from wells, 30 Mill. m^3/yr utilized by the Palestinians from springs, 40 Mill. m^3/yr used by the Israelis and 78 Mill. m^3/yr to be developed in the future. The number of Palestinian wells in the eastern aquifer is 95 wells with an average abstraction of about 25 Mcm/yr, *(PWA, 2005).* According to the surface and subsurface hydrological divisions of the West Bank, Jericho area is part of the Jerusalem Ramallah sub-basin and accordingly part of the Eastern Basin (Fig. 14).

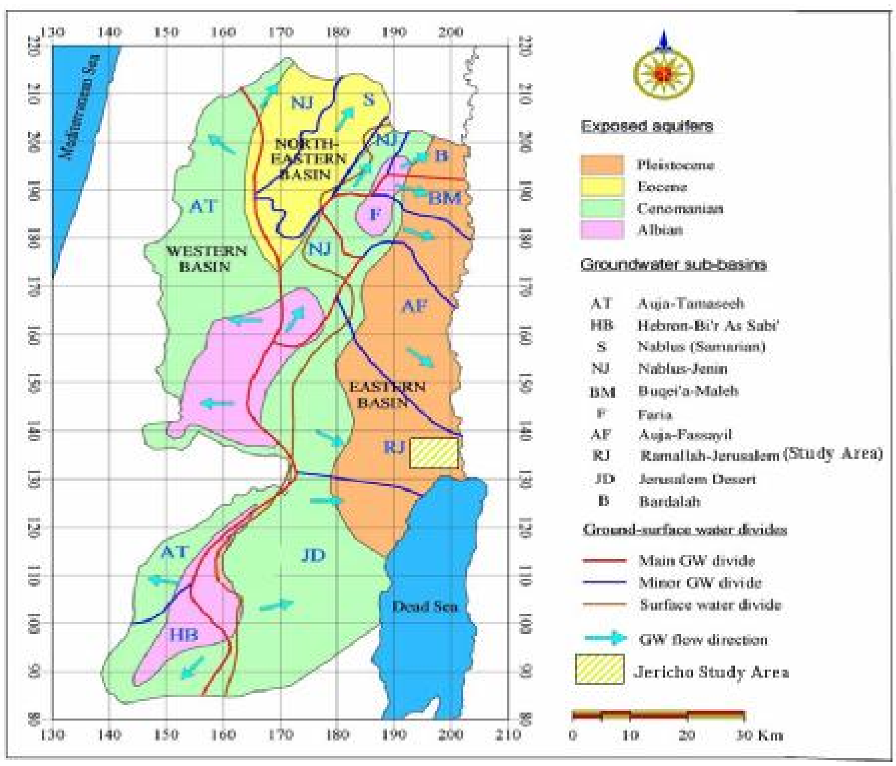


Fig. 14: Ground water *basins* and exposed aquifers in the West Bank / Palestine. *(Modified after ARIJ 1995 and Husary et al. 1996).*

Large parts of this aquifer basin are located within the eastern borders of the West Bank as shown in (Fig. 14). The mountains forming the highlands in this basin consist mainly of carbonate sedimentary rocks with deeply incised wadis draining to the east. The surface water divide runs parallel to the axis of t he mountains, and surface water drains eastwards towards the Jordan River Valley with minimal infiltration in the carbonate rocks or soil profile due to the high degree of slope in the wadis.

The elevation of these mountains ranges from 600-1,000 m above msl, yielding an elevation difference of more than 1,300 meters between the mountain peaks and the adjacent Jordan River Valley.

The flow direction in this area is to the southeast east towards the Jordan River and Dead Sea (Fig.15) Eastern Aquifer system in the study area covers two sub-basins: *(ARII, 1995; Wolfer, 1998; and Aliewi et al 2005).*

1. Auja-Fasayel sub-basin, which drains the Neogene plestocene and Upper Cenomanian aquifers, with flow direction to the southeast.

2. Ramallah-Jerusalem Sub-basin drains the lower and Upper Cenomanian, Neogene, and Pleistocene aquifers, with flow direction to the east and southeast.

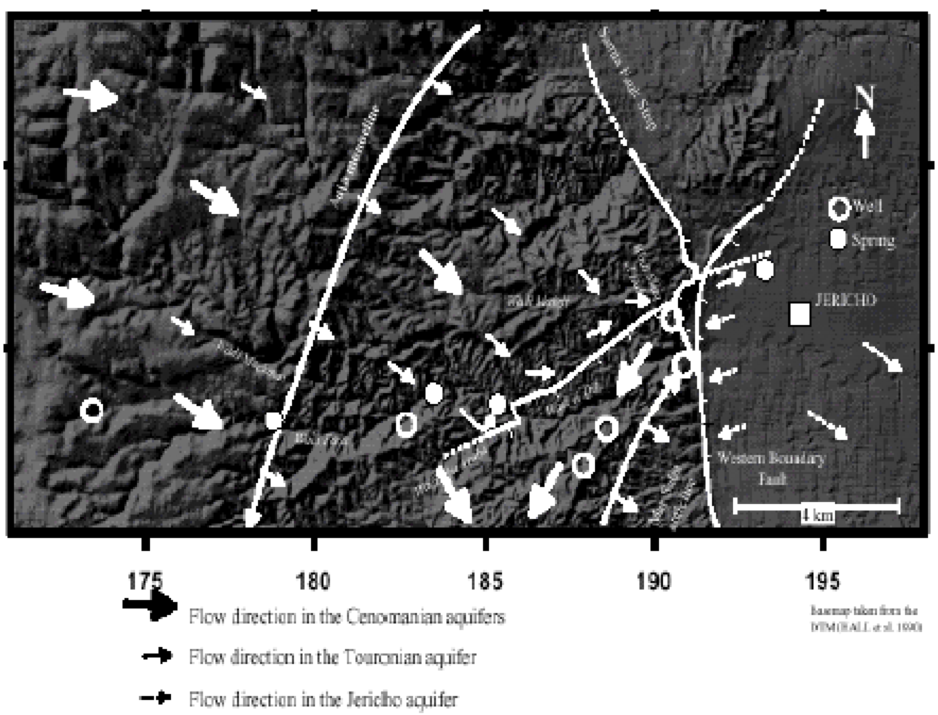


Fig. 15: Conceptual *model* of the groundwater flow in Wadi el Quilt and Jericho area. *(Wolfer, 1998; After Aliewi et al 2005).*

2.8.2 Ramallah Jerusalem sub-basin

Jerusalem Ramallah sub-basin is a part of the eastern basin in the West Bank. It is mainly fed by inflows of excess water from the surface runoff across the wadis and the neighboring aquifers, namely the lower Cretaceous Kurnub sandstone aquifer and the Albian to Turonian limestone and dolomite aquifer, also known as the lower and upper aquifer. The main local aquifer systems in the study area are:

- The upper Cretaceous carbonate aquifer from where the springs are draining.
- The Pleistocene shallow aquifer.

The aquifer potentiality of the geological formations Jerusalem Ramallah sub-basin is represented in (Table 2). The main local aquifer systems in the study area are (Fig.16):

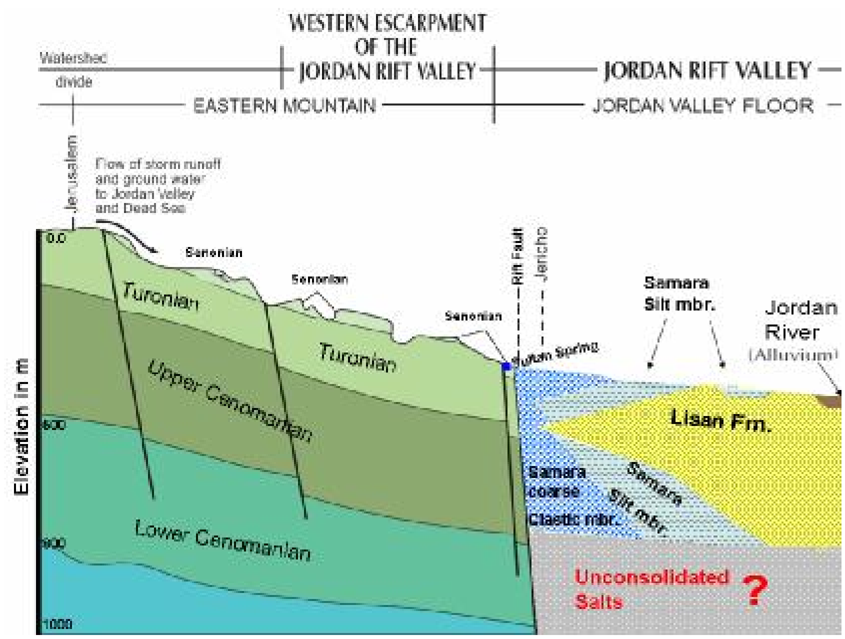


Fig. 16: Schematic hydrogeological cross-section in the study area. *(Modified from Exact, 2000 and Rosenthal 1978,after Khayat 2006).*

The basin as well as the whole area is considered as semi-arid, the annual precipitation amount in the main recharge zones for the aquifer in Jerusalem and Ramallah mountains is about 540mm *(Marie, 2001).* However, the area across the basin contains several surface water flow that drained from the upper mountains of Jerusalem and Ramallah through two main wadis, these are: Wadi Nuwe'meh and Wadi Qilt.

Wadi Qilt is a natural protectorate of great natural and historical values. Its environmental system represents the desert and depression, It extends from the upper mountains of Ramallah and Jerusalem through small tributaries consisting a large stream that drained down to across the Jericho western boundary Fault and entering the Jericho plain area. The whole area environment comprises desert areas and wetland regions where the aridity increases with distance to the east, with a lot of springs in depression towered by high mountains within the Wadi. The Jericho plain springs lay by the foot of the mountain near the Jericho fault and considered the main sources of drinking and agriculture.

Water resources in this region are threaten by pollution due to different sources of natural and anthropogenic effluent via the water runoff pathway this including the wastewater and urban waste from the Bedouins and urbanized area surrounded the basin. There are no sewage treatment plants and wastewater disposal in the area is the cesspits. Geologically, the area has a highly fractured outcropping due to the intensive faulting and fracturing in the area, which occurred during the formation of the Jordan Rift Valley. This causes a mature karstification in the area, which allows recharged water to be infiltrated with less natural infiltration. Some of the springs in the study area such are deteriorated to the cesspits wastewater disposal system and open waste streams that contribute into the wadis.

2.8.3 The Upper Cretaceous Carbonate Aquifer (UCCA)

This aquifer is of Cenomanian to Turanian age. Composed of Karstified rocks, and characteristic of the aquifer system and represent one of the most important water resources in the region. The thickness of the upper Cretaceous aquifer ranges between 170 m in the western of the study area and 200 m in the upper Jerusalem Mts. area. The aquifer is divided into two sub-aquifers. A lower confined sub-aquifer includes the Kefira and the Givat Yearim Formations (Lower Beit Kahil Formation) and an upper sub-aquifer that includesm the Aminadav (Hebron Formation), Veradim (Bet-Lehem Formation) and Bina Formations (Jerusalem Formation) (Table2). The outlets of this sub-aquifer are in the Jericho springs and Wadi Qilt Springs and Wadi Nuwe'meh Springs in the lower part of Wadi Makuk, close to the Jericho Fault.

2.9 Springs

This basin supports over 79 springs. These springs constitute around 90% of the total annual spring discharge in the West Bank. They mainly discharge along small Wadis that drain from west to east and feed the underlying aquifers *(ARIJ, 1997).*

Wadi Qilt hosts several springs such as Fara, Fawwar, and Qilt. They all discharge from the upper aquifer (Fig. 5). The sampled springs (spring = Ein) in Wadi Qilt are Ein Fara and Ein Qilt, and in the western border of Jericho Plain Ein Dyouk and Ein Sultan. The springs in Wadi Qilt immediately response to precipitation in the mountains and due to that discharge is highly fluctuates *(Guttman, 2000; 2004).* The springs in Wadi Qilt area are strongly controlled by the geological structure, mainly the Auja Monocline and Marsaba Anticline (*Toll, 2001; Wolfe,r 1998*) (Fig.5 and 6). Across the eastern slope the rainfall decreases but runoff starts infiltration through soil and fractures.

The springs in the study area (Fig. 5) are discharge from the upper Cretaceous aquifer. The springs are strongly related to the Auja Monocline, NW-SE trending rift faults and joints, where the faults and joints may represent a zone of higher permeability and consequently preferred flow of the groundwater which is tapped by an old caustic shaft in the Wadi bottom, which now forms the spring outlet .All of the springs discharge fresh water with 8 to 14 meq/l total dissolved ions *(Wolfer 1998)*. According to their geographic distribution and discharge behavior, the springs in the study area can be divided into two groups:

2.9.1 The Eastern Slope springs of Wadi Qilt

This group of springs is located in Wadi Qilt and its tributary. These wadis are deeply incised canyons and only here the Turanian aquifer is exposed and spring outflow occurs. The spring's discharge varies with the precipitation and characterized by an immediate response to precipitation and a highly fluctuating discharge pattern. From year to another, with total average discharge of this system about 5 MCM *(WBWD, 1994.IPCRI, 1993)*. Wadi Qilt is fed from three main springs; Ein Fara, Ein Fawwar, Ein El Qilt (Fig.17)

Ein Fara is seasonal spring, which emerges upstream at an elevation of 325 m above msl through the floor of the Wadi. Ein Fawwar Considered to be seasonal spring placed 4 Km downstream at elevation of 80 m above msl, estimated average discharge 30,000-100,000 m^3/d. Ein El-Qilt Third spring in row, 2.5 Km downstream of Ein Fawwar. Almost at sea level, 10 m above msl). In general little variation in flow rate in different seasons. The catchments area extends to 176 Km^2 with annual rainfall of 550 mm, in charge for 20% of Groundwater recharges in the Upper Cenomanian Aquifer (ARIJ, 1995).

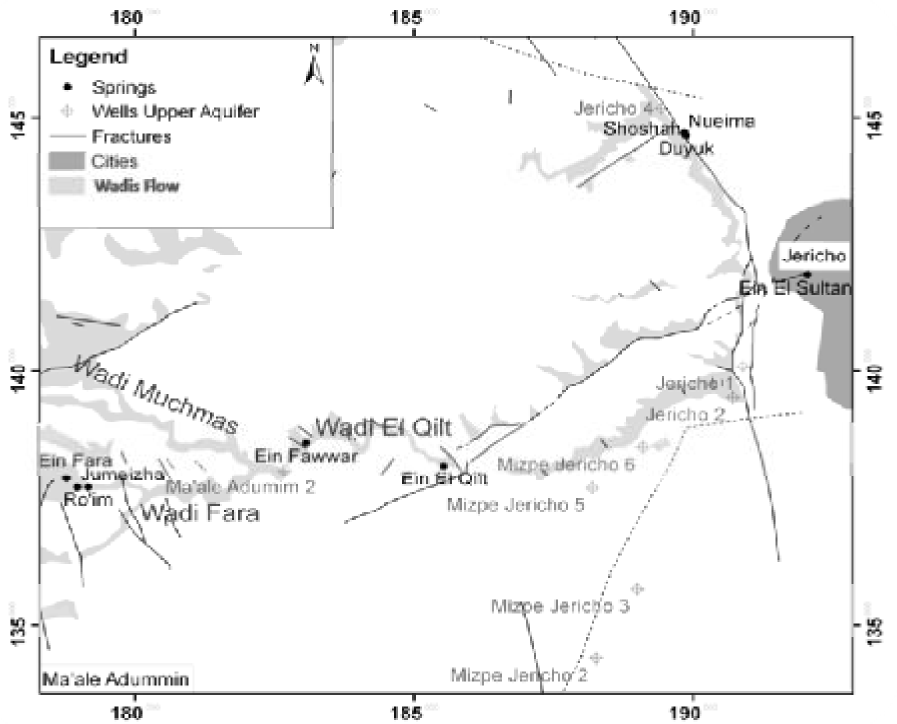


Fig. 17: Study area showing location of sampling site of the springs

2.9.2 Jordan Valley springs

The springs located in the Jordan Valley, northeast to Wadi Qilt, discharge at a constant rate. Related to the Samia Fault; Duyuk Spring, Nuwe'meh Spring and Shosha Spring. Or to a NW-SE trending Rift faults Ein El Sultan. Due to various step faults close to the Jordan Valley the base of the Uppermost Aquifer is exposed. The fluctuations in the discharge pattern depend on the precipitation rate in the recharge zone *(Wolfer, 1998)*. The main springs of this group are described as follow:

1) Sultan Spring

Sultan is located 2 km NW of Jericho and discharges at an elevation of 215 m below msl. Sultan spring was used for 10,000 years for domestic water supply of Jericho. The outflow of this spring is structurally controlled by a large SW-NE trending normal fault postulated by Wolfer (1998) and the spring can be classified as a fault spring. The mean annual discharge of Ein El Sultan is 4 to 5, 6 MCM (Table.

6/Appx.) *(ARIJ, 1995; PWA, 2006).* As it the main source for water for both municipal and Agricultural needs of Jericho *(WBWD, 1994).*

2) Dyouk Springs

Nuwe'meh spring and Shosha Spring; discharges at the margin of the Eastern Slopes 3.7 km NW of Ein Sultan. Emerging on a fault parallel to Rift Fault, they are fed from Upper Cenomanian Aquifer. The system consists of three springs emerging at 110 m below msl *(Toll, et al 2005).* The outflow of these is collected in a concrete channel and farmers for irrigation purposes use water. The average annual discharge of Duyuk spring is 5 MCM, while the average annual discharge for Nuwe'meh spring is ca. 2,7 MCM and for Shosha is about 0.6 MCM (table 6/Appx.) *(Israeli Hydrological Survey, 1974).*

2.10 Hydrochemistry

The main hydrogeological investigations in the Wadi Qilt area were carried out by Rofe and Raffety (1963), Arad and Michaeli (1967), Kroitoru et al. (1985), and Kroitoru (1987) (After Khayat, 2005,2006). Throw the geological history, four main periods, the rock sequence were flushed of earlier formed brines and evaporates and were made ready for the following generations of liquids. Brines were formed which make vulnerable all the Groundwater reservoirs of the Dead Sea-Jordan Rift system .The following major scenarios of brine formation and of salinisation of Groundwater are considered *(Rosenthal, 2005; After Khayat, 2005).*

1. Original Brine

Seawater penetrated from the Mediterranean Sea into the Rift, which afterward confined as a result of tectonic processes, later up flow of brines was assumed to be controlled by the movement of blocks. According to schematic hydrochemical evolution seawater was evaporated to generate "original brine," which was later diluted to yield the "Sea of Galilee brine."

2. The Mg-rich Brines

Emerging from the springs along the western shore of the Dead Sea derived from evaporated Pliocene seawater that was trapped in the primordial Sdom depression within the Rift. . Ca-chloride brine is known from a considered these Rift brines as the main source of salts in the contemporary Dead Sea water. and became confined and pressurized in an unexplained manner

3. Ablation of post-halite evaporites

There is geological and geophysical evidence for the existence of similar evaporite bodies at other places along the Rift. Ablation of such bodies creates Mg-rich brines such as encountered along the eastern and southern shore of Lake Tiberius. The Ca-rich brines encountered along the western littoral of Lake Tiberius and elsewhere in the Rift, could be the result of Mg removal by dolomitization *(Rosenthal, 2005; After Khayat, 2005).*

4. Mixing of two different evaporation brines

As the salinity of one end member. and the second end member was generated, when evaporative loss exceeded the inflow of seawater. When the total evaporation rate from the surface of the shrinking water body equaled seawater supply, the mixing process came to a halt.

The Late Proterozoic-Early Cambrian, and Later, the Triassic; thick layers of Upper Triassic gypsum [and locally of halite] were laid down both west- and east of the present-day Jordan River. While in the Mio-Pliocene, brines were mainly generated by the post-Messinian ingression of seawater which dissolved evaporates previously deposited on the dried-up Mediterranean Sea bed and in the erosive channels incised into the adjoining coastal areas. And after that in the Pleistocene, having fluvio-lacustrine conditions the samra fresh water lake became progressively saline, probably as the result of dissolution and flushing of salts from the previous hypersaline Sdom Sea resulting in the saline Lisan Lake. From the Pleistocene onwards, the Lisan Lake became more and more saline by evaporation and by subsequent flushing of evaporates. Finally have the Dead Sea *(Rosenthal, 2005; After Khayat, 2005)*.

The main significant groundwater quality problems in the area were the increase of salinity and nitrate. The springs to the west still have relatively higher quality than the groundwater from the wells in the east. Although, it's subjected to various fluctuated content of pollutants, this fluctuation depend on several factors like the annual precipitation rate for each year, the annual pumping rate, the season of the groundwater sampling and the activities. Many previous studies identified the common sources of salinity and groundwater deterioration in Jericho and vicinity. The common sources of this high salinity rate was reported by Marie & Vengosh, (2001), where they identified the in situ dissolution of salts within the well from Lisan formation, the apprising of deep brackish water and anthropogenic effluent as the three sources for this phenomenon. Many other studies referred to the high Ca-Cl and Na-Cl water to the upcoming of deep-seated brine water along the fractures of the Rift Valley or to a current. These studies concentrated on the spatial variation of the groundwater quality and its relation to the geology of the basin.

The composition of groundwater in the aquifer of the eastern basin has repeatedly been studied in the last few years *(Wolfer 1998; Toll 2001; Guttman, 1997*, 2004) determined the recharge quantity and delineated the groundwater flow in the area.

These studies revealed only minor spatial and temporal relationships between changes in chemical composition, the geological structure of the aquifer, and its recharge mechanism in the Jerusalem-Ramallah Mts. and in the wadis heading towards the Jericho Plain. East of Jericho, the groundwater is affected by the high-salinity groundwater of the Jordan Valley. The available potential resource of the eastern basin is estimated between 100, 150 and 172 Mill.m3/yr *(Tahal, 1990; IPCRI, 1993;* Oslo 2 Accords 1995*)* but it is not exploited because of its poor water quality.

Mediterranean seawater was flux to the topographically low Rift Valley *(Kafri & Arad, 1979).* Vengosh & Rosenthal, 1994 described two main type of the brine water as the main cause of salinity in the region these are: Ca-chloride brine waters encountered in the Jordan Dead Sea Rift Valley, in various parts of the Negev and of the Coastal Plain, and Na-chloride saline water identified in the subsurface of the Negev and in the southern part of the Coastal Plain. They found that the intensive exploitation of groundwater in the area has disturbed the natural equilibrium, which prevailed between fresh and saline water. The newly established groundwater flow regimes have facilitated the migration of saline water bodies, their participation in the active hydrological cycle and the progressive contamination of fresh groundwater.

These processes that were not anticipated by planners and water resources managers emphasize that large-scale groundwater exploitation was undertaken without giving sufficient consideration to the occurrence and subsurface migration of saline water and brines. Geophysical surveys of groundwater in the Jericho area *(Gropius & Klingbeil, 1999)* have suggested that brine occupies the deepest part of the Pleistocene sediments at a depth of ~80 m, and is overlain by less-saline groundwater. The chemistry of groundwater in the Jericho area indeed reflects a mixture of these two water sources *(Marie & Vengosh, 2001)*. However up to now, no fixed data regarding the origin or driving mechanisms of the saline water in many areas along the valley has been identified. Also, Farber et al., 2003 conclude that the extensive irrigation over the flood plains of the Jordan River enhances dissolution and leaching of sediments that together with underlying brackish water control the salt content of shallow groundwater. However up to now, no fixed data regarding the origin, the share of different sources, or driving mechanisms of the saline water in different areas along the valley has been identified. Further details about the problem of Salinity and groundwater deterioration with other anthropogenic contaminants as well as detailed description of the study area will be described in the results.

3. Methodology

The interpretation of monitoring for the anthropogenic nitrate and dissolved organic carbon in the springs, along with spatially and temporally variations of other geogenic (nature) and anthropogenic chemical composition of the groundwater as will as stable isotopes $\delta^{18}O$ and $\delta^{2}H$.in the groundwater and precipitation in the Jerusalem Ramallah sub-basin during the hydrological year 2006-2007 has been carried out.

3.1 Sampling Time and Site

Samples were collected at different periods between September 2006 and April 2007, 7 to 14 days after the occurrence of storm event. 30 Rainfall water samples were taken, in addition to 30 flood water samples in wadi Qilt (Hizma Wadi) through the same period The groundwater samples were collected from 4 springs along Wadi Qilt area, these are Ein Fara, Ein Qilt, Ein Dyouk and Ein Sultan (Fig.5 and 17).

The plan of groundwater sampling and selection of the samples sites was based on providing a supplement analyses for tracers which had not been previously used in the groundwater and its variation with location. Times sampling of 21 water samples from springs and wells were collected, the first time at the end of October/2006 (dry season) and the second time at the end of March/2007 (at the end of wet season). Two water samples are belonging to the Sultan and Dyouk springs in the western and northwestern side of the study area

3.2 Sampling and Analysis

The springs of Fara and Qilt in Wadi Qilt and of Dyouk and Sultan in the Jericho Plain were sampled shortly before and after the occurrence of rainy storms in the winter season 2006/2007 (Pic.2). In each sampling site temperature, electrical conductivity, redox potential, and pH were recorded. The samples were collected in

60 ml HDPE bottles with tight caps. The cation samples were preserved using concentrated nitric acid and trace amounts of $HgCl_2$ were added to the anion samples with in order to prevent any bacterial activity.

Pic. 2: On site during tacking sample.

Therefore, the chloride concentrations were determined from the cations samples. All samples were analyzed by ion-chromatography at the Helmholtz Center for Environmental Research in Leipzig, Germany. HCO_3^- was determined by Gran titration in the field. All results are summarized in Table 3. Dissolved CO_2, partial pressure of CO_2, and saturation indices of calcite and dolomite are estimated by PHREEQC.

3.3 Determination of Chemical Parameters

Onsite measurements for physicochemical parameters (pH, temperature, m-value and redox potential) were done. All the samples were tested for the Cations and Anions as well as for some trace elements. The samples were filtered with 0, 45+0, 2 µm Cellulose-Acetate-Filters and filled in 2x 60 ml HDPE bottles (cations and anions). In order to stabilizing the anion and cations were acidified using $HgCl_2$ for prolonged preservation of nitrate. The Mercury Chloride is highly dissolve in water, the chemical formula for the reaction of Mercury Chloride in water is given as:

$$HgCl_2 + H_2O \longrightarrow HgO + 2HCl \qquad (1)$$

The Hydrochloric Acid, keep the water sample in acidic media, thus prevent any bacterial growth. Moreover, the resulted inorganic mercury has been reported to have effects at concentrations of the metal in the bacterial culture medium of 5 µg/liter.

Therefore, Mercury Chloride is used as a topical antiseptic or disinfectant agent. Mercury is bound to the cell walls or cell membranes of microorganisms, apparently to a limited umber of binding sites. This means that effects are related to cell density as well as to the concentration of mercury in the substrate. These effects are often irreversible, and mercury at low concentrations represents a major hazard to microorganisms *(Komura, et al 1971).*

Because samples were collected in the agricultural seasons all the sampled wells were in operation for a long period, thus no further water purging was necessary before sampling, and the samples were collected immediately. The collected samples then were kept and cooled until measurement. The concentration of cations were measured using Inductive Coupled Plasma – Atom adsorption spectrometry (ICP-AES) and for

Anions using Ions-chromatography (IC) at the UFZ Department for Analysis in Leipzig (Table 3).

Table.3: Illustration for the analytical methods, and detection limits.

Messgröße	Methode/Technik	RSA* [%]	Detection limits [mg/l]
Ca^{2+}	ICP-AES+	≤1	0,03
Mg^{2+}	ICP-AES	≤1	0,04
K^{+}	ICP-AES	≤1	0,3
Na^{+}	ICP-AES	≤1	0,4
Mn (II,IV,VI,VII)	ICP-MS#	≤5	0,05
Fe (II,III)	ICP-AES	≤5	0,05
B^{3+}	ICP-AES	≤1	0,04
NH_4^{+}	Photometrie	≤2	0,01
Ba^{2+}	ICP-AES	≤1	0,01
Sr^{2+}	ICP-AES	≤1	0,01
Si^{4+}	ICP-AES	≤1	0,09
Cl^{-}	IC$	≤1	0,07
SO_4^{2-}	IC	≤1	0,12
HCO_3^{-}	Titration		
Br^{-}	IC	≤1	0,18
NO_3^{-}	IC	≤1	0,12
NO_2^{-}	IC	≤1	0,05
PO_4^{2-} (P_2O_5)	Photometrie	≤1	0,05
Rb^{+}	ICP-MS	≤4	6

+ICP-AES: Inuctive-Coupled-Atom Emission spectroscopy

#ICP-MS: Inuctive-Coupled-Mass spectroscopy

$IC: Ions chromatography

*RSA: relative Standartabweichung (Die RSA ist abhängig von der spezifischen Elementkonzentration in der Wasserprobe. Mit zunehmender Annäherung an die Elementspezifische Nachweisgrenze (RSA>33%) wird die RSA geräteunabhängig mit <10% angegeben.)

ICP-AES: Insofern die Konzentration der Einzelelemente oberhalb des mittleren Konzentrationsbereiches der ICP-AES liegt, wird die Probe soweit verdünnt, dass die Konzentration sich innerhalb dieses Bereiches befindet. Die RSA beträgt 0,5-1%.

ICP-MS:

IC: Bei IC-Messungen beträgt die RSA ≤2%.

[Quelle: persönliche Kommunikation mit Dr. Wennrich (2005): Departmentleiter Analytik UFZ Leipzig-Halle GmbH]

Water samples were collected in 60 ml HDPE bottles for Anions and poisoned with small drops of Silver Chloride solution to prevent any biological activities in the solution, while the samples for DOC analysis were collected in 15 ml niskin bottles and refrigerating in low temperature. Nitrate concentrations were measured using a high performance liquid chromatographic method (HPLC), while DOC was analyzed by the high-temperature catalytic oxidation method *(Anderson et al., 1994).* All analysis was held in the laboratories of UFZ-Helmholtz Center for Environmental Research.

3.4 Isotopes

3.4.1 Stable Isotopes

Stable isotopes as a means in identifying the sources of ground water contamination, it's considered to be widely used in hydrological application and meteorological application as will as environment studies. (Barestic et.al, 2007). It's used to determine the flow path, recharge area and relative age of ground water (Li et.al, 2006). Stable isotopes in water (^{18}O and ^{2}H) are affected mainly by meteorological processes that provide a characteristic fingerprint of their origin *(Clark and Fritz, 1997).*

Values are expressed as δ values as part per thousand or per mil (‰) difference from the standard reference. Positive δ values are said to be “Enriched “or “heavy,” while a negative δ values are said to be “Depleted” or “light”.

The isotopic content of rainfall can vary with geographic location (due to deference in temperature, elevation latitude, and distance from the coast. *(School, et.al, 2000).* There are nine isotopic configurations for water molecule, which are distinguished by their mass numbers as well as their characteristics most common interests to the hydrochemists are $^{1}H_2{}^{16}O$ (common), $^{1}H^{16}O$ (rare) and $^{1}H^{18}O$ (rare).

Models of isotopic variability take into account vapor pressure, humidity, temperature, altitude, rainout and moisture content, evaporation and solute concentration, and combinations of them Craig (1961) showed that ^{18}O and 2H behave predictably and that ^{18}O and 2H in fresh waters correlate on a global scale. He developed a “global meteoric water line” that defines the worldwide fresh surface water relationship between ^{18}O and 2H by the equation:

$$\delta\,^{2}H = 8\ \delta^{18}O + 10\ ‰\ SMOW \qquad (2)$$

3.4.2 Measurement of $\delta^{18}O$ and deuterium δD (^{2}H)

The most common method for determining the oxygen composition of water is by equilibration with CO_2; generally its easily applied commercial automated preparation lines to handle a larger number of samples at the same time.

Each run of automated preparation of the system comprises determination of 20 duplicate and 8 standard samples (at the end of equilibrated CO_2 gas is measured by connected mass spectrometer). The equilibrium device consists of two valve blocks (units) with 24-sample connection; each valve block is mounted on a pneumatic lift and consists of 3 banks of 8-sample valve. Bellow manifold the units are evacuated, filled with equilibrium gas (CO_2), and connected to the mass spectrometer via a cold trap that prevent water vapor from entering the inlet. Base of the CO_2 equilibrium method are the physical in water with:

CO_2 (gas) $\longrightarrow$ CO_2 (aqua).

And its chemical reaction to HCO_3- and H_3O+:

CO_2 (aqua) $+H_2O \longrightarrow HCO3 + H_3O+$

The isotopic exchange reaction can be written as:

$C^{16}O_2 + H_2{}^{18}O \longrightarrow {}^{16}O^{18}O + H2^{16}O$.

Samples were collected in 60 ml polyethylene bottles. Gas Source Isotope Ratio Mass Spectrometry (IRMS) was used to determine the hydrogen and oxygen isotope ratios of collected groundwater samples. Oxygen isotope ratios were measured by the Carbon Dioxide Equilibration Syringe method proposed by Matsui (1980), in which carbon dioxide is equilibrated with CO_2 (Epstein & Mayeda, 1953) (to Gl.-M2: $H_2{}^{18}O + C^{16}O_2 \leftrightarrow H_2{}^{16}O + C^{18}O_2$) and then isolated from water vapor and other trace gases prior to injection into the mass spectrometer. Gehre et al. (1996) method was used to prepare samples for deuterium analysis in the mass spectrometer. This method involves reducing sample water into elemental hydrogen through use of a Heated

Chromium Furnace packed with oxidizable material at 850 °C. The resulted H2 was measured in Isotope Ratio Mass Spectrometer (IRMS) of delta S type (Fa.Finnigan MAT, USA). Data quality was checked through an internal laboratory calibration of standards *(Coplen et al., 1991).*

Samples for tritium were collected in 500ml bottles. Distillation of samples under N2-Atmosphaere, then NaO_2 in electrolysis cells was added as batch process electrolytically decomposes: Enrichment (T for instance 15-18-fach) heavy H^2-Isotope in the arrears (D, T) (Taylor, 1983; Rozanski & Groening, 2004). PbCl2 was added on the produced NaOH. A distillation process was adopted until drying , water after addition of Ultima gold radiometric detection over 1000 min in liquid scintillation spectrometer Quantulus 1220 Canberra luggage pool of broadcasting corporations 2770 TR/SL (EG&G Wallac, Finland). By this method, Tritium emits beta decay electrons, which excites the solvent. The solvent transfers its energy to the solute, which emits light photon pulses which are detected and counted. The $\delta\ ^{18}O$ value is refured to the Vienna standard Main Ocean water (VSMOW) standards and exhibits error of 1 ‰.

Hydrogen isotope analysis is carried out in the principle the same way as for $d^{18}O$ but using Hydrogen of known isotopic composition as equilibrium gas .the equilibration procedure tacks around 30 minute. Since H_2S poisons the practically indefinite reusable Pt catalysts it has to be removed prior. Each equilibrated hydrogen gas sample is then transferred into the mass spectrometer; witch again is operated in dual inlet configuration. There its isotopically analyses against a H^2 reference gas of known isotopic composition .the sample is referred to the VSMOW standard with error 1‰.

4. Results and Discussion

4 .1 Meteorological Data for the year 2006/2007

For the study period, hydrological year 2006-2007, the meteorological data was obtained from two sources, due to demonstrative technical problems, in the Palestinian Metrological Stations, the missing meteorological data was emend it with the assistance from the data from NOAA *(www.arl.noaa.gov)*, and was found accord to our observation that we have assembled.

During the study period, as shown in the (Fig.18 and 19), the variation in mean daily and monthly temperature assists the division of season into two periods, Autumn (Sep. to Nov) having average mean daily Temperature of 20 C, winter period (Dec. to March) with lower average mean daily Temperature 10 C. The lowest mean daily Temperature was not directly in a relation with rain events, neither with amount nor with the rain event duration. Even it's, as we will see, some how related to the source of the storm, with the correlation with the d-excess (Sec.4.5.3). The lowest mean temperature was recorded to be 4 ºC at 27th, Dec. 2006, with 28 mm rain amount. Thou we can see that the most major storm event cumulate 100 mm in 26th, Dec. 2006) record the daily mean temperature of 10 ºC.

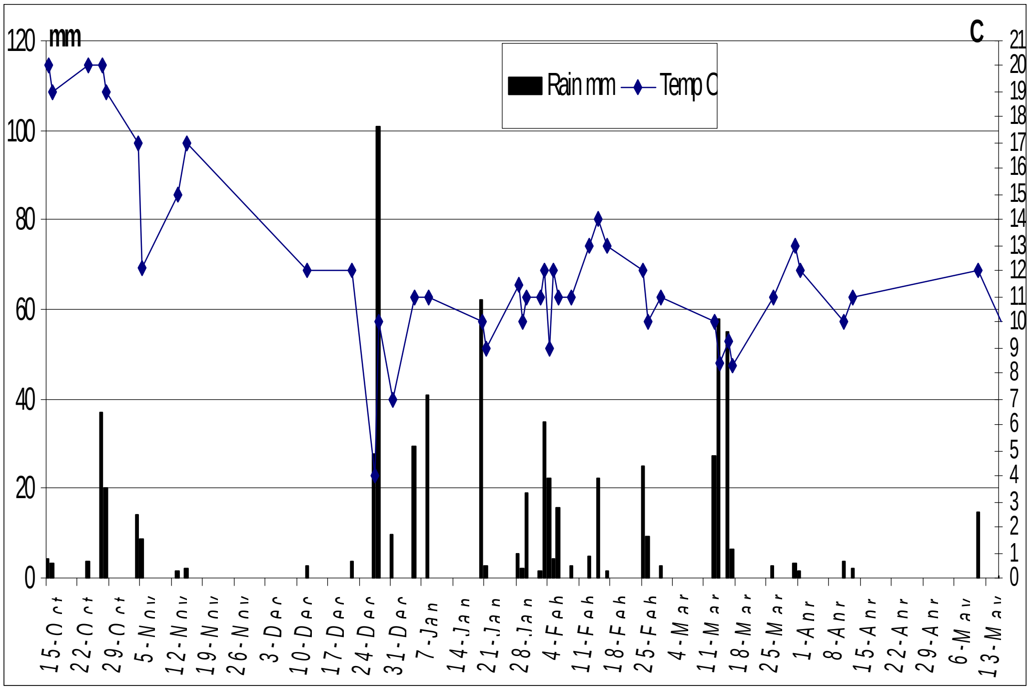


Fig. 18: Correlations between Rains mount (mm) Vs. Mean air Temp. (ºC) in the study period. *(Hydrological year 2006/2007,Table,5/ Appx).*

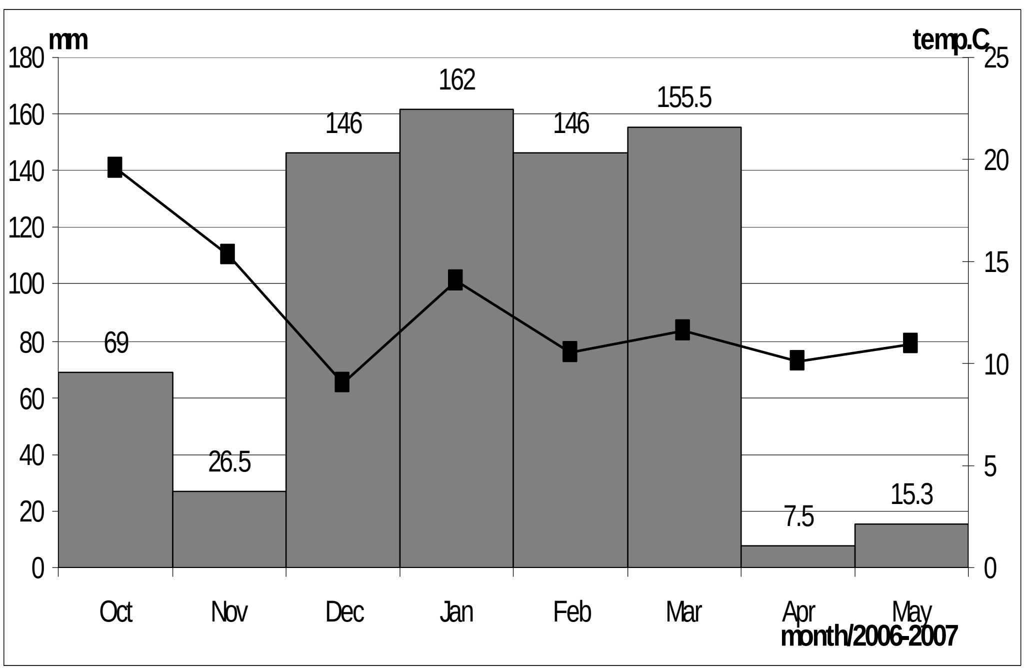


Fig. 19: Avg. Monthly Rain Amount (mm) Vs. Avg. Mean air Temp. (ºC) in the study area. *(Hydrological year 2006/2007,Table6/ Appx.).*

4.2 Fluctuation of Groundwater with time

Studying the fluctuation of Groundwater discharge (Springs natural flow) for in Ein Sultan and Ein Dyouk, we see that there is no clear trend between the discharge in Ein Sultan and Ein Dyouk, from the correlation between springs flow discharge and rainfall events (significant recharge events), time and concentration, in the past two years (Fig.20).

Also it appears that there is a non-substantial response following to the rain events, as we have some points in which an increase in the spring discharge comes following to significant rainstorm. The interflow (subsurface) that precipitation does not enter the groundwater only occurs at shallow depth subsequent after recharge event with short time. The Piston effect as will as the karstic formation has a share in driving this pattern of flow (*Guttman, 2004).*

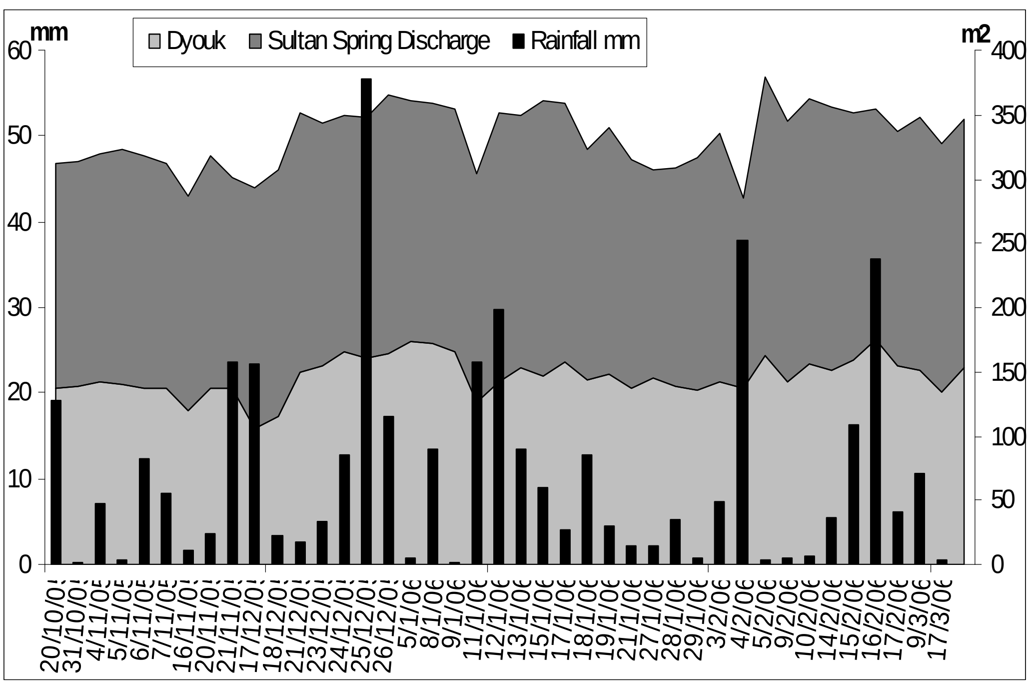


Fig.20: Rain fall Mount Vs the Natural Discharge in Dyouk and Sultan Springs.(Table 6/Appx.)

4.3 Hydrochemistry

4.3.1 Nitrate (NO3)

In rainwater samples the nitrate (NO3) detected to be high in the first rain event, where the first significant rain event (15, October) shows the highest nitrate value of 49 mg/l, and was repeated with less extent in 23 of December after the long draught period mentioned above where no considerable rain event were occurred in between (Fig.21, Table.4). The nitrate content in the precipitation has decreased the end of the winter season as an indicator on atmospheric wash out effect with the continuity of rain events until the end of season.

The relatively high values in the nitrate for the first rain event could be due to the high content of nitrogenous gas compound in the atmosphere which might accumulated during the dry summer period forming acid rain, the nitrogenous compounds in the atmosphere must be as a result of the Israeli's industrial activities and other gas emotions from volatiles chemical such as pesticides.

The spring's response to the rain events and its contents of nitrate shows no clear trend (Fig.22). The springs show a stable nitrate trend for the first few months of winter (to the mid of Dec.). The samples then show two different trends as a nitrate shock and depression: the first trend for the Fara and Qilt springs, the first springs in the Wadi Qilt close to the catchment's area, where the groundwater samples from these springs show a nitrate depression after short period of an intensive rain event. While Dyouk and Sultan springs show a nitrate shock at the same time.

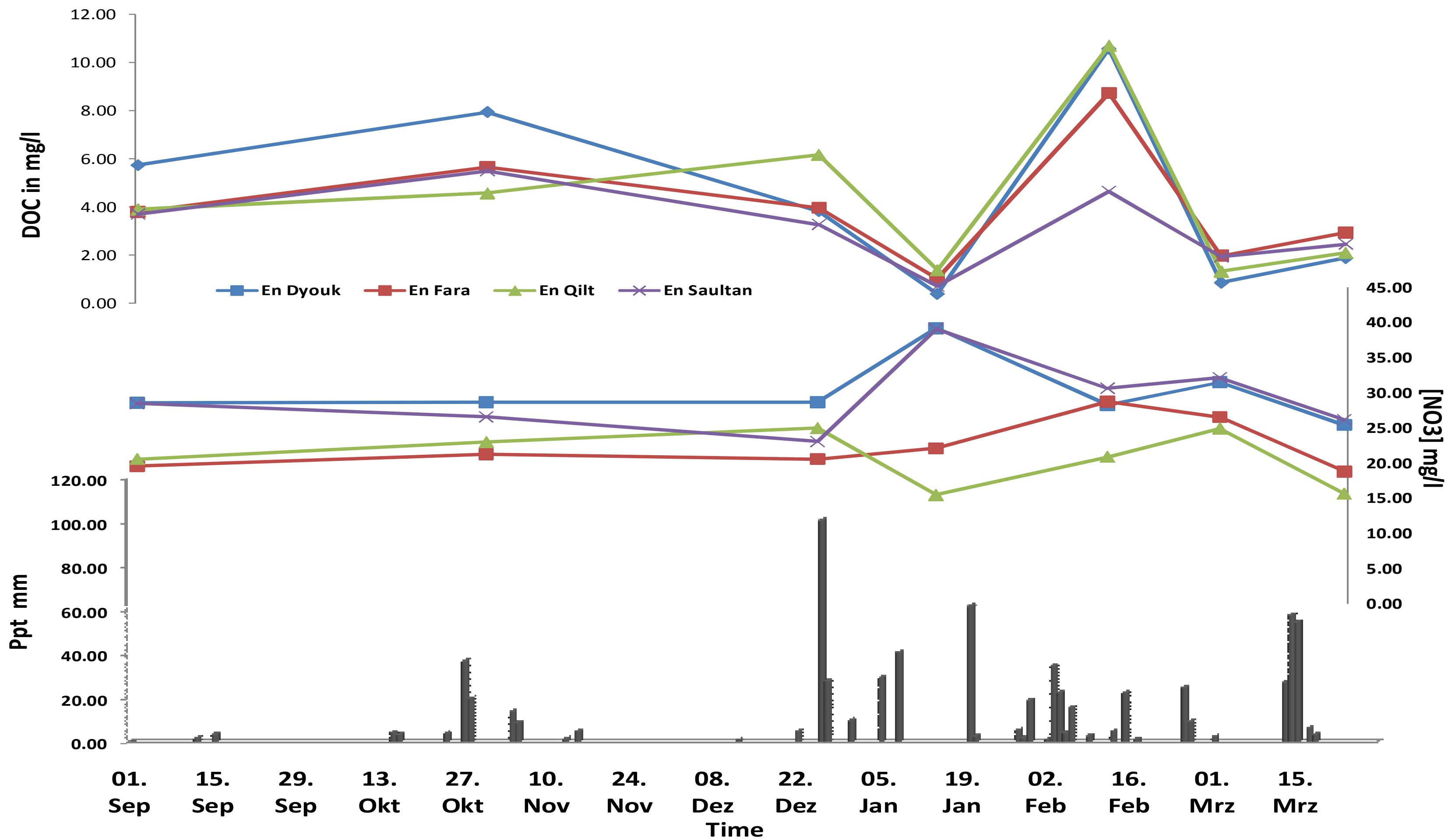


Fig.21: Daily Precipitation values compared to nitrate and DOC in the groundwater in mg/L.

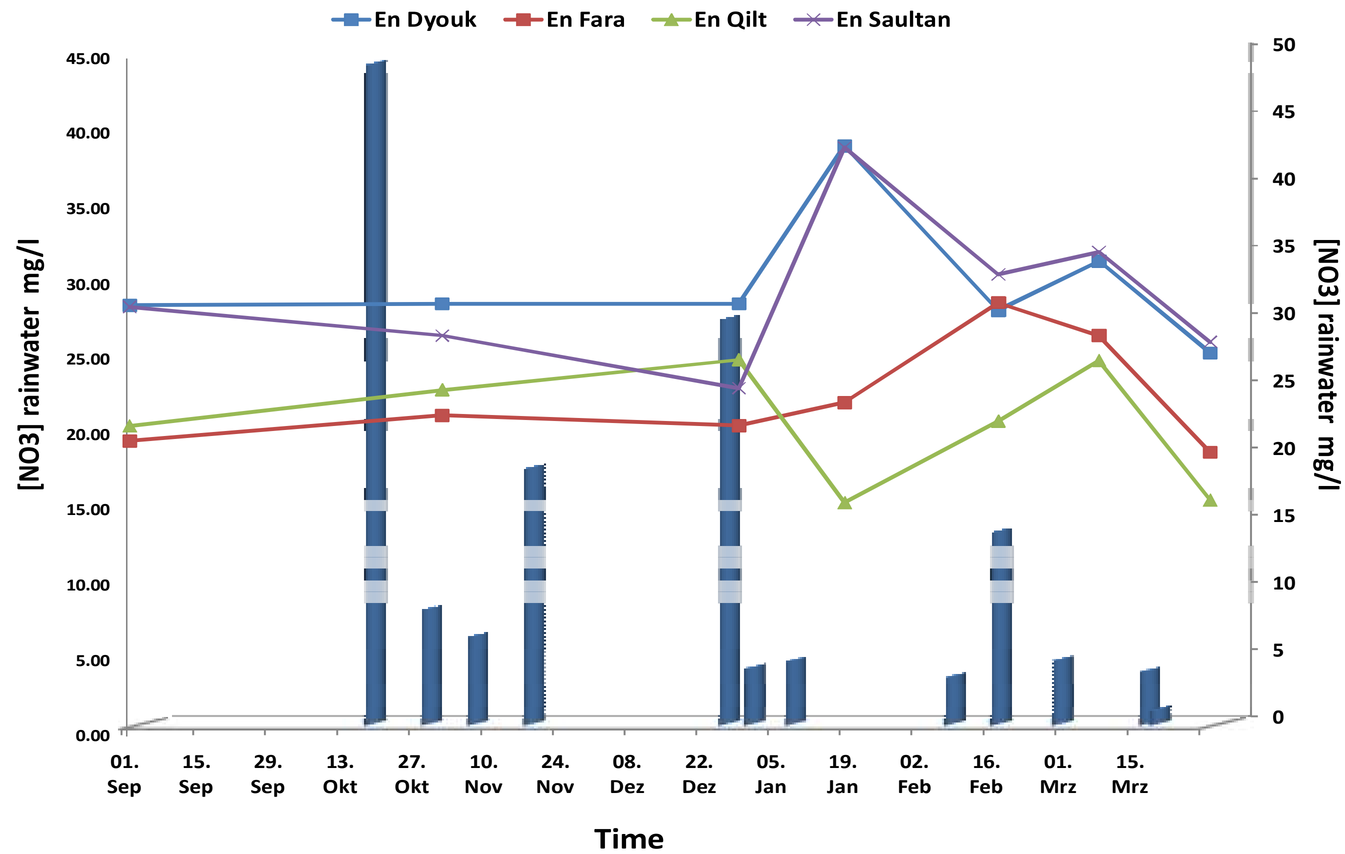


Fig.22: Nitrate in rainwater compared to nitrate in groundwater samples from springs. (Table 4)

This can be explained as the location and distance effect from the upper catchment area and the mode of aquifer replenishment. The depression of the nitrate content in the springs closed to the catchment area is due to the dilution effect with freshwater runoff in the Wadi that feed the aquifer directly with precipitation, this amount of freshwater dilute the wastewater effluent drained from the adjacent settlements. The converse nitrate shock in the Sultan and Dyouk springs at the same period is due to the far distance from the precipitation and replenishment point, the stored nitrate and other pollutants in the aquifer area washed out from the aquifer under the pressure of the storm event in the upper mountain which moving the old stored water in the aquifer quickly under the pressure of new replenished water. The groundwater samples from Qilt and Fara return to increase another time later on (after the second significant rain event) also under the washout effect and the continuity of wastewater effluent.

In general, the springs response to the rain intensity and quality didn’t show consequent relation for most of the springs in the study area especially in the lower area where Sultan and Dyouk springs are coincident, this is also due to the fact that the catchment area is far away from the spring and the infiltrated water needs a long period of time to reach the discharge zone of Sultan, where the same indication was also described for Auja springs by Gutman, 2004.

4.3.2 Dissolved Organic Carbon DOC

The DOC values in the spring's groundwater show relatively different trend in response to rainwater intensity. The DOC trend shows quicker increase in the first few months of the winter, but the first high shock in the DOC content was exposed in the middle of February after a big storm events coming respectively after the end of December with high intensity where the DOC amount in the groundwater reach 12 mg/L. This significant shock in the DOC content should be taken into account mainly in Sultan spring, thus to avoid any side product after doing chlorination for the drinking water.

The nitrate and DOC values show no clear relation. Based on data collected in the dry period, it seems that the nitrate concentrations are limited by concentrations of dissolved organic carbon (DOC) in ground water, as shown in (Fig 23).

The presence of organic carbon in ground water in low-oxygen environments appears to be a major factor governing the abundant of nitrate. Therefore, some groundwater samples with high DOC tend to have low nitrate concentrations. In contrast, the same samples in wet period show by the end of wintertime exhibits lower DOC values (Fig.23).

This can be explained, as an electron donor, such as organic carbon, is present in a low-oxygen environment, bacteria may use it to reduce nitrate dramatically and convert it to nitrogen gas, nitrogen oxides, or ammonia *(Korom, 1992)*. The aquifer without further replenishment in dry season enhance low oxygen environment within the aquifer and slight De-nitrification for nitrate can be also enhanced *(Khayat, 2006)*.

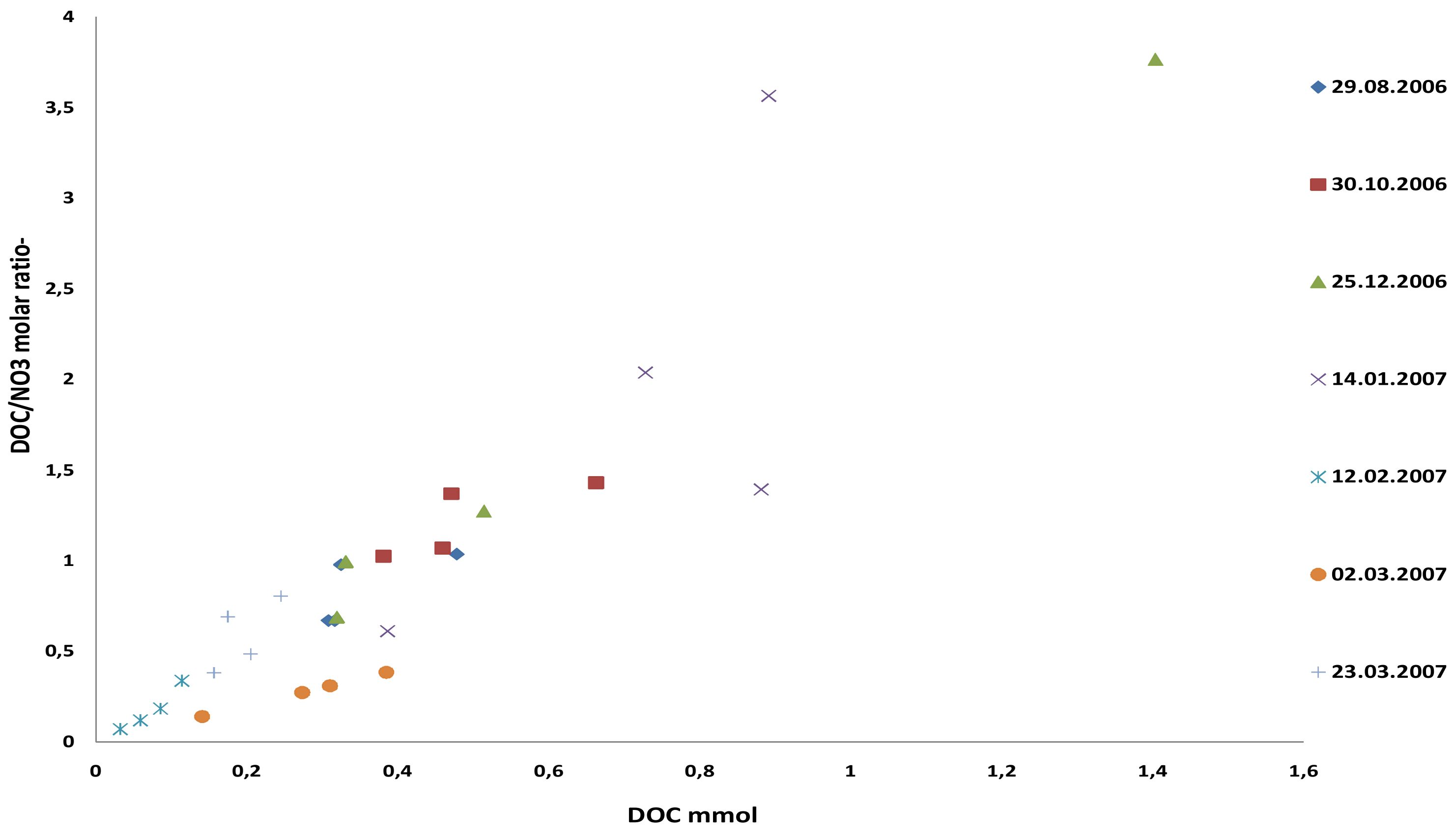


Fig.23: Nitrate and dissolved organic carbon distributed assigned to the time of sampling in groundwater samples from Sultan, Dyouk, Fara, and Qilt springs (Table 4).

4.3.3 Total Dissolved Solids (TDS)

Groundwater samples in the study area are of Ca-HCO_3 type as part of limestone aquifer (Table 2). In the Durov diagram the water analyses clusters narrowly (Fig.24). The wide spread of total (TDS) is strongly related to alkalinity.

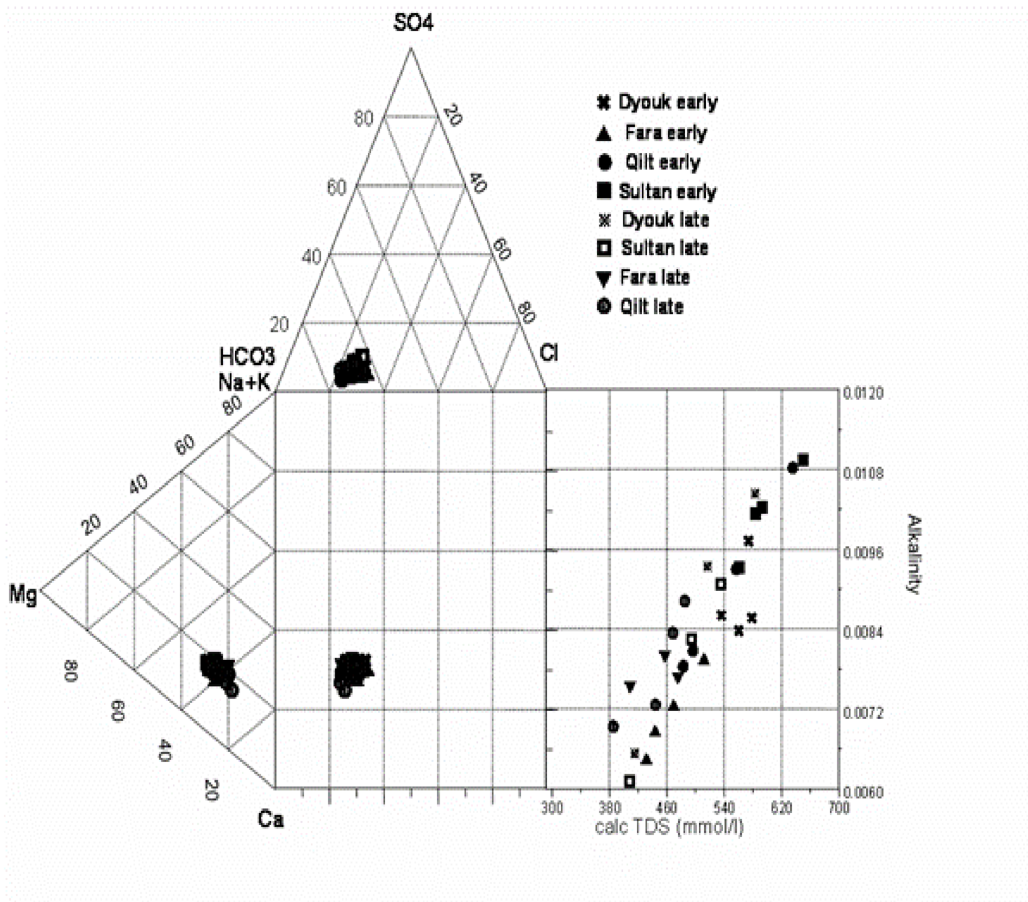


Fig. 24: Durov diagram and Alkalinity with TDS

There is no tendency of TDS to increase with dissolved CO_2 or pCO_2, although the behavior of each spring is different (Fig.25). It varies at constant dissolved CO_2 as well as TDS is constant at variable CO_2. This is only possible when HCO_3^- and pH vary accordingly in order to satisfy the first ionization of H_2CO_3.

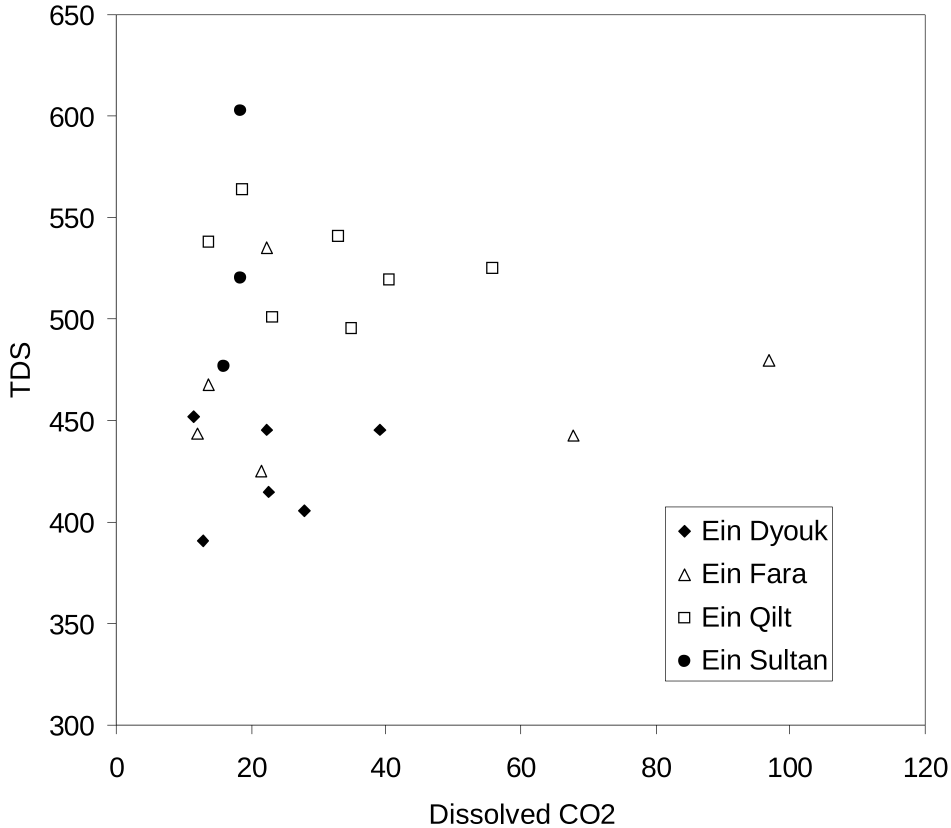


Fig 25: Cross plots of TDS and dissolved CO_2. (Table 4).

During the wet winter season, however, the concentrations of solutes vary locally and temporally (Fig. 26a). At comparable times, the samples from Ein Fara (=F) and Ein Qilt (=Q) show slightly lower TDS than those from Ein Dyouk (=D) and Ein Sultan (=S). This indicates an increase in TDS with distance from the recharge area in the upper mountains along the flow path from the mountains -> Ein Fara -> Ein Qilt ->Ein Dyouk/Ein Sultan.

Temporally, TDS increases in the first half of winter but decreases significantly in the second half due to increasing recharge in the mountain aquifer, which enhances flow water in the aquifer. The increase in the TDS in the first half might refer to the flushing of soluble components stored during the earlier dry periods which are washed out under the pressure of the first few recharge events. In general, the time-dependent trend of TDS is parallel to that of Ca and HCO3- (with exception of Ein Qilt) but none of the other dissolved species.

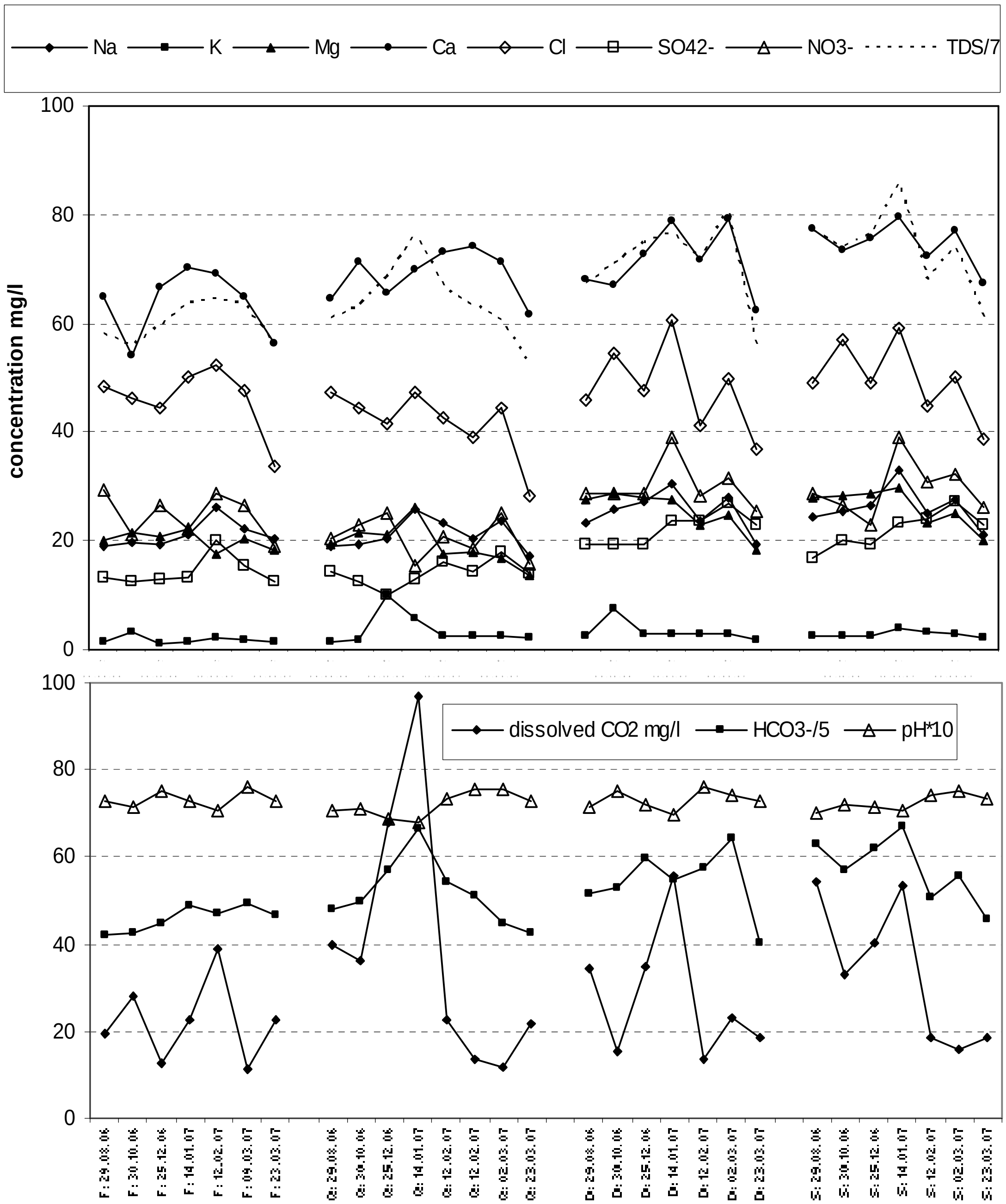


Fig 26: Time-dependent concentrations of dissolved species in spring water from Ein Fara (F), Ein Qilt (Q), Ein Dyouk (D) and Ein Sultan.

Table 4: The main physical and chemical results in mg/L for the groundwater samples from the springs at different times during the hydrological year 2006/2007.

Spring	Sample_Date	pH	Eh[mV]	Temp	Cond	Na	K	Mg	Ca	Cl	SO4	NO3	HCO3	DOC	SI Calcite	SI Dolomite	CO2	pCO2
En Dyouk	29.08.2006	7.14	275	22.3	680	23.2	2.4	27.6	68.1	45.7	19.4	28.6	257.42	5.74	-0.06	-0.2	34.276	0.020893
En Dyouk	30.10.2006	7.5	293	22.9	680	25.8	7.6	28.5	67.2	54.5	19.2	28.7	264.13	7.95	0.3	0.56	15.504	0.009333
En Dyouk	25.12.2006	7.19	292	21.4	698	27.3	2.7	28.1	72.9	47.5	19.5	28.7	298.29	3.83	0.06	0.01	34.98	0.02138
En Dyouk	14.01.2007	6.95	268	22	745	30.4	3	27.6	78.9	60.6	23.7	39.2	274.65	10.6	-0.18	-0.5	55.88	0.033884
En Dyouk	12.02.2007	7.6	284	19	650	23.5	2.7	23.1	71.6	41.2	23.6	28.3	286.7	0.39	0.41	0.6	13.64	0.007586
En Dyouk	02.03.2007	7.4	291	21.1	708	27.8	2.8	24.9	79.2	50.0	27.0	31.5	320.25	0.86	0.32	0.44	23.188	0.013804
En Dyouk	23.03.2007	7.3	334	21.2	618	19.2	1.7	18.4	62.3	36.9	23.0	25.4	201.3	1.88	-0.04	-0.32	18.656	0.01122
En Fara	29.08.2006	7.3	264	21	548	18.9	1.4	20.2	64.9	48.3	13.4	29.3	209.3	3.80	-0.01	-0.24	19.404	0.011482
En Fara	30.10.2006	7.14	251	22.2	552	19.8	3.3	21.4	54.3	46.1	12.6	21.3	211.67	5.65	-0.22	-0.53	28.028	0.017378
En Fara	25.12.2006	7.5	286	22	558	19.4	1.2	20.9	66.6	44.3	12.9	26.7	223.26	3.97	0.23	0.28	12.804	0.007943
En Fara	14.01.2007	7.3	267	21	624	21.2	1.6	22.4	70.2	50.1	13.4	22.14	244.61	8.74	0.08	-0.04	22.572	0.01349
En Fara	12.02.2007	7.05	274	21	648	26.3	2.0	17.5	69.0	52.3	19.9	28.8	236.07	1.03	-0.19	-0.68	38.94	0.023442
En Fara	09.03.2007	7.6	312	20.7	594	22.3	1.7	20.5	64.8	47.5	15.3	26.6	246.44	1.98	0.34	0.48	11.44	0.006761
En Fara	23.03.2007	7.3	32	21.3	578	20.3	1.4	18.4	56.3	33.8	12.4	18.9	232.41	2.94	-0.02	-0.22	22.44	0.012882
En Qilt	29.08.2006	7.05	229	21.7	555	18.9	1.6	19.4	64.4	47.3	14.4	20.6	240.95	3.90	-0.2	-0.61	40.04	0.023988
En Qilt	30.10.2006	7.1	248	21.7	586	19.2	1.9	21.6	71.3	44.3	12.7	23	248.27	4.57	-0.1	-0.4	36.08	0.021878
En Qilt	25.12.2006	6.89	227	21.4	625	20.5	10	21.3	65.6	41.5	10.2	25	285.48	6.17	-0.29	-0.76	67.76	0.040738
En Qilt	14.01.2007	6.8	246	21.2	657	25.9	5.86	26.3	69.9	47.4	12.8	15.5	331.84	10.7	-0.3	-0.72	96.8	0.057544
En Qilt	12.02.2007	7.35	261	21.2	620	23.4	2.5	17.5	73.2	42.7	16.2	20.9	270.84	1.37	0.19	0.07	22.44	0.01349
En Qilt	12.02.2007	7.55	283	21.1	625	20.6	2.6	18.0	74.2	39.0	14.4	18.7	256.2	1.75	0.37	0.43	13.64	0.007943
En Qilt	02.03.2007	7.55	291	20.1	650	23.8	2.5	16.7	71.3	44.6	18.1	25.0	223.26	1.32	0.29	0.23	11.88	0.006761
En Qilt	23.03.2007	7.27	308	21.3	450	17.1	2.1	13.7	61.5	28.4	14.1	15.7	213.5	2.10	-0.04	-0.43	21.56	0.012882
En Saultan	29.08.2006	7.02	256	22.1	685	24.5	2.5	28.1	77.4	49.1	16.9	28.5	313.54	3.70	-0.05	-0.23	54.12	0.033113
En Saultan	30.10.2006	7.2	263	26	690	25.6	2.5	28.4	73.5	56.9	20.0	26.6	286.09	5.51	0.12	0.19	33	0.02138
En Saultan	25.12.2006	7.15	279	21	699	26.5	2.5	28.7	75.6	49.2	19.5	23.1	310.49	16.9	0.05	-0.03	40.48	0.023988
En Saultan	14.01.2007	7.05	302	22.5	735	33	3.8	29.7	79.5	59.2	23.3	39.1	335.5	4.64	0.01	-0.09	53.24	0.033113
En Saultan	12.02.2007	7.4	286	21.6	671	25.1	3.1	23.4	72.3	44.9	24.0	30.7	253.15	0.71	0.2	0.23	18.48	0.01122
En Saultan	02.03.2007	7.5	295	21.3	705	27.7	2.7	25.2	77.2	50.2	27.2	32.2	278.16	1.93	0.36	0.53	15.928	0.00955
En Saultan	23.03.2007	7.35	331	23	525	21.1	2.3	20.2	67.4	38.8	23.1	26.2	228.78	2.46	0.11	0.03	18.48	0.0104

4.3.4 Hydrochemical variations

Ca, Mg shows strong step function with time, which is also paralleled by Na in Dyouk and Sultan water. In early winter, Ca increases in Ein Fara and Ein Qilt but remains nearly constant in Ein Sultan and Dyouk. In late winter, Ca always decreases .K mostly shows a peak after the first significant rain storm and returns to initial values in the late period of the season. HCO_3- of groundwater along the water flow path from Wadi Qilt is increase toward the Jericho western boundary fault with the springs of Sultan and Dyouk (Fig.26b). Dissolved CO_2 shows a strong maximum in Ein Qilt, in Ein Dyouk and Ein Sultan in mid-January. These peaks may refer to the same rain event, whereas the significantly lower peak in the Ein Fara water from mid-January may reflect a later strong rainfall.

Temporal changes of equivalent concentrations of Ca+Mg and HCO3-+SO42- show little correlation (Fig.27), although their main sources should be calcite, dolomite, and gypsum. HCO_3-+ SO_4^{2-} balances neither Ca alone nor Ca+Mg. Different from Ca+Mg, Ca alone shows trends corresponding with those of HCO_3-+ $SO_4^{2-.}$ This indicates that Mg is less related to carbonate dissolution.

Defining the difference of (Ca+Mg)-(HCO_3-+ SO_4^{2-}) as "Mg" and (Cl+NO3-)-(Na+K) as Cl-excess Mg-Cl water evolves (Fig. 28). This Mg-Cl saline water can only be leached from the aquifer rocks: it may be still present as seawater included in the Judea limestone.

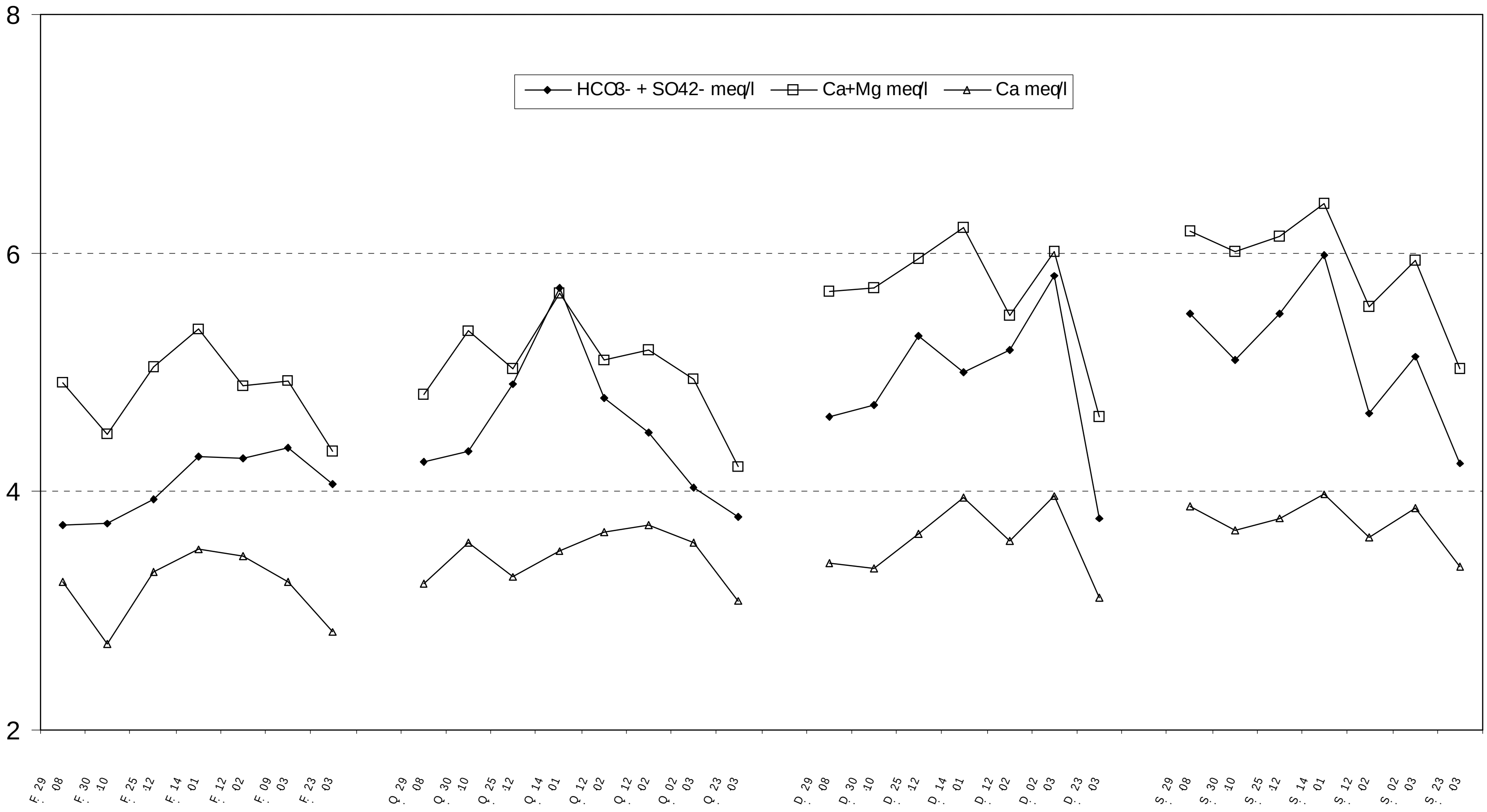


Fig 27: 7Time-dependent changes of HCO3-+SO42-, Ca2++Mg2+, and Ca2+ in spring water from Ein Fara (F), Ein Qilt (Q), Ein Dyouk (D), and Ein Sultan (S).

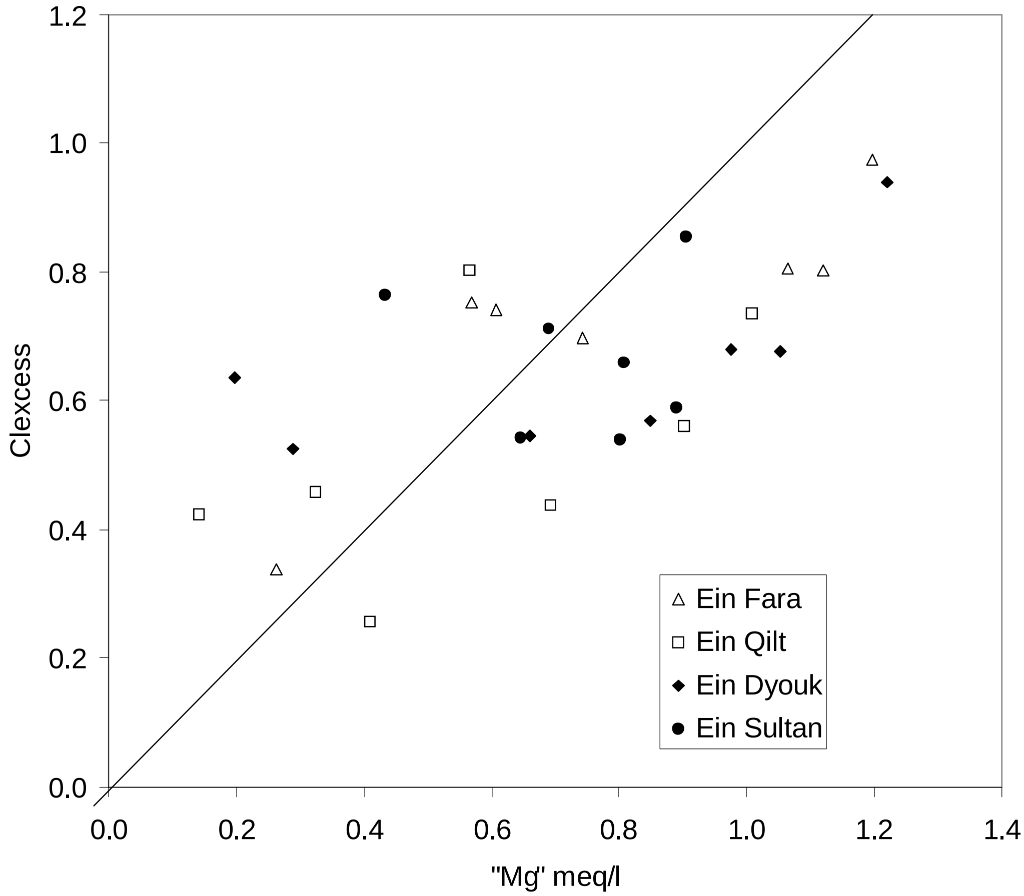


Fig 28: Cross-plots of Cl excess vs. Mg .

4.3.5 Mg/Ca ratio

The Mg/Ca ratio of 0.5 characterize the initial conditions in Ein Fara and Ein Qilt and the final ones in Ein Dyouk and Ein Sultan which showed initial ratios between 0.6 to 0.7 (Fig. 29). The high Mg/Ca ratios of Ein Dyouk and Ein Sultan indicate that here Mg is leached during the dry season and that this groundwater is now replaced and mixed with younger water of lower ratios.

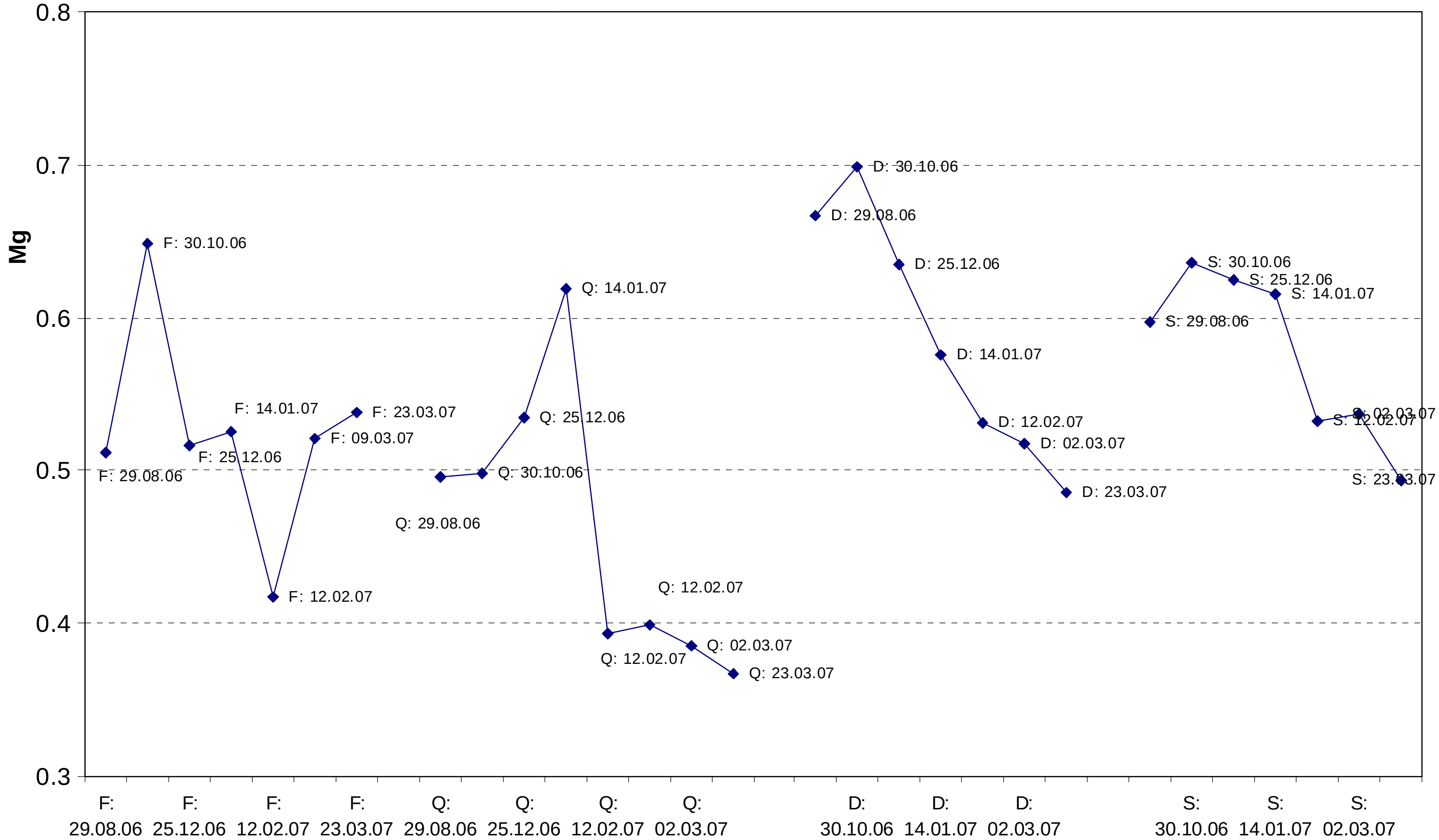


Fig.29: Time-dependent changes of Mg/Ca wt ratios in spring water from Ein Fara (F), Ein Qilt (Q), Ein Dyouk (D), and Ein Sultan (S).

The continuous decrease of Mg/Ca wt ratios in Ein Dyouk and Ein Sultan indicate mixing of water in the aquifer by the new recharge water. The mixing demands for a dual porosity flow in which the recharge water with low Mg/Ca ratio uses the larger karst conduits and has just the chance to mix with the old water with high Mg/Ca ratio which is present in parts of the aquifer with less transmissivity. The latter pool decreases with time and thus the ratio of the spring water decreases.

The rather constant but different Mg levels in early and late season requests a rather large pool of Mg that acts as a buffer. In Ein Dyouk and Ein Sultan this behavior is paralleled by Na, which is much less pronounced for Ein Qilt and Ein Fara. Such a pool could be clay minerals in marly layers of the overlying Lisan Formation acting as aquitard. The clay minerals may act here as ion exchanger. Leaching of Mg-Cl water from sediments or rocks is also a possibility. In any case the equilibrium is quickly established.

Dissolution of carbonates is the process controlling dominantly Ca. Dissolution of calcite is slow because the waters are largely saturated with respect to calcite. High-magnesium calcite releases Mg by forming low Mg-calcite. Equilibration with dolomite at this low temperature is impossible. This explains why these waters are mostly over saturated with respect to dolomite.

After an initial increase of Mg/Ca in Ein Dyouk and Ein Sultan the springs show a gradual decrease in Mg/Ca molar ratio resulting from higher decreases in Mg than in Ca (Fig. 29), i.e. from about 0.65 to about 0.5 in the late winter season. A similar trend is also present in water from Ein Qilt but here the ratio decreases from 0.5 to 0.4. Values of 0.5 are typical ratios in calcareous aquifers (Schoeller 1977; Rosenthal, 1987). Ein Fara shows a trend of its own, the general decrease of Mg/Ca ratios is associated increasing precipitation and runoff. These results show that by the middle and end of winter season, with the increase of rainwater recharge the stored water in both zones of the aquifer are flushed out. In the early period the water shows the solute contents gained due to long contact with minerals of the aquifer rock during the dry period. This water is replaced by directly infiltrating runoff in Wadi Qilt zone (zone 1) and then is going to replace the water in plain zone of Sultan and Dyouk springs (zone 2) by the underground flow.

In general, the compositional changes in Ca and Mg concentrations mainly depend on the residence of water in the aquifer, which is controlled by the volume, and mechanisms of recharge as well as the distance from recharge area. The absolute ratios, however, do not yield a measure of the residence time. For instance, the ratio of 0.5 indicates long residence time in Fara and Qilt, but short ones in Ein Dyouk and Ein Sultan, although all these springs discharge water from the same aquifer. The mineralogical composition of the aquifer of the springs in Wadi Qilt show less soluble Mg bearing minerals than that from which the Jericho springs originate.

The Mg/Ca ratio is commonly used as an indicator of the residence time of the water in aquifers (*Edmunds and Smedley, 2000; Kloppmann et al., 1998; Langmuir, 1971),* resulting from the incongruent dissolution of calcite, magnesium calcite, and dolomite *(Bakalowicz, 1979; Musgrove and Banner, 2004).*

Irrespective of fluctuations, Cl^- concentrations show a decreasing tendency with time, whereas sulfate increase. NO_3^- behaves in between. NO_3^- is related with SO_4^{2-} (Fig.30) insofar as Ein Qilt and Ein Fara show lower contents than Ein Dyouk and Ein Sultan. In case of Cl^-, NO^{3-} is less related. The range of Cl^- concentrations is nearly identical in all springs. Only the NO_3^- concentrations differ for Ein Qilt and Ein Fara on one hand and Ein Sultan and Ein Dyouk on the other.

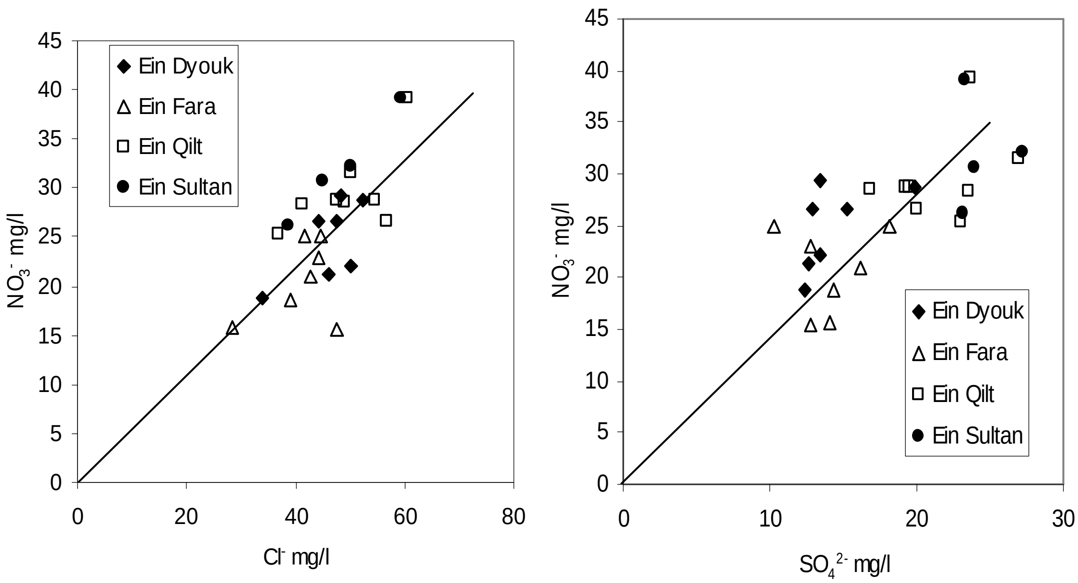


Fig 30: Cross-plots of NO_3^- vs. Cl^- (a) and SO_4^{2-} (b)

The correlation of NO_3^- and SO_4^{2-} with Cl^- indicate that these anions have a similar source which could be soil containing gypsum and of course evaporates from previous rainy seasons (halite, gypsum) and nitrate from sewage. These components easily leached by percolating rainwater.

Related to leachable inorganic components are organic ones comprised as dissolved organic compounds DOC (Table 2). They are the sources of changes in dissolved CO_2, which is discussed later.

4.3.6 Calcite Saturation

Dissolved CO_2, pH, and HCO_3^- concentrations vary within limits that are shown by (Fig. 31) in order to cover the spread of pH/pCO_2 pairs it has to be assumed that

HCO_3^- concentrations vary between 0.005 and 0.007 mol/l. The higher concentrations are preferably associated with high pCO_2 partial pressure.

In most cases, the groundwater in limestone aquifers is close to saturation (Fig.32) with respect to calcite (and less so for dolomite). The majority of the reported waters are supersaturated with respect to calcite. Only when the Groundwater is enriched in CO_2, decreased in pH (Fig. 26b) the spring waters are under saturated with respect to calcite (and dolomite). Because equilibration between CO_2, pH, and HCO_3 is a fast process, the reaction with carbonates (dissolution and precipitation). Calcite saturation varies during the rainy season is controlled by dissolved CO_2. Excepting Ein Qilt, saturation of calcite but not of dolomite is present at the beginning and at the end of the rainy season. During the season excursions of +0.4 to -0.2 occur for calcite. SI dolomite varies between +0.6 and -0.8 (Fig 32).

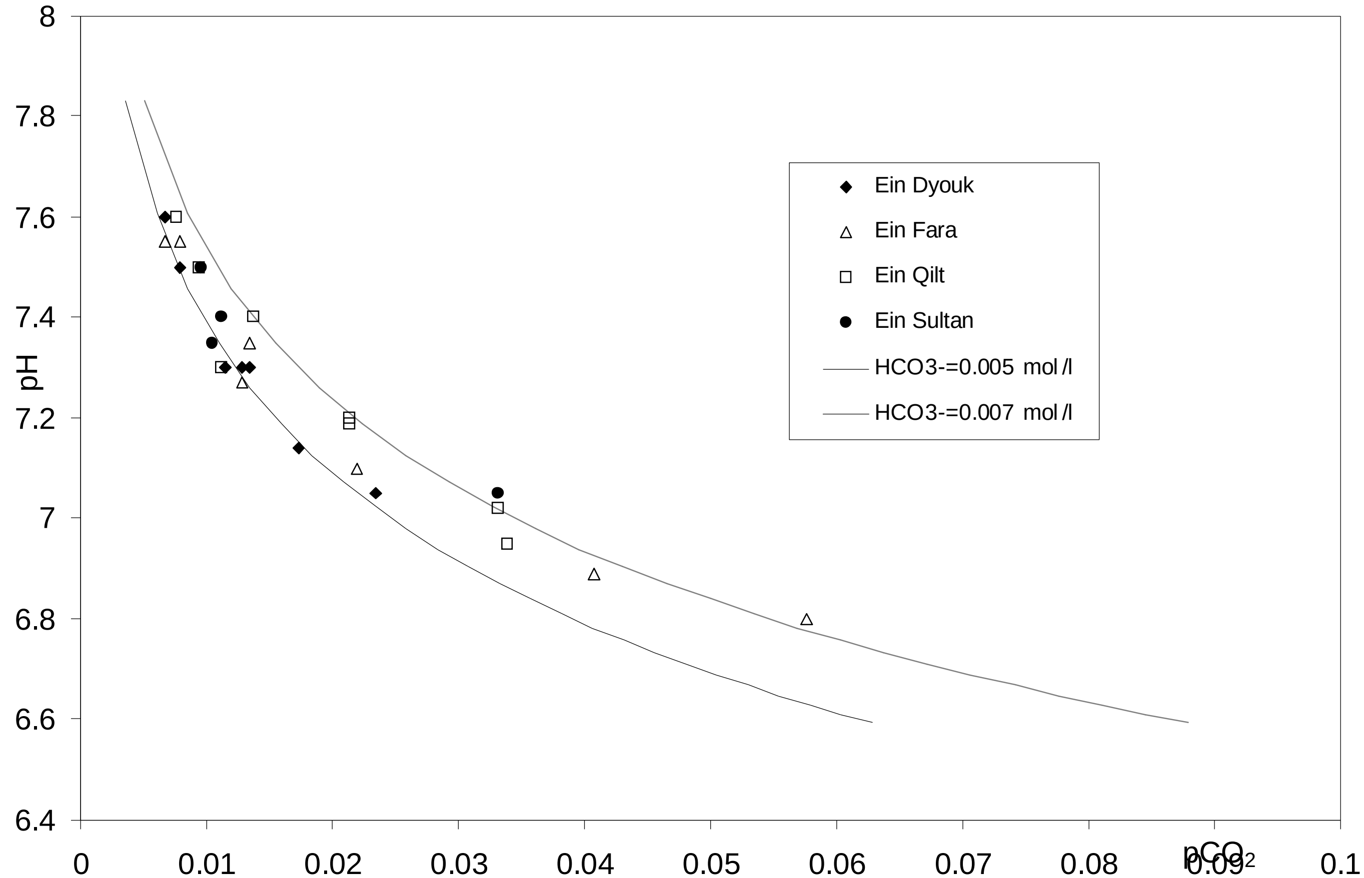


Fig 31: Cross-plots of pH vs. pCO_2.

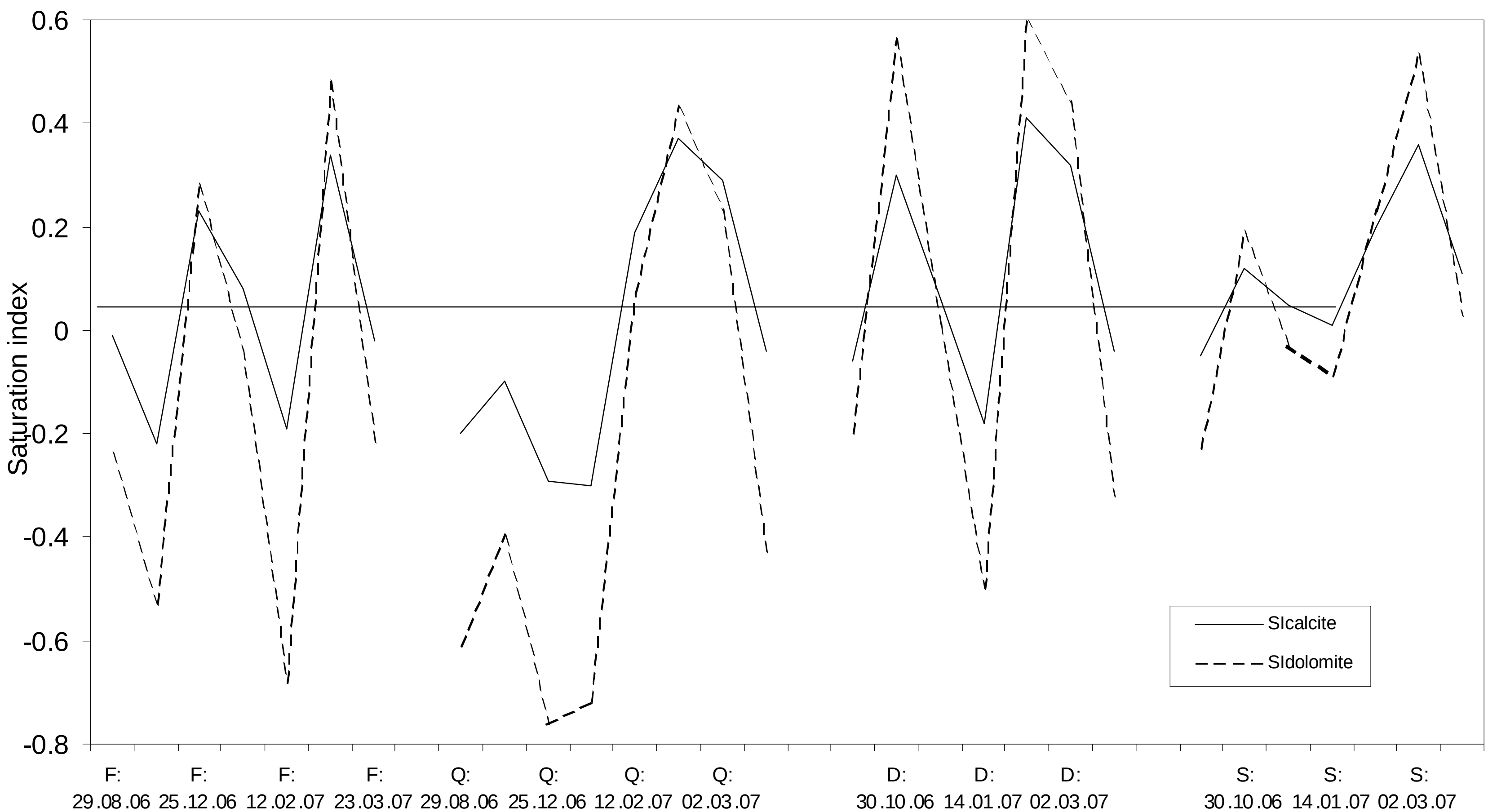


Fig 32: Time-dependent changes of saturation index of calcite and dolomite in spring water from Ein Fara (F), Ein Qilt (Q), Ein Dyouk (D) and Ein Sultan (S).

4.4 Anthropogenic pollutants and natural chemical variation

DOC plays a significant role in groundwater chemistry. Organic substances leached from soil and garbage is oxidized according to reaction (1).

$$R\text{-}CH_2\text{-}CH_3 + 3\ O_2 \Leftrightarrow R\text{-}H + 2CO_2 + 2H_2O \qquad (1)$$

Because HCO_3^- is always greater than dissolved CO_2 oxidation of organics has a greater impact on dissolved CO_2 in closed systems and thus pH decreases (eq. (2)). Decreasing pH finally it ends to undersaturation.

$$pH = pK1 + \log [HCO_3^-] - \log [CO_2] \qquad (2)$$

DOC is the residual of organics dissolved in the early infiltrating water. Low values indicate that decomposition by oxidation is nearly complete, whereas high ones show that oxidation has not been acting for long time. Therefore, high values are present particular in late wintertime, which indicates that the oxidation is a slow process and the initially low values are the product of low water flow and negligible infiltration during the summer season. Assuming that the high peak of dissolved CO_2 in (Fig.26b) represents the water that was enriched in CO_2 during the summer season and is now replaced under the influence of the first significant precipitation event (Fig. 18) with a time interval of about 2.5 months characterizes the flow time from the recharge in the mountain aquifer to Ein Qilt, Ein Dyouk and Ein Sultan. This peak is not repeated as a response to later strong precipitation events that suggest that the organics present as DOC are immediately washed out by water at the beginning of the rainy season. Towards the end the CO_2 concentration is the same in all springs and similar to that at the beginning of the winter period in Ein Fara. Due to changes in dissolved CO_2, pH varies and consists of an early and late branch (Fig.26 b).

This increase in dissolved CO_2 induced dissolution of carbonates and thus Ca but not Mg increase. The dissolution of calcite dominantly leads to increase in TDS. The increase in the concentrations of Ca^{2+}, HCO_3^-, (and Mg^{2+}), especially during the dry period, resulted from the dissolution of the host matrix, mainly calcite, under the influence of dissolved CO_2 or the partial pressure of CO_2. Dissolution plays a role in the first half of the winter period. Thereafter, concentration of most dissolved species decreases and so does TDS due to dilution (Fig. 26).

After the first replenishment of the aquifer in early winter time the flow of water increased and the residence time decreases and thereby the possibility for reactions of DOC. The step like trend of Mg and Na in Ein Dyouk and Ein Sultan reflects the dilution effect. Simultaneous SO_4^{2-} increases probably by leaching gypsum from soil in the catchment, and affects the low concentrations of SO42- much more than the high ones of Ca. Sulfate behaves oppositely to Mg in Ein Dyouk and Ein Sultan.

At high water level in the aquifer, gypsum is leached from the overlying Lisan Formation, which is predominant in the Jericho Plain. Because the Lisan Formation is absent in the recharge area, this effect is not seen in Qilt and Fara. Without gypsum dissolution the Ca decrease would be more than observed. This means that gypsum is an additional source for Ca and sulfate in Dyouk and Sultan springs, while in Qilt and Fara springs gypsum dissolution does not play a major role.

Other anthropogenic pollutants, such as nitrate being strongly related to sulfate and less so to Cl-, which indicates leaching from soil and rocks by irrigation return flow. In general, there is some correlation between NO_3^- and Cl^-, which is not explicable by dilution. The rather constant NO_3^-/Cl^- ratio may be due to leaching both components from soil or this may be due to sewage. Anyway NO_3^- shows a Y-axis intercept that is higher in the Ein Dyouk and Sultan than in Ein Qilt and Ein Fara. NO_3^- is related with SO_4^{2-} and both species suggest leaching from soil and surface (Fig. 30).

The correlation of sulfate, chloride, and nitrate reflect that these species are washed out from fertilized soils. Indeed, Ein Dyouk and Ein Sultan in intensive farming area yield significant higher nitrate concentrations than Ein Qilt and Ein Fara. The slope of the indicated trend line in (Fig. 30) yield NO3-/Cl- wt ratios of 0.54, which is quite high indicating significant contamination by human activity such as farming etc.

4.5 Stable Isotopes

The isotopic signatures for the rain events along the rainy season (Hydrological year 2006/2007) (Fig.33; Table.5), were varied depending on the weather conditions, Orographic effects; the altitude effect as mountains get rain from many air masses where the lower areas get less frequently with more moister thus have been subjected to less rainout previously *(Alley and Vally, 1998)*. The local meteoric water line for the whole catchment area was found to be: $\delta^2H = 7.95\ \delta^{18}O + 19.75$ ‰. SMOW (Fig.33).

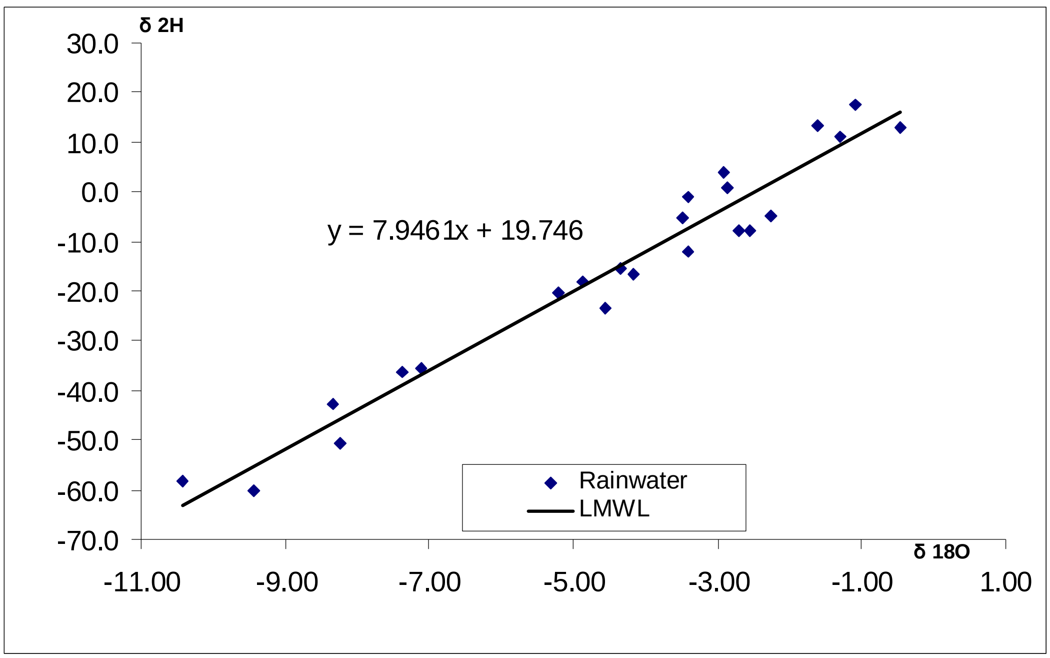


Fig. 33: Local Meteoric Water Line for the rainwater from Ramallah mountains area in the winter season 2006/2007(Table.4).

4.5.1 Isotopes Variation in rainwater

The values of δ^2H and $\delta^{18}O$, measured for the daily precipitation in the upper mountain of the study area (Ramallah hills) and in the shadow area (Hizma hills), shown in Fig (34.and 35.a and b) respectively (Table.5).

Table 5: The isotopic signatures for the rainwater from Ramallah mountains and groundwater from Wadi Qilt and Jericho springs.

No.	Sample Sign	Sample type	Date	[δ°/₀₀] -> VSMOW O-18 / EQ	[δ°/₀₀] -> VSMOW D / EQ	Exzess
1	SMART/X1	Rain water	15/10/2006	-1.30	11.1	21.5
2	SMART/X2	Rain water	26/10/2006	-3.40	-1.2	26.1
3	SMART/X3	Rain water	04/11/2006	-1.60	13.5	26.3
4	SMART/X4	Rain water	15/11/2006	-2.87	0.7	23.6
5	SMART/X5	Rain water	13/12/2006	-1.09	17.5	26.2
6	SMART/X6	Rain water	23/12/2006	-5.22	-20.5	21.3
7	SMART/X7	Rain water	28/12/2006	-7.37	-36.3	22.6
8	SMART/X8	Rain water	05/01/2007	-8.35	-42.6	24.2
9	SMART/X9	Rain water	05/02/2007	-2.91	3.7	27.0
10	SMART/X10	Rain water	14/02/2007	-4.86	-18.0	10.9
11	SMART/X11	Rain water	26.02.2007	-3.50	-5.1	12.9
12	SMART/X12	Rain water	14/03/2007	-3.41	-12.1	15.1
13	SMART/X13	Rain water	16/03/2007	-10.42	-58.1	25.3
14	SMART/Y1	Rain water	27/10/2006	-4.36	-15.4	19.5
15	SMART/Y2	Rain water	13/12/2006	-4.17	-16.6	15.8
16	SMART/Y3	Rain water	27/12/2006	-7.10	-35.7	23.2
17	SMART/Y4	Rain water	06/01/2007	-9.43	-60.0	15.5
18	SMART/Y5	Rain water	21/01/2007	-8.22	-50.8	15.0
19	SMART/Y6	Rain water	29/01/2007	-0.46	12.9	11.6
20	SMART/Y8	Rain water	06/02/2007	-2.26	-5.0	13.0
21	SMART/Y9	Rain water	16/02/2007	-4.56	-23.6	12.9
22	SMART/Y10	Rain water	27/02/2007	-2.70	-8.0	-7.6
23	SMART/Y11	Rain water	14/03/2007	-2.56	-7.9	10.6
24	SMART/1	Qilt spring	29.08.06	-5.70	-25.1	20.5
25	SMART/1b	Qilt spring	25.12.06	-5.66	-24.6	20.8
26	SMART/1c	Qilt spring	14.01.07	-5.72	-24.7	21.1
27	SMART/1dII	Qilt spring	12.02.07	-5.80	-27.5	18.9
28	SMART/1dI	Qilt Spring	12.02.07	-5.83	-27.5	19.2
29	SMART/1e	Qilt Spring	02.03.07	-5.56	-24.2	20.3
30	SMART/1F	Qilt Spring	23.03.07	-6.04	-28.3	20.1
31	SMART/1Fa	Fara Spring	30.10.06	-5.62	-23.6	21.3
32	SMART/1Fb	Fara Spring	30.10.06	-5.61	-23.8	21.1
33	SMART/1Fe	Fara Spring	09.03.07	-5.46	-23.6	20.1
34	SMART/1Fd	Fara Spring	12.02.07	-5.43	-23.3	20.1
35	SMART/12	Dyouk Spring	29.08.06	-5.82	-24.8	21.7
36	SMART/12a	Dyouk Spring	30.10.06	-5.90	-23.8	23.4
38	SMART/12b	Dyouk Spring	25.12.06	-5.88	-24.6	22.4
39	SMART/12c	Dyouk Spring	14.01.07	-5.86	-24.6	22.3
40	SMART/12e	Dyouk Spring	02.03.07	-5.82	-25.4	21.2
41	SMART/12d	Dyouk Spring	12.02.07	-5.83	-25.5	21.1
42	SMART/12F	Dyouk Spring	23.03.07	-5.91	-25.8	21.5
43	SMART/13	Sultan Spring	29.08.06	-5.83	-24.8	21.8
45	SMART/13a	Sultan Spring	30.10.06	-5.75	-24.8	21.1
46	SMART/13b	Sultan Spring	25.12.06	-5.77	-24.4	21.7
47	SMART/13c	Sultan Spring	14.01.07	-5.91	-24.6	22.6
48	SMART/13d	Sultan Spring	12.02.07	-5.8	-25.9	20.6
49	SMART/13e	Sultan Spring	02.03.07	-5.8	-25.8	20.7
50	SMART/13F	Sultan Spring	03.03.07	-5.9	-26.0	20.9
51	SMART/R2	Run off	02.03.07	-5.25	-22.9	19.1
52	SMART/R3	Run off	03.03.07	-6.73	-33.98	29.89
53	SMART/RQ4	Run off	16/03/07	-5.82	-26.51	20.07
54	SMART/RFW	Run off	16/03/07	-7.12	-35.65	21.35
56	SMART/R4	Run off	06/11/06	-4.60	-17.29	19.49
57	SMART/R5	Run off	23/03/07	-5.80	-25.64	20.73

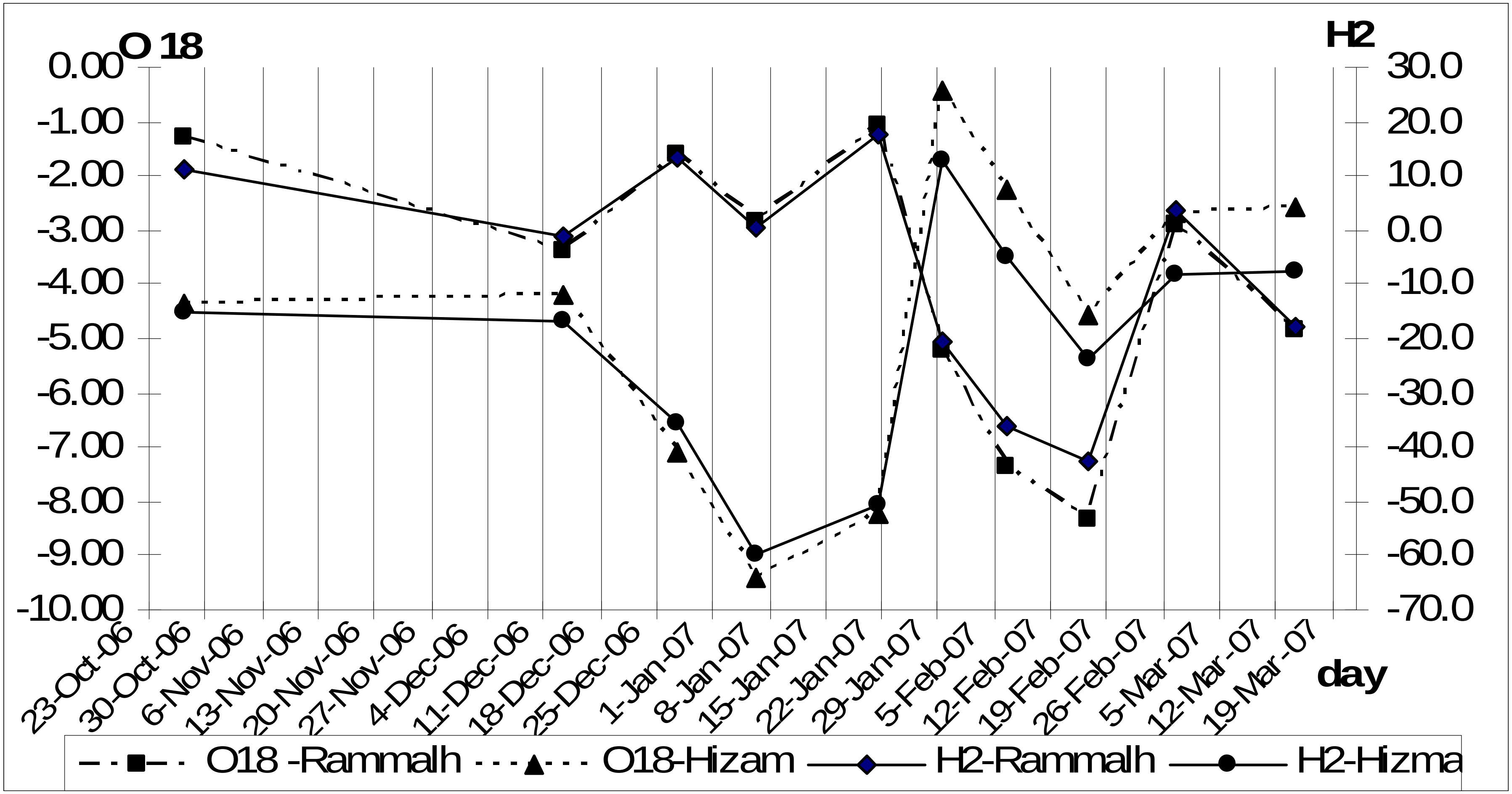


Fig. 34: The values of δ^2H and δ^{18}O for the daily precipitation in respect to time and place (Table 5).

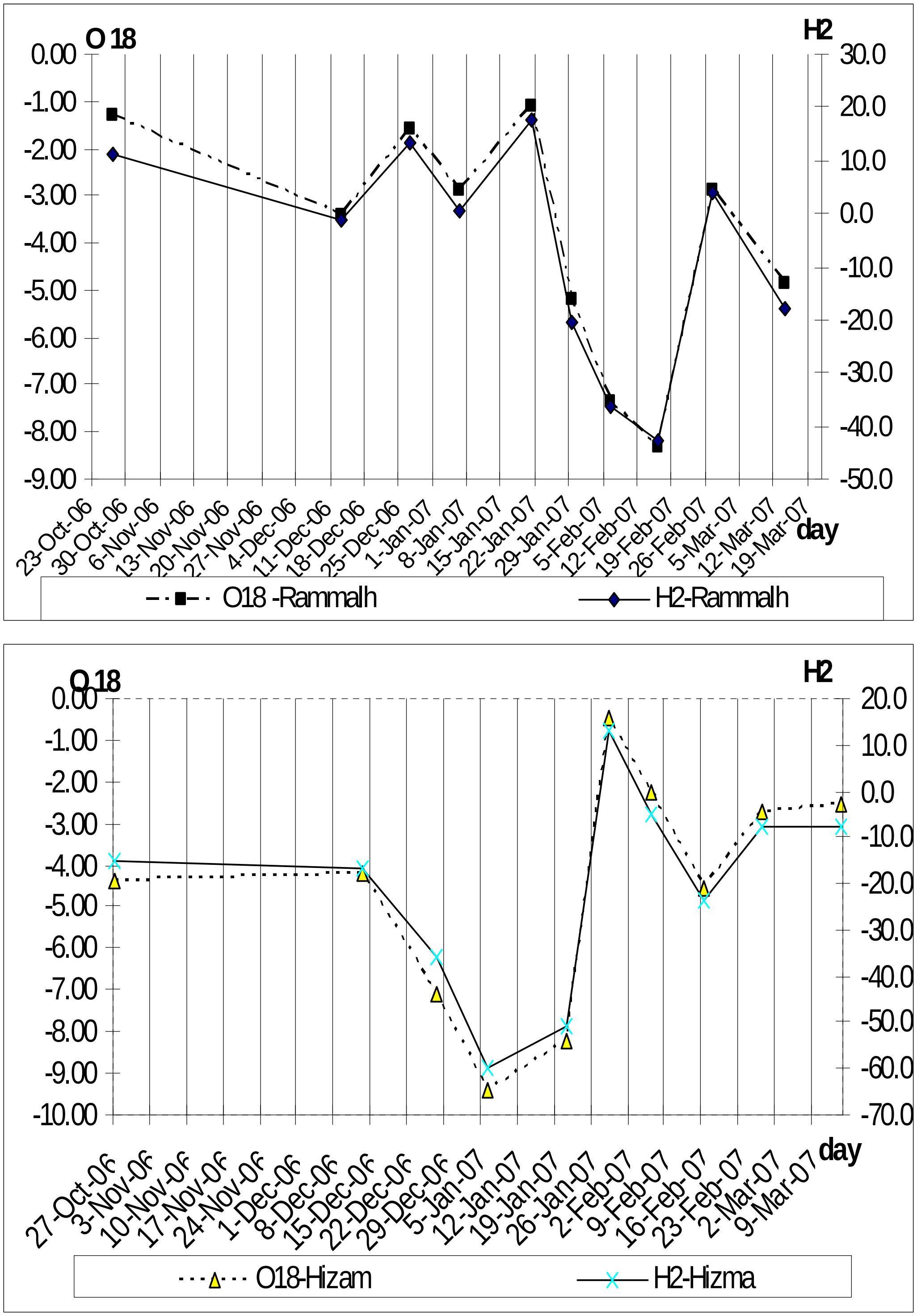


Fig. 35: The values of δ^2H and δ^{18}O for the daily precipitation in (a)Ramallah hills and in (b)Hizma hills .

For all the samples that were taken, 13 and 10 samples in Ramallah and Hizma Hills respectively (Table.5). The mean values is δ^2H = -15.53 ‰ and $\delta^{18}O$ = 4.44 ‰. There was clear contrast between the two locations, with respect to time, in the first three-month, autumn period (Sec. 2.5 & 4.1), the δ^2H, $\delta^{18}O$ in Ramallah shows slightly enriched values, (mean values δ^2H = -11.33 ‰, $\delta^{18}O$ = -4.33 ‰). While the second location in shadow area, Hizma hills, exhibits relatively lower δ^2H, $\delta^{18}O$ values (with mean values δ^2H = -20.99 ‰, $\delta^{18}O$ = -4.58‰.) with a noticeable difference in deuterium values. When the second period of season starts, the values in the two locations were behaves divergence with more enriched values in the upper mountain hills, and lower depleted values in the shadow area of Hizma Hills, this behavior obviously changes vise versa, by the end of the winter season, (Fig.35).

Close linear relationship between $\delta\ ^{18}O$ and $\delta\ ^{2}H$ is expected, as the relative sizes of fractionation should be constant for precipitation. The trend of the isotopic variation extends from relatively enriched signatures for $\delta\ ^{18}O$ and $\delta\ ^{2}H$ in early season to more depleted signatures in late season *(Clarck and Fritz 1997).*

The isotopic data were divided into two periodic local meteoric water line (PLMWL), one for Ramallah and another Hizma collection points. The first period is in the beginning of winter season (September to November) and the second is between December and April (late season). Tacking into consideration the difference in Temperature, altitude and distance from sea, as well as other rain intensity that clearly varies from west to east in the study area; and changing from Ramallah hills across the east-passing wadi al Qilt (far away from the Mediterranean sea, where also the decreasing in elevation occur). For the two locations, we obtained correlation between

δ^2H and $\delta^{18}O$ on the base of two time periods (P1, P2: period 1 and respectively) (Fig.36).

From (Fig.36 and 37), for the Upper Mountains (Ramallah Hills) the Local water meteoric line RWML is $\delta^2H = 7.03\ \delta^{18}O + 22.15$ *‰. SMOW* And $\delta^2H = 7.88\ \delta^{18}O + 22.24$ *‰ SMOW*, for the 1st and 2nd periods respectively. For the upper mountain (Ramallah hills) the local water meteoric line (RWML) during the two time periods is: $\delta^2H = 8.02\ \delta^{18}O + 23.38$ *‰ SMOW*. While for the shadow area (Hizma Hills),during the whole winter season The local water meteoric line HLML is: $\delta^2H = 7.70\ \delta^{18}O + 14.31$ *‰ SMOW*. Having the Local water meteoric line for whole study area over the winter season 2006/2007 to be $\boldsymbol{\delta^2H = 7.95\ \delta^{18}O + 19.75}$ ***‰ SMOW.***

The above described results and different in behaviors between the two location can be understand by the illustration suggested by Ayalon et al. (1998), and locally emphasized by Qannam (2001), where they found that the relation between $\delta^{18}O$ and δ^2H of the rain water is a function of the storm intensity and amount of rain. In our case the intensive rainfall events mostly occurs in the late period. Moreover the rain intensity in the upper mountain of Ramallah was much bigger than this in Hizma area, where the semi arid conditions begin toward eastward. The mountain area shows usually more than 20 mm rainfall per event, as well as the average annual isotopic values, define a slope approach to 8, with a d-excess of 21 ‰, whereas light rain showers form a trend along evaporation line with a slope of < 8 and d-excess of < 20 ‰. These deviations from the LMWL are consequences of evaporation processes happening to rain drops during their fall from the cloud to the ground (Gat 1996; Gat and Dansgaard 1972 and Gat and Carmi 1970).

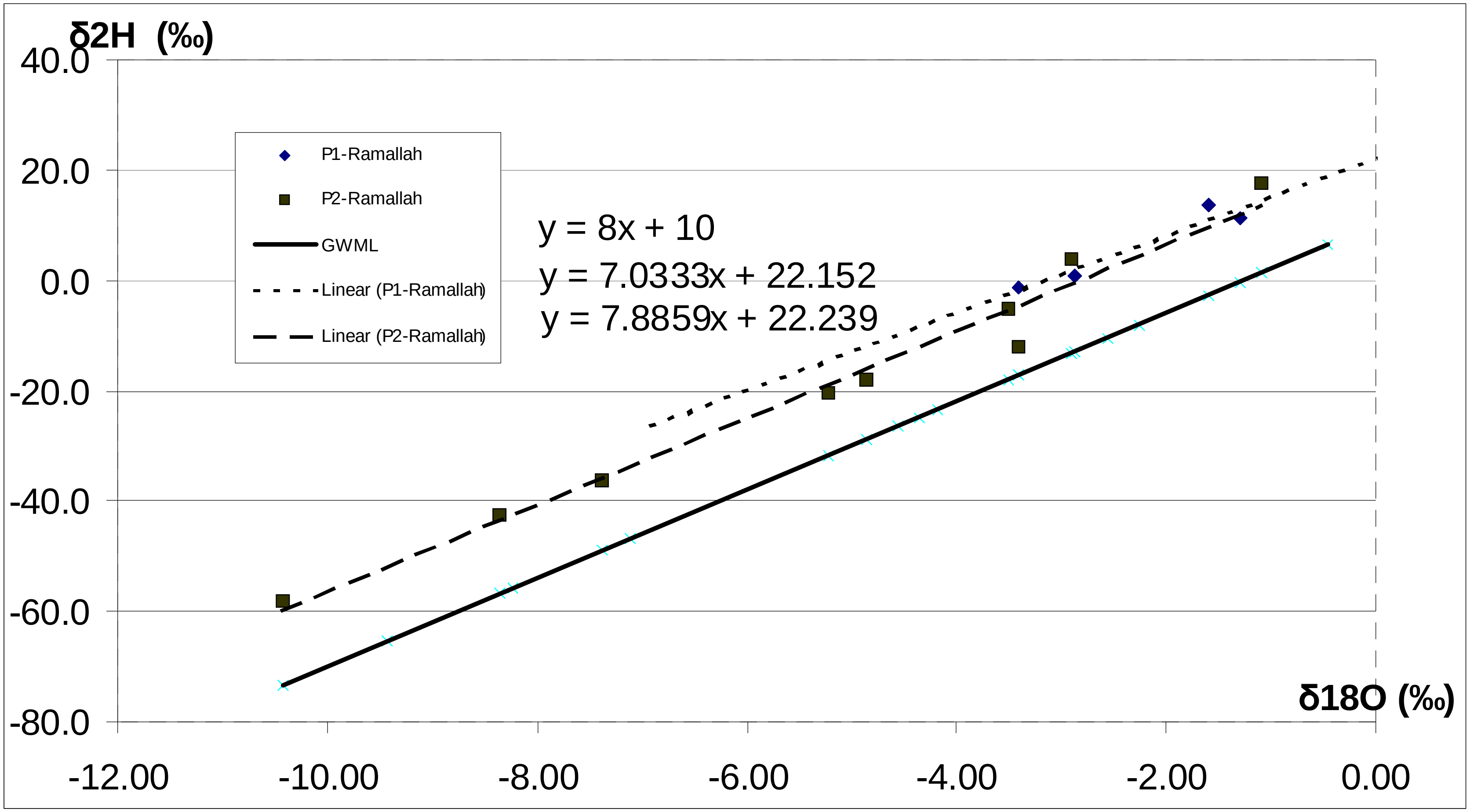


Fig. 36: Local Meteoric Water Line for the rainwater from Ramallah mountains area in the winter season 2006/2007 on the base of two time periods.

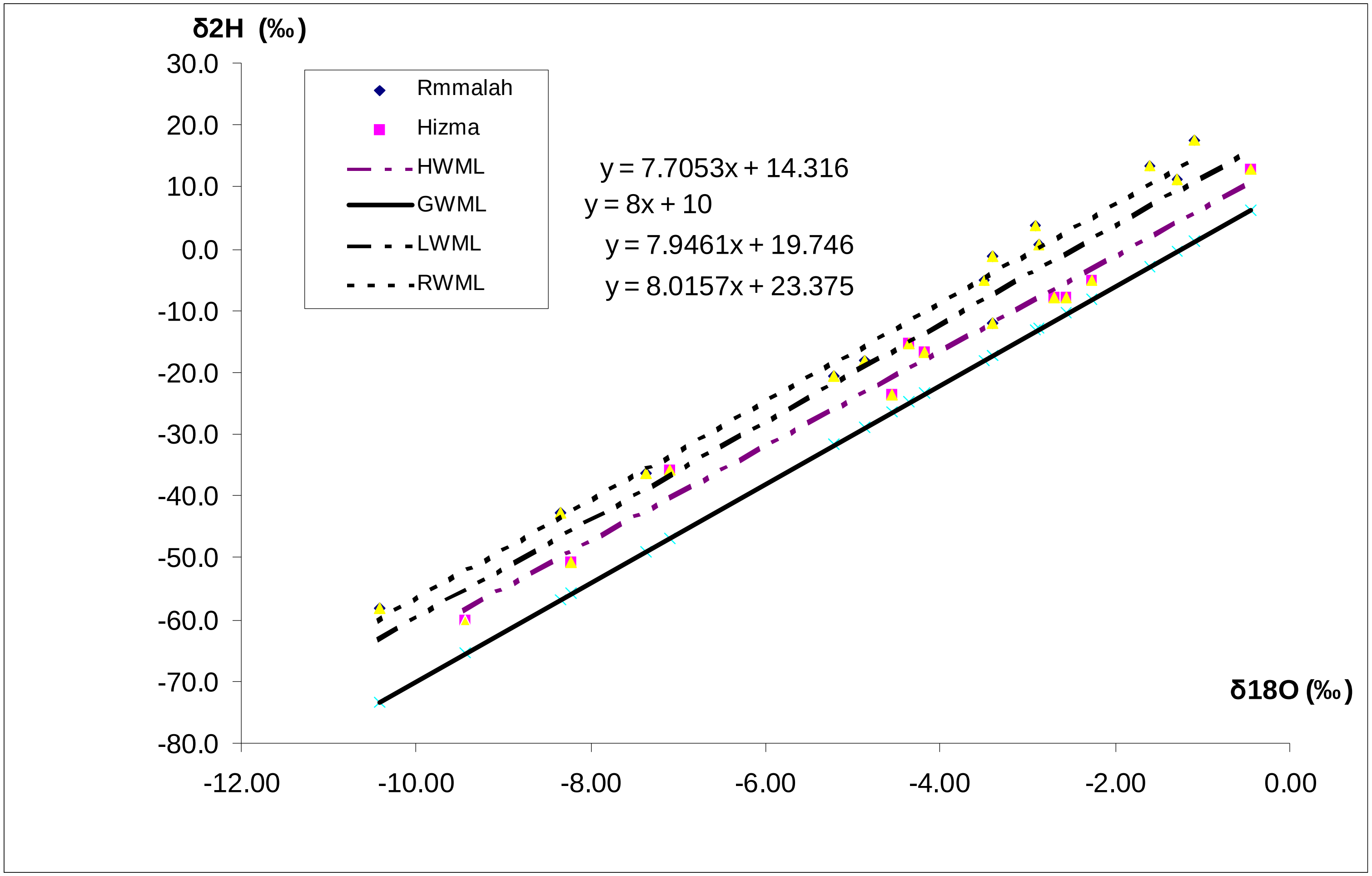


Fig 37: Local Meteoric Water Line for the rainwater from Ramallah mountains area and for the shadow area in the winter season 2006/2007 .

4.5.2 Deuterium Excess

Departure from the GMWL can be quantified by parameter know as the Deuterium excess (D-excess), defined as d= δ^2H - $8\delta^{18}O$ (Clarck & Fritz 1997), and obtained from δ^2H and $\delta^{18}O$ (Table. 5). It is linked with strong relation to the meteorological and area condition, for that, a comparison between different precipitation events can bring to a close conclusion the origin of water vapor for each storm event.

Generally, the rain water in the Eastern Mediterranean region, part of it is the West Bank, is enriched in δ2H relative to the meteoric water line (MWL) with a d-excess of around 21 ‰. This was attributed to the interaction of the cold and relatively dry fronts originated from the Atlantic Ocean, which is the origin of the most storm tracks reaching the Eastern Mediterranean region, with the warm and humid air above the Mediterranean Sea during winter (Gat and Dansgaard 1972; Gat and Carmi 1987 and Gat1996).

Figure 37 shows that the average signature of the d-excess for the precipitation in the study area is around 21 ‰ where most of the samples for rain events have high d-excess. This emphasize that most of the air masses are originated from Mediterranean area during autumn.

In general most of lower records in the d-excess were coming directly in the first storm events and/ or directly after long dry period of time (rain stop). Winter precipitation originating from the Mediterranean Sea is characterized by distinctly higher excess values, reflecting the specific source conditions during water vapour formation. Thus, it was clearly noticed that the d-excess values from Ramallah upper mountain precipitation shows relatively higher values than lower area of Hizma hills, where the first location is closer and exposed directly to the Mediterranean Sea.

Although, the increase in the deuterium excess in precipitation can also arise from significant addition of re-evaporated moisture from continental basins to the water vapour travelling inland, most of the data doesn't show such phenomena along the season, but the d-excess values in both points getting down as the season proceed to end (Fig. 37, 38 and 39).

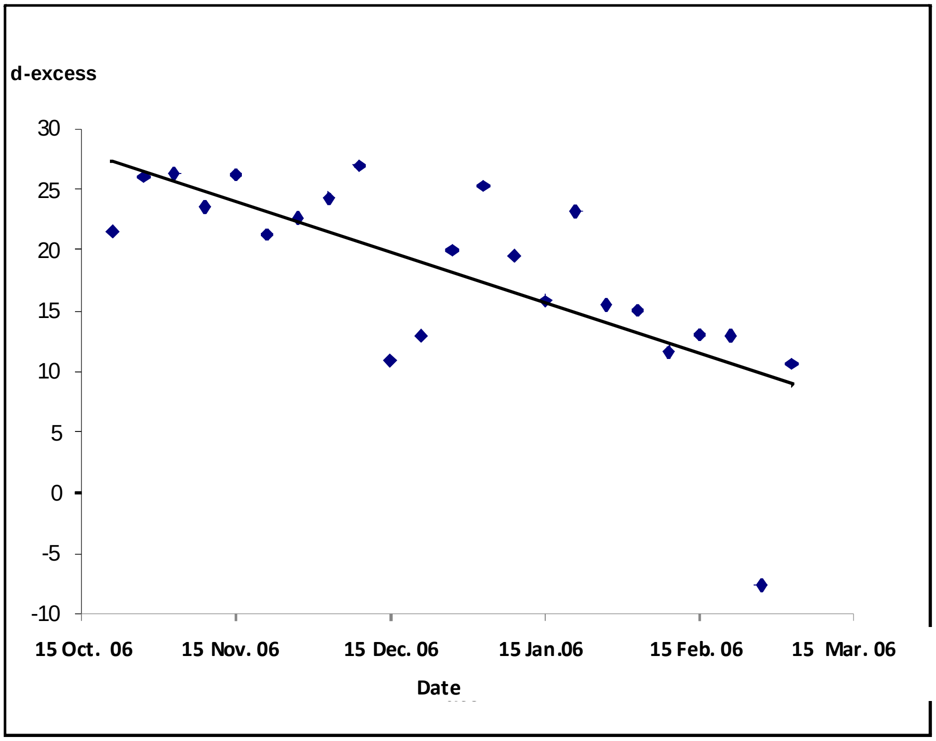


Fig. 38: The d-excess for the daily precipitations samples during the hydrological year 2006/2007 in the study area.

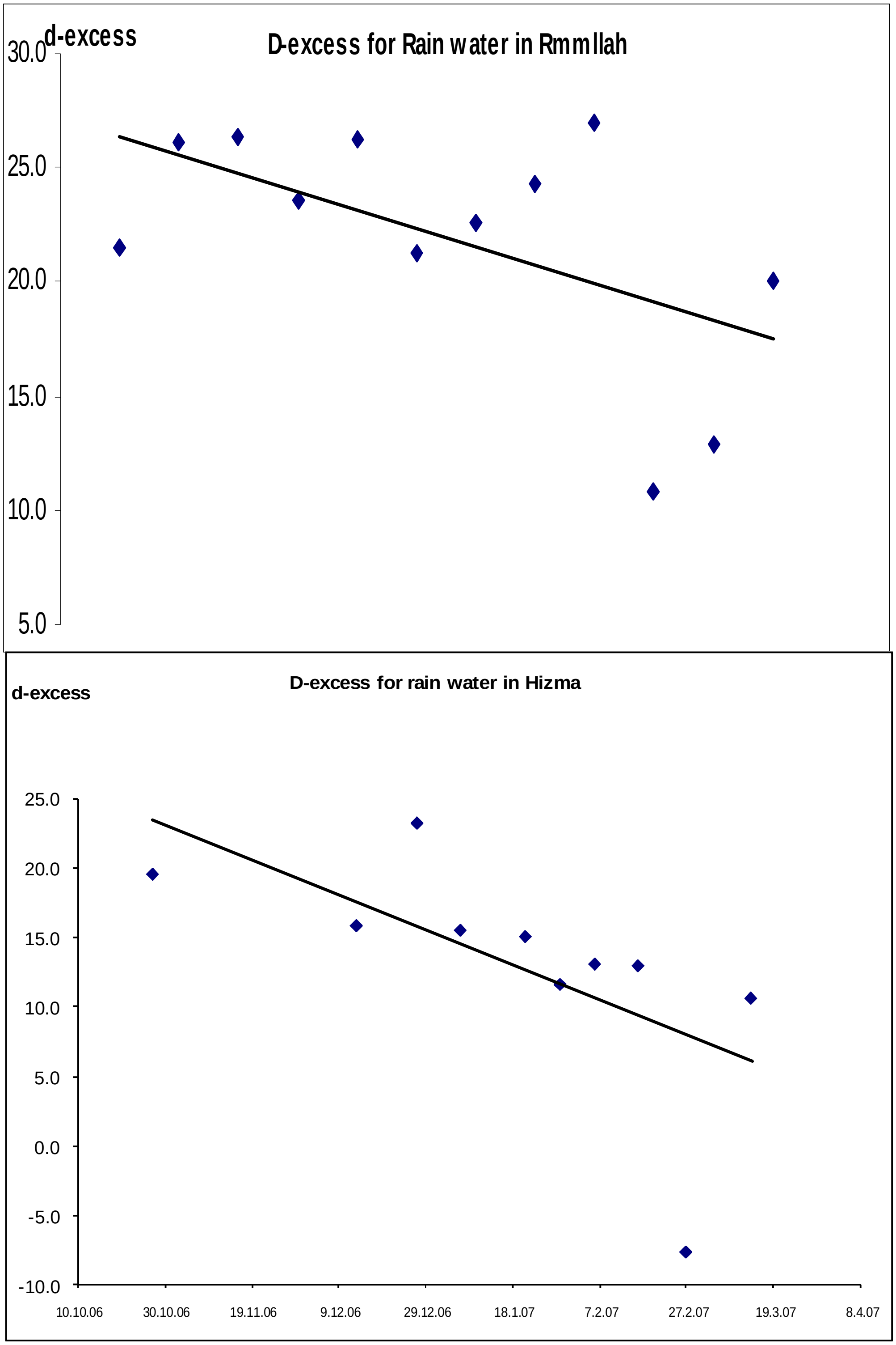


Fig. 39: The d-excess for the daily precipitations samples during the hydrological year 2006/2007 in (a) Ramallah and (b) Hizma.

4.5.3. Isotopes variation in Ground water

Springs show also a variation in the isotopic signature spatially and temporally. Although, the springs show no significant variation from the early to the late winter season, the signatures tend to get slight depletion by the late of the season. This depletion process is due to wash out effect where the old stored water in the aquifer with relatively enriched signatures is washed out and replaced by new fresh water with depleted signatures.

The most significant variation for the groundwater from the springs was noticed for the deuterium rather than $\delta\ ^{18}O$, where the Sultan and Dyouk springs show a temporal slight variation in deuterium. This reason for this variation is due to the difference in the groundwater residence time which is described in further details through the following section 5.4.4.

Spatially the isotopic signatures for the Fara spring close to Hizma station shows more enriched values than the other springs which reach -5.4 for the $\delta\ ^{18}O$ and -23.3 for the Deuterium (Table 4).

Samples of runoff and springs are all shifted to the left of the LMWL for the rainfall samples. It's express that kinetic isotopic enrichment happen in a similar degree for nearly all of the samples which indicate the same source and condition, as they all belonging and contribute to the same aquifer.

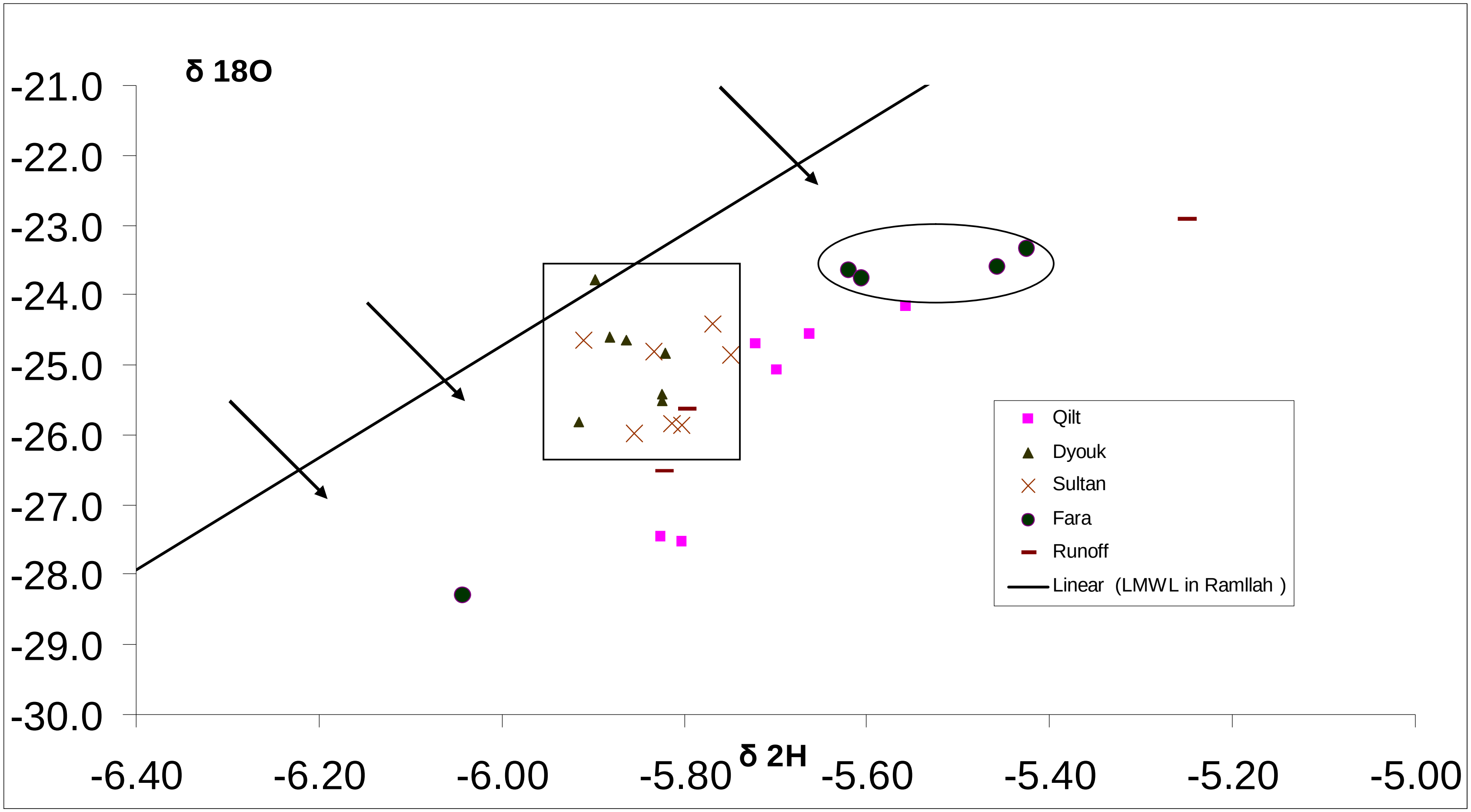


Fig. 40: Distribution of isotopes signatures for the groundwater from the sampled four springs along the winter season 2006/2007 .

4.5.4. Deuterium ($\delta\ ^{2}H$) signatures and groundwater residence

As shown in the previous sections most of the springs in the study area are have depleted values for the deuterium signatures with time from the beginning to the end of the rainy season.

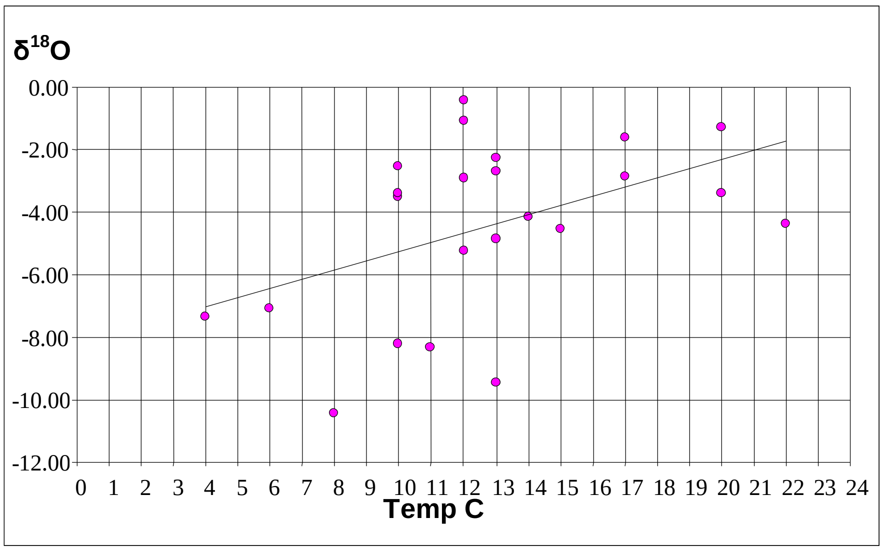
The spatial depletion process for the deuterium signatures in Sultan and Dyouk springs also emphasize, beside the indicators from hydrochemical data which described previously, that the ground water have had a long contact with aquifer materials during dry period causing longer adsorption of ground water to the clay minerals during summer time and early winter which leached from sediments and rock after the rain events occur.

This depletion correlation with residence time is referred to what called ultra-fractionation process which only effects on deuterium rather than $\delta\ ^{18}O$. Such process was defined by Coplen and Hanshaw, (1973) as ‘ultrafiltration’. Hoefs, (2004), shows that the hydrogen isotopes fractionation is affected by the absorption of water on mineral surfaces due to the tendency for clay and shales to act as semipermeable membranes. The fractionations of hydrogen isotopes occur during this process in such a way that the residual water will be enriched in deuterium due to its preferential adsorption.

During the continuous recharge in wet season the increasing of hydraulic pressure flush out the residual old water. This water which is enriched in deuterium by ultrafiltration process is moves a long aquifer, replaced by the new recharge water in the upper layer.

4.5.5. Isotopes signatures and Temperature

Correlation between the stable isotopic δ^2H and δ^{18}O values in precipitation daily samples shows slight trend with Temperature Variation parallel to the different origin of the air masses and the storm origin (Sec. 5.4.2). Figure 41a. and 41b. the δ^2H and δ^{18}O for daily Rain water samples against to mean air Temperature are presented, where positive enrichment with temperature increase is clearly obvious.



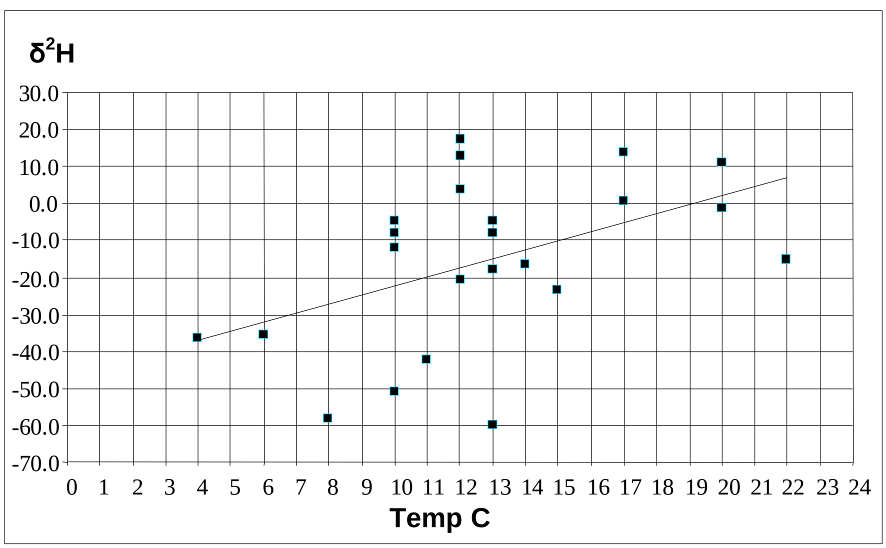


Fig. 41: The δ^2H (a) and δ^{18}O (b) for daily Rainwater samples Vs mean air Temperature

In (Fig. 42) the correspondence change in $\delta^{18}O$ Values, with respect to mean daily air temperature in the two areas, shows higher slope in the upper mountain hills than in the shadow area. The effect of rain amount differences between both collection locations, which was described in section 4.5.1, is here considered (700 mm, 300 mm annual rain fall in the mountain and shadow area respectively). Tacking into account the Orographic effects; the altitude effects as mountains get rain from many air masses. The higher the mean temperature, the lower the slope of the isotopic composition is. This also meet the $\delta^{18}O$ vs. temperature correlation on the global scale, which categorize the slope with higher value for the colder regions and lower slope in the warmer regions.

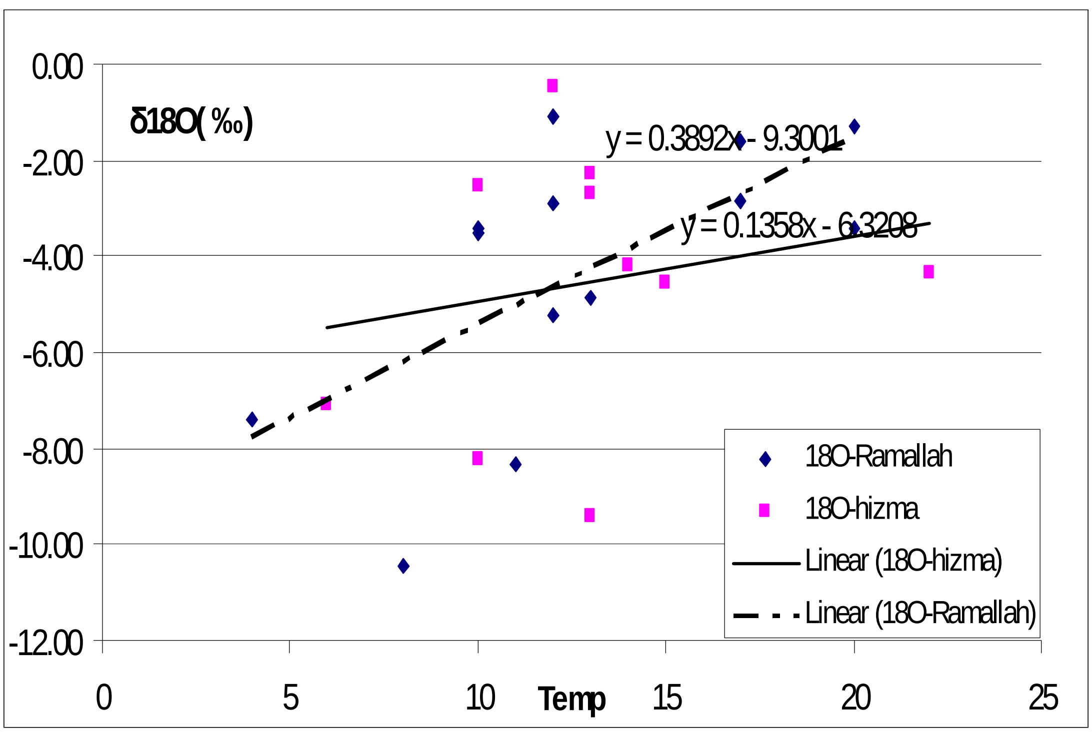


Fig. 42: The correspondence change in $\delta^{18}O$ Values with respect to mean daily air temperature in the two areas

The relation between the $\delta^{18}O$ and mean air temperate was investigated in respect to the two winter periods (early and late winter period) in the upper mountain of

Ramallah collection point (Fig. 43). It was noticed that the $\delta^{18}O$ shows stability in the early winter period where the mean average daily temperature was around 17 °C., while in the 2nd period there was a significant depletion with temperature decrease, so that the decrease of one °C in the mean average daily temperature impress a change in 2‰ in $\delta^{18}O$ values.

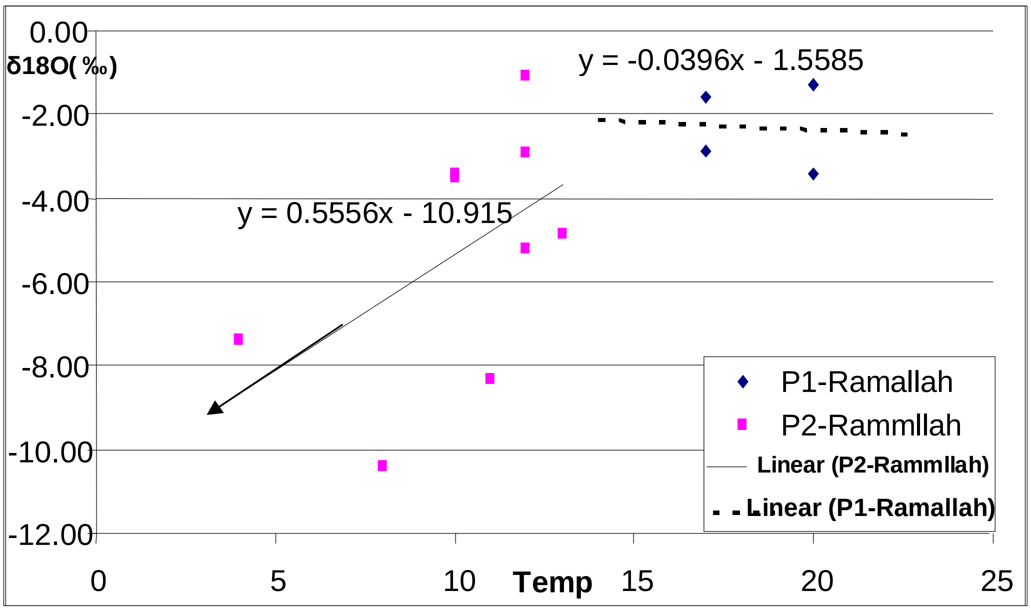


Fig. 43: Relation between the $\delta^{18}O$ and mean air temperate in respect to the two winter periods in the upper mountain hills area

4.6 Variation in the Groundwater recharge mechanisms

The Groundwater recharge and flow is affected by intensive ground water abstraction and leakage of reservoirs and artificial changes, whereas mainly controlled by two factors: the geologic structure and geometry of the aquifer along the flow path. These factors play an important role in controlling the aquifer flow across the eastern slope, which is reflected by the behavior of solutes within the aquifer in the different zones of Wadi Qilt and Jericho Plain.

Zone 1 represented by Ein Fara and Ein Qilt is fed directly through the infiltration of meteoric water and surface runoff from the mountains. This infiltration zone is located to the west of the Marsaba anticline (Fig.5 and 6). The section west of the anticline is uplifted. Thus, the base of the aquifer is raised and the flow gradient increases which resulted in an increase of the flow velocity and reduced residence time.

Contrastingly, zone 2 represented by Ein Sultan and Ein Dyouk is located east to the Buqea syncline and Marsaba anticline parallel to the western fault boundary. Here, the aquifer thickness decreases from the syncline to the anticline (Fig. 6) that might act as a retardation factor to flow. The Marsaba anticline prevents the groundwater of the Upper Cretaceous aquifer from flowing further eastwards and thus the replenishment of the springs east to the anticline take longer period of time *(Wolfer, 1998; Guttman, 2004)* and these springs are fed by groundwater with high solute contents leached from aquifer rocks.

The mentioned spring (zone 2) is located along the western boundary fault in the western part of Jericho-Auja area, where the fault acts as a barrier to flow. The water normally flows laterally along the fault; the latter confines the groundwater for additional period of time resulting in increasing contact time between rocks and groundwater. The recharge mechanism for the zone 2 springs is different from those in zone 1 due to different geological structures. The zone of Sultan and Dyouk springs is covered by a chalky Eocene layer (Fig. 6) which is considered an aquiclude preventing further surface runoff infiltration into the aquifer zone. Therefore, the aquifer doesn’t receive little replenishment in this zone except that by underground flow.

5. Conclusion and Recommendations

5. 1 Conclusion

The chemical composition of spring water from an inclined aquifer changes with residence time of groundwater in the aquifer and with distance from the recharge area. A very important factor is the oxidation of organics derived from sewage and garbage resulting in variable dissolved quantities of CO_2. High CO_2 yields lower pH values and thus under saturation with respect to calcite and dolomite. Low CO_2 concentrations result in over saturation. At the beginning and at the end of the rainy season calcite saturation is always achieved.

A detailed analysis of dissolved species reveals that besides dissolution of carbonates, nitrate, chloride, and sulfate are leached from the aquifer rocks together with small amounts of Mg. Thus Mg not only originates from carbonates but also from Mg-Cl saline waters included in the rocks. This effect is particularly high at the beginning of the winter season and lowest at its end.

Two zones are distinguished: In zone 1 on the eastern mountain slopes recharge of the aquifer is mainly by direct infiltration of precipitation and runoff combined with less groundwater residence time and high flow rate. The second zone is near the western border of Jericho at the foothills, which is mainly fed by the underground water flow from the eastern slopes. This zone is characterized by higher groundwater residence time and slow flow rate than in zone 1. The main factors affected the groundwater residence time and flow rate are the geological structure of the aquifer, the amount of active recharge to the aquifer and the recharge mechanism. The presence of high CO_2 concentration results from degradation of dissolved organic matter, which thus is a major source for increase of water hardness and mineralization because it reduces pH in the aquifer and enhanced dissolution of carbonates.

5.2. Recommendations

- The groundwater quality for the springs along the Wadi Qilt and Nue'meh catchment varied with time and distance from replenishment source, this due to some other contribution of pollutants along the Wadi path mainly the wastewater discharge from the settlements. Therefore, more investigations about the sources of pollutants discharge to the wadi and its quality, as wastewater should be done.

- The dissolved organic carbon shows high values that reach to 12 mg/L after a short period of an intensive rain event. Any processes for water chlorination mainly in sultan spring could lead to production of side products such as halogenated hydrocarbons, thus special attention to the time of DOC shock occurrence within winter season should be taken into account.

- The rainwater content of nitrate shows a high values after a dry period (long time without rain), this mean that a lot of nitrogenous gases related to industry and agriculture released to the atmosphere, thus further investigation about the anthropogenic gases emotion to the atmosphere should be done with concentration on the Israeli industries and its effect on the Palestinian environment.

- Special attention should be drawn to the values of nitrate in the groundwater especially in Sultan and Dyouk spring should be monitored periodically as the two springs considered as the main sources from drinking water in the surrounded area, the presence of relatively high nitrate value in the springs >40 mg/L should be considered a serious warning about more high values from the surrounding pollutants from the upper Wadis in the future, thus the main drinking water resources in this semi-arid area is still under threaten.

The results of the project might really be useful for stakeholders and decision makers in the local authorities and institutes, and should be taken into account in the process of any coming projects for efficient exploitation of freshwater resources in the region, i.e., the results which depend mainly on the present of dead zone where a little surface recharge can be occur, and the role of DOC in complicating the problem of water hardness can be taking into account for any of future planning for the sub-catchment. For example water from the upper mountains can be collected in active zone 1 where it can infiltrate and laterally replenished the aquifer beneath the dead zone 2. Also it is recommended that a special pre-treatment for the collected rain water and run off to get rid or minimize the amount of DOC in the water, thus to minimize the groundwater hardness result from the problem described above. Other special attention should be drawn to minimize and treat the amount of sewage and garbage discharged from surrounding urban area and Bedoins to the Wadi stream. The water treatment unit in Al-Beireh at the upper recharge point should make further studies about the quality of the discharged treated water to the Wadi. Moreover, question mark should be put on the unknown discharged wastewater from the surrounding Israeli settlement, which might be industrial waste. On the other hand, a good calculated amount of artificial recharge might really face the problem of saline water that originates in the eastern part near Jericho. Also, infiltration of collected water in one good infiltration zone (zone1) can lowering the amount of Ca, Mg and other constituent's dissolutions to the groundwater. Moreover, such way of extensive recharge might reserve a huge amount of groundwater within the aquifer with continuous input that make the groundwater in continuous movement and less contact with the aquifer matrix with less Mg content. The results thus might be very useful for more efficient freshwater exploitation in the region, as precautions should be take place for the replenished water, and the runoff water should not be freely infiltrated along the Wadi as the last has a bad infiltration zone in one of its parts (zone 2) and thus much more water could be lost by evaporation. Depending on these results that the catchment area in zone 2 plays low role in recharge process, a good new project for efficient water exploitation can be done depending on:

- Selecting a good infiltration area in Zone 1 where more infiltration could be occurring (still need more investigation about soil and hydrological characteristics, and Storms intensity and amount of giving water should also be investigated in details).
- Construction of a big reservoir in the selected zone where all the runoff water can be there collected (the size and the characteristic of the reservoir should be identified carefully in further studies).
- Special treatment for the recharged collected water should be done to minimize the dissolved organic carbon after occurrence of big storms at the beginning of rainy season (still need more investigations about the type and mechanism of treatment).
- Further studies should be made on the amount and quality of the wastewater and garbage drained down from the surrounded settlements, as well as more studies should be done on the treated water output from Al-Beireh treatment plant which discharge the treated water direct to the Wadi, in a way that the efficient of the treatment procedure for the treatment plant can be raised.
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Appendices

Table 1: Annual precipitation since 1974 (from JWU, Ramallah station)

Averages	0.0	18.8	79.0	147.5	180.6	157.6	89.0	25.1	0.2	1.7	699.4
YEARS	SEP	OCT	NOV.	DEC.	JAN	FEB	MAR	APR	MAY	JUNE.	TOTAL.
90/91	0.0	0.0	49.4	9.1	208.0	96.0	134.0	14.8	3.6	0.0	514.9
91/92	0.0	28.7	143.0	498.0	219.0	611.0	62.5	0.0	0.0	28.5	1590.7
92/93	0.0	0.0	120.0	310.0	158.0	0.0	0.0	0.0	0.0	0.0	588.0
93/94	0.0	8.9	39.2	33.0	202.7	141.9	142.2	23.3	0.0	0.0	591.2
94/95	0.0	17.3	267.2	255.6	39.6	113.5	48.4	0.0	0.0	0.0	741.6
95/96	0.0	0.6	92.2	45.2	199.6	58.8	207.6	0.0	0.0	0.0	604.0
96/97	0.0	25.4	18.4	90.3	166.8	188.1	146.0	20.5	0.0	0.0	655.5
97/98	0.0	21.2	50.0	165.7	163.5	87.2	176.2	3.2	0.0	0.0	667.0
98/99	0.0	0.0	9.2	28.7	126.7	76.6	47.4	18.1	0.0	0.0	306.7
99/00	0.0	2.0	18.0	22.7	355.4	77.4	50.5	0.0	0.0	0.0	526.0
00/01	0.0	54.8	0.0	165.0	116.2	136.6	0.0	0.0	0.0	0.0	472.6
01/02	0.0	6.4	134.5	171.0	274.2	93.3	46.1	90.0	0.0	0.0	815.5
02/03	0.0	45.4	18.5	217.7	123.0	438.7	218.5	52.0	0.0	0.0	1113.8
03/04	0.0	2.0	74.8	155.8	199.8	95.9	28.6	0.0	0.0	0.0	556.9
04/05	0.0	19.0	214.8	76.7	226.3	215.1	39.0	15.2	0.0	0.0	806.1
05/06	0.0	19.0	63.5	117.3	130.2	102.5	11.0	181.5	0.0	0.0	625.0
06\07	0.0	69.0	29.5	145.0	162.0	146.0	155.5	7.5	0.0	0.0	714.5

Table 2: Daily amount of precipitation (Rain mm) and mean air temperature (C) for the hydrological year 2005-06 **(PMD,2006)**

20-Oct-	19.2	15.8	11	13	84	5.1	2.8	12.3	917.8
31-Oct-	0.3	13.5	10.8	11.8	91	3.6	3.3	14.8	919.7
4-Nov-	7.1	15.4	10.8	11.9	92	4.4	0.7		916
5-Nov-	0.5	14.4	9.8	11	95	6.7	1.5		917
6-Nov-	12.4	15.4	9.6	8	88	4.1	2.1		918.8
7-Nov-	8.2	8.2	9.6	10.8	100	5.6	4.1		918
16-Nov-	1.6	15	10.6	12	93	5	3		917
21-Nov-	3.6	17.2	10.8	13.7	85	8.5	3.8		917
22-Nov-	23.7	11.2	10	10.1	100	4.5	0.9		91.8
19-Dec-	23.3	12.6	8	10.1	98	0.6	1.7	14.3	916.4
20-Dec-	3.4	14.7	8.4	11.5	79	4.5	3.4	8.8	919.1
23-Dec-	2.6	10	6.3	8.1	96	1.5	2.7	9.8	920.2
25-Dec-	4.9	8.8	5.4	6.6	99	0.1	1.8	14	913
26-Dec-	12.8	7.4	5.2	5.69	94	3.3	1.8	17	910
27-Dec-	56.5	4.8	3.3	4	99	2	3.3	21	913
28-Dec-	17.3	8.6	3.6	5.6	99	1.5	2	7	922
1-Jan-06	0	16.5	11.3	14.2	36	6.1	3.6	9.3	920.2
2-Jan-06	0	16.7	10.9	13.2	40	8	4.5	5.8	921.2
3-Jan-06	0	14.6	8.6	12.6	31	9	6.5	21.8	919.7
4-Jan-06	0	13.2	9.2	12.2	54	1.6	7.2	31.8	917.7
5-Jan-06	0.6	17.8	10.2	15.6	55	8.3	5	11.3	918
6-Jan-06	0	18	13	10.1	81	7.4	2.2	9.5	917.3
7-Jan-06	0	12.6	8.2	8.2	98	5.7	2.4	12	915.9
8-Jan-06	13.5	8	6.7	7	100	1.3	4	13.8	914.9
9-Jan-06	15.5	10.4	6	7.4	96	3.6	8.7	9.3	915.9
10-Jan-	0.2	10	6	6.4	100	2.4	3.2	7.3	912.4
11-Jan-	23.6	7.5	3.6	5.4	100	1.5	2.6	13.5	911
12-Jan-	29.7	6.8	4.5	5.6	99	0.8	1.7	15.8	915
13-Jan-	13.5	7.8	4.6	4.3	97	2.2	1	11.5	916.5
14-Jan-	0	7.8	4	4.6	98	3.4	1.3	10.5	917.4
15-Jan-	8.9	6.7	3.5	4.4	87	3.7	1.4	10.5	918.5
16-Jan-	0	9.3	3.5	5.2	97	6.1	0.2	5.3	919.1
17-Jan-	4	8.1	4	5.7	98	6.9	1.8	11.5	920.1
18-Jan-	12.8	7.5	4.4	5.7	96	1.5	1.8	13.3	920.8
19-Jan-	4.5	12	4.5	8.4	71	9.8	0.5	6	921.6
20-Jan-	0	10.5	5.6	6	81	7.9	3	19	920.5
21-Jan-	2.2	10	5.2	6.2	92	9.4	1	13.3	921.2
22-Jan-	0	14.5	6	11.8	66	7.4	2.5	9.5	918.8
23-Jan-	0	15.4	10.4	9.2	61	6.2	3.3	12.5	914.5
24-Jan-	0	15.4	8	11.8	74	5.7	2	7.8	916.1
25-Jan-	0	13	6.2	6.6	83			16.3	911
26-Jan-	0	9.8	5.5	5.6	88	5.3		19.3	915
27-Jan-	2.2	7.2	4.5	5.6	99		2.4	17	920.4
28-Jan-	5.2	8	4.4	5.8	97	3.8	0.4	15.8	920.9
29-Jan-	0.6	10	4.4	4.6	91	4.4	1.1	8.8	921.5

30-Jan-	0	11.6	3.9	5.6	84	9.6	1.3	10	918.2
31-Jan-	0	14.5	4.4	8.9	67	9.7	2	10.5	915.4
3-Feb-	7.4			8.3	99	3.3	1.8	14.5	908
4-Feb-	37.7			8.5	97	4.1	5.7	13.3	917
5-Feb-	0.4			10.2	76	9.7	2.4	7	917
9-Feb-	0.6			5.2	91	1.1	3	23.8	914.6
10-Feb-	1			8.4	85	5.8	1.6	6.5	921.6
14-Feb-	5.4			6		1.8	3.4		
15-Feb-	16.3			4.3	99	2	2.1	22	911.6
16-Feb-	35.7			3.7	93	7.6	3.3	24	9142
17-Feb-	6.2			9.3	94	5.3	2.9	8	919.2
9-Mar-	10.6	7.4	5.5	5.9	80	5	1.8	19.2	912.6
18-Mar-	0.5	11.6	6.6	8.3	95	3.9	2.3	13.5	915.5
30-Mar-									

Table 3: Daily amount of meteorological parameters for January 2006 (PMD,2006).

Date	Rain(mm)	Mean	RH	SunShine	Evap	Wind	Pressure	Max	Min
1-	0	14.2	36	6.1	3.6	9.3	920.2	16.5	11.3
2-	0	13.2	40	8	4.5	5.8	921.2	16.7	10.9
3-	0	12.6	31	9	6.5	21.8	919.7	14.6	8.6
4-	0	12.2	54	1.6	7.2	31.8	917.7	13.2	9.2
5-	0.6	15.6	55	8.3	5	11.3	918	17.8	10.2
6-	0	10.1	81	7.4	2.2	9.5	917.3	18	13
7-	0	8.2	98	5.7	2.4	12	915.9	12.6	8.2
8-	13.5	7	100	1.3	4	13.8	914.9	8	6.7
9-	15.5	7.4	96	3.6	8.7	9.3	915.9	10.4	6
10-	0.2	6.4	100	2.4	3.2	7.3	912.4	10	6
11-	23.6	5.4	100	1.5	2.6	13.5	911	7.5	3.6
12-	29.7	5.6	99	0.8	1.7	15.8	915	6.8	4.5
13-	13.5	4.3	97	2.2	1	11.5	916.5	7.8	4.6
14-	0	4.6	98	3.4	1.3	10.5	917.4	7.8	4
15-	8.9	4.4	87	3.7	1.4	10.5	918.5	6.7	3.5
16-	0	5.2	97	6.1	0.2	5.3	919.1	9.3	3.5
17-	4	5.7	98	6.9	1.8	11.5	920.1	8.1	4
18-	12.8	5.7	96	1.5	1.8	13.3	920.8	7.5	4.4
19-	4.5	8.4	71	9.8	0.5	6	921.6	12	4.5
20-	0	6	81	7.9	3	19	920.5	10.5	5.6
21-	2.2	6.2	92	9.4	1	13.3	921.2	10	5.2
22-	0	11.8	66	7.4	2.5	9.5	918.8	14.5	6
23-	0	9.2	61	6.2	3.3	12.5	914.5	15.4	10.4
24-	0	11.8	74	5.7	2	7.8	916.1	15.4	8
25-	0	6.6	83	5.6	2.3	16.3	911	13	6.2
26-	0	5.6	88	5.3	2.1	19.3	915	9.8	5.5
27-	2.2	5.6	99	4	2.4	17	920.4	7.2	4.5
28-	5.2	5.8	97	3.8	0.4	15.8	920.9	8	4.4
29-	0.6	4.6	91	4.4	1.1	8.8	921.5	10	4.4
30-	0	5.6	84	9.6	1.3	10	918.2	11.6	3.9
31-	0	8.9	67	9.7	2	10.5	915.4	14.5	4.4

Table 4: Averages mean values for the meteorological parameters for the last 25-year(ARIJ,2005).

	Jan.	Feb.	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Max. Temp	11.4	12.9	16	20.9	24.8	27.3	28.4	28.6	27.5	24.5	18.7	13.3
Mean Min.Temp	6.1	6.9	8.7	10.3	15.3	17.7	18.9	19	18.1	16.4	12.3	8
Abso.Max Temp	20.2	21.8	26.3	34.5	38	36.8	35.6	37.3	37.2	32.7	27.2	26.5
Abso.Min Temp	-4.1	-3.4	1	0.2	4.6	9	13.6	14.4	8.6	8.5	0.2	-1
Mean Temp.	0.7	9.9	12.3	15.6	20	22.5	23.6	23.8	22.8	20.4	15.5	10.6
Mean Wind Speed	16.3	18	18.5	18.5	18	19.4	20.4	18.6	17	13	14.1	16
pressure	924	923	921	921	922	921	919	919	922	924	925	925
Mean Sunshine	5.4	7.1	9.4	9.4	11.4	12.4	12.1	11.8	10.1	7.3	6.5	5.9
Mean RH %	67	66	50	50	45	45	53	57	58	56	59	66
Total Rainfall	143.1	117.7	26.1	26.1	3.6	0.3	0	0	0.3	18.3	63.8	155.3
Total Evaporation	110	104	195	195	238	232	252	228	127	128	63	55

Table 5: Rains mount (mm) Vs. Mean air Temp for winter 2006/2007(PMD,2007)

Date			rain mm	Temp
15/10/2006	15/10/2006	15-Oct-06	4.5	20
16/10/2006	16/10/2006	16-Oct-06	3.5	19
24/10/2006	24/10/2006	24-Oct-06	4	20
27/10/2006	27/10/2006	27-Oct-06	37	20
28/10/2006	28/10/2006	28-Oct-06	20	19
11/04/2006	11/04/2006	04-Nov-06	14	17
11/05/2006	11/05/2006	05-Nov-06	9	12.1
13/11/2006	13/11/2006	13-Nov-06	1.5	15
15/11/2006	15/11/2006	15-Nov-06	2	17
12/12/2006	12/12/2006	12-Dec-06	3	12
21/12/2006	22/12/2006	22-Dec-06	4	12
26/12/2006	26/12/2006	28-Dec-06	101	10
27/12/2006	27/12/2006	27-Dec-06	28	4
31/12/2006	31/12/2006	31-Dec-06	10	7
01/05/2007	01/05/2007	05-Jan-07	29.5	11
01/07/2007	01/08/2007	08-Jan-07	41	11
20/1/2007	20/1/2007	20-Jan-07	62	10
21/1/2007	21/1/2007	21-Jan-07	3	9
28/1/2007	28/1/2007	28-Jan-07	5.5	11.5
29/1/2007	29/1/2007	29-Jan-07	2	10
30/1/2007	30/1/2007	30-Jan-07	19	11
02/02/2007	02/02/2007	02-Feb-07	1.5	11
02/03/2007	02/03/2007	03-Feb-07	35	12
02/04/2007	02/04/2007	04-Feb-07	22.5	9
02/05/2007	02/05/2007	05-Feb-07	4.5	12
02/06/2007	02/06/2007	06-Feb-07	16	11
02/09/2007	02/09/2006	09-Feb-07	3	11
13/2/2007	13/2/2007	13-Feb-07	5	13
15/2/2007	15/2/2007	15-Feb-07	22.5	14
17/2/2007	17/2/2007	17-Feb-07	1.5	13
25/2/2007	25/2/2007	25-Feb-07	25	12
26/2/2007	26/2/2007	26-Feb-07	9.5	10
03/01/2007	03/01/2007	01-Mar-07	2.5	11
13/3/2007	13/3/2007	13-Mar-07	27.5	10
14/3/2007	14/3/2007	14-Mar-07	58	8.4
15/3/2006	16/3/2006	16-Mar-07	55	9.3
17/3/2007	17/3/2007	17-Mar-07	6.5	8.3
26/3/2007	26/3/2007	26-Mar-07	2.5	11
31/3/2007	31/3/2007	31-Mar-07	3.5	13
04/01/2007	04/01/2007	01-Apr-07	1.5	12
04/11/2007	04/11/2007	11-Apr-07	4	10
13/4/2007	13/4/2007	13-Apr-07	2	11
05/10/2007	05/11/2007	11-May-07	14.5	12
16/5/2007	16/5/2007	16-May-07	0.8	10

Table 6: the Natural Discharge in Dyouk and Sultan Springs(PWA 2007)

Al Dyuk	Eastern	Jericho	Jericho	23/01/2000	138.5
Al Dyuk	Eastern	Jericho	Jericho	21/02/2000	136.7
Al Dyuk	Eastern	Jericho	Jericho	27/03/2000	138
Al Dyuk	Eastern	Jericho	Jericho	24/04/2000	141.5
Al Dyuk	Eastern	Jericho	Jericho	23/05/2000	139.5
Al Dyuk	Eastern	Jericho	Jericho	25/06/2000	136.4
Al Dyuk	Eastern	Jericho	Jericho	23/07/2000	137.2
Al Dyuk	Eastern	Jericho	Jericho	27/08/2000	120.2
Al Dyuk	Eastern	Jericho	Jericho	24/04/2001	136.5
Al Dyuk	Eastern	Jericho	Jericho	27/05/2001	137.6
Al Dyuk	Eastern	Jericho	Jericho	15/10/2001	105.6
Al Dyuk	Eastern	Jericho	Jericho	27/11/2001	115.7
Al Dyuk	Eastern	Jericho	Jericho	06/01/2002	150.3
Al Dyuk	Eastern	Jericho	Jericho	09/02/2002	154.8
Al Dyuk	Eastern	Jericho	Jericho	24/10/2002	164.9
Al Dyuk	Eastern	Jericho	Jericho	03/02/2003	160.1
Al Dyuk	Eastern	Jericho	Jericho	15/03/2003	164.3
Al Dyuk	Eastern	Jericho	Jericho	15/04/2003	172.7
Al Dyuk	Eastern	Jericho	Jericho	24/05/2003	172.3
Al Dyuk	Eastern	Jericho	Jericho	21/06/2003	164.7
Al Dyuk	Eastern	Jericho	Jericho	30/08/2003	126.6
Al Dyuk	Eastern	Jericho	Jericho	30/11/2003	142.2
Al Dyuk	Eastern	Jericho	Jericho	28/12/2003	152.3
Al Dyuk	Eastern	Jericho	Jericho	24/01/2004	146.6
Al Dyuk	Eastern	Jericho	Jericho	20/03/2004	157.6
Al Dyuk	Eastern	Jericho	Jericho	28/04/2004	143
Al Dyuk	Eastern	Jericho	Jericho	22/05/2004	148.5
Al Dyuk	Eastern	Jericho	Jericho	19/06/2004	137
Al Dyuk	Eastern	Jericho	Jericho	25/07/2004	144.8
Al Dyuk	Eastern	Jericho	Jericho	25/08/2004	138.5
Al Dyuk	Eastern	Jericho	Jericho	23/10/2004	135
Al Dyuk	Eastern	Jericho	Jericho	28/11/2004	142
Al Dyuk	Eastern	Jericho	Jericho	20/12/2004	136.5
Al Dyuk	Eastern	Jericho	Jericho	24/01/2005	162.9
Al Dyuk	Eastern	Jericho	Jericho	27/02/2005	142.2
Al Dyuk	Eastern	Jericho	Jericho	22/03/2005	155.6
Al Dyuk	Eastern	Jericho	Jericho	19/04/2005	151.8
Al Dyuk	Eastern	Jericho	Jericho	21/05/2005	158.9
Al Dyuk	Eastern	Jericho	Jericho	24/07/2005	174.9
Al Dyuk	Eastern	Jericho	Jericho	24/08/2005	154.7
Al Dyuk	Eastern	Jericho	Jericho	24/09/2005	151.9
Al Dyuk	Eastern	Jericho	Jericho	20/10/2005	134.3
Al Dyuk	Eastern	Jericho	Jericho	22/11/2005	153.3
Al Dyuk	Eastern	Jericho	Jericho	17/12/2005	148.8
Al Dyuk	Eastern	Jericho	Jericho	28/01/2006	160.1
Al Dyuk	Eastern	Jericho	Jericho	23/02/2006	159.6
Al Dyuk	Eastern	Jericho	Jericho	25/03/2006	150.9
Al Dyuk	Eastern	Jericho	Jericho	20/04/2006	148.8
Al Dyuk	Eastern	Jericho	Jericho	22/05/2006	160.3
Al Sultan	Eastern	Jericho	Jericho	21/02/2000	175.3
Al Sultan	Eastern	Jericho	Jericho	27/03/2000	174.7
Al Sultan	Eastern	Jericho	Jericho	24/04/2000	178.4

Al Sultan	Eastern	Jericho	Jericho	23/05/2000	183.4
Al Sultan	Eastern	Jericho	Jericho	25/06/2000	181.4
Al Sultan	Eastern	Jericho	Jericho	23/07/2000	175
Al Sultan	Eastern	Jericho	Jericho	27/08/2000	166.5
Al Sultan	Eastern	Jericho	Jericho	24/04/2001	181.5
Al Sultan	Eastern	Jericho	Jericho	16/10/2001	162.7
Al Sultan	Eastern	Jericho	Jericho	27/11/2001	187.2
Al Sultan	Eastern	Jericho	Jericho	06/01/2002	190.8
Al Sultan	Eastern	Jericho	Jericho	09/02/2002	201.1
Al Sultan	Eastern	Jericho	Jericho	05/11/2002	188.5
Al Sultan	Eastern	Jericho	Jericho	03/02/2003	184.7
Al Sultan	Eastern	Jericho	Jericho	15/03/2003	188.7
Al Sultan	Eastern	Jericho	Jericho	15/04/2003	200.9
Al Sultan	Eastern	Jericho	Jericho	24/05/2003	187.5
Al Sultan	Eastern	Jericho	Jericho	21/06/2003	186.06
Al Sultan	Eastern	Jericho	Jericho	30/08/2003	190
Al Sultan	Eastern	Jericho	Jericho	30/11/2003	178
Al Sultan	Eastern	Jericho	Jericho	28/12/2003	208.6
Al Sultan	Eastern	Jericho	Jericho	24/01/2004	197.5
Al Sultan	Eastern	Jericho	Jericho	16/02/2004	214.1
Al Sultan	Eastern	Jericho	Jericho	20/03/2004	200.7
Al Sultan	Eastern	Jericho	Jericho	28/04/2004	179.7
Al Sultan	Eastern	Jericho	Jericho	22/05/2004	191.2
Al Sultan	Eastern	Jericho	Jericho	19/06/2004	177.5
Al Sultan	Eastern	Jericho	Jericho	28/07/2004	162.1
Al Sultan	Eastern	Jericho	Jericho	25/08/2004	170.4
Al Sultan	Eastern	Jericho	Jericho	23/10/2004	182.2
Al Sultan	Eastern	Jericho	Jericho	28/11/2004	193.5
Al Sultan	Eastern	Jericho	Jericho	20/12/2004	147.9
Al Sultan	Eastern	Jericho	Jericho	24/01/2005	216.1
Al Sultan	Eastern	Jericho	Jericho	27/02/2005	203.1
Al Sultan	Eastern	Jericho	Jericho	22/03/2005	207.1
Al Sultan	Eastern	Jericho	Jericho	19/04/2005	204.4
Al Sultan	Eastern	Jericho	Jericho	21/05/2005	191.9
Al Sultan	Eastern	Jericho	Jericho	24/07/2005	178.8
Al Sultan	Eastern	Jericho	Jericho	24/08/2005	181.6
Al Sultan	Eastern	Jericho	Jericho	24/09/2005	196.2
Al Sultan	Eastern	Jericho	Jericho	20/10/2005	192.5
Al Sultan	Eastern	Jericho	Jericho	22/11/2005	192.4
Al Sultan	Eastern	Jericho	Jericho	17/12/2005	190.9
Al Sultan	Eastern	Jericho	Jericho	28/01/2006	193.1
Al Sultan	Eastern	Jericho	Jericho	23/02/2006	204.1
Al Sultan	Eastern	Jericho	Jericho	25/03/2006	185.3
Al Sultan	Eastern	Jericho	Jericho	20/04/2006	196
Al Sultan	Eastern	Jericho	Jericho	22/05/2006	193.5

- The End.

ملخص

لقد تم تنفيذ عملية مراقبة المياه الجوفية الموجودة في منطقة الينابيع المجاورة لمجرى وادي القلط في منطقة منحدرات القدس- رام الله ،إضافة لسهل أريحا.، الواقعة في الضفة الغربية/فلسطين، إضافة للمياه الامطار في حوض القدس-رام الله خلال موسم شتاء ٢٠٠٦- ٢٠٠٧. حيث تم تتبع النترات NO3 ذات مصدر التلوث الصناعي والكربون العضوي المذاب DOC في الينابيع ومياه الامطار، إضافة إلى تغيرات أخرى مكانية ومرحلية ضمن التكوين الكيميائي الأرضي، وضمن التكوين الطبيعي –الإنساني- للمياه الجوفية، وكذلك يشمل النظائر المستقرة $\delta^{18}O$ and $\delta^{2}H$.

ويوضح تحليل مفصل للعناصر المذابة أنه ما عدا إذابة الكربونات والنترات والكلوريد والكبريت، فإن هذه المركبات المذابة تمتص من قبل التربة والصخور للخزان الجوفي، إضافة لكميات صغيرة من ال Mg. هكذا، فإن ال Mg ينشأ من الكربونات في الكربونات إضافة لل Mg-Cl المياه المالحة الموجودة في الصخور. يجب التعامل مع مياه ال Mg-Cl المالحة بشكل مناسب، كمصدر محتمل لتراجع المياه العذبة، التي تسحب من أعلى جبل، وتتراجع حالما تذهب مزيدا للشرق وتصل للشرق، بالقرب من حدود أريحا.

التغيرات الزمانية و المكانية في الخصائص الكيميائية تكشف ان المشكلة في المياه العذبة مرتبطة بعامل الزمن ، المدة الزمنية لبقائها ووجودها في الخزان الجوفي و التجمعات الملحية.اما العوامل الرئيسة التي تؤثر في ذلك فهي زمن المكوث في الخزان الجوفي ومعدل التدفق في التكوينات الجيولوجية والية وكمية التغذية .
زمن المكوث بلاضافة الى كثافة التساقط(التغذية) يلعب دورا هاما في التحكم بخصائص والتركيب الكيميائي للمياه الجوفية.و تبين ان المياه الجوفية في المنطقة القريبة من اريحا ، وتحديدا عين السلطام وعين ديوك تمتاز بطول زمن المكوث وتعد اقدم من تلك التي قي المنطقة العليا من وادي القلط وذللك استنادا للارتفاع في نسبة الكتلة المولية Mg/Ca بالاضافة للمؤشر النظير ^{2}H الاعلى.

ومن المؤشرات المهمة ،اكسدة المواد العضوية الناتجة عن مخلفات الصرف الصحي و النفايات و التي تنتج Co_2 المذاب.وتؤدي زيادة CO_2 لانخفاض pH وبالتزامن مع حالة دون الاشباع بالنسبة ل calcite (وdolomite) .وكذلك الحال في انخفاض تركيز CO_2 ينتج حالة فوق الاشباع ، وهذا يعني ان اشباع calcite يحدث في نهايه الموسم المطري وهذه المشاهدة كانت واضحة في بداية موسم الشتاء، وبشكل اوضح اعلى قيمة في بدايته من نهايته . بينما تظهر مياه الينابيع حدوث تغير مفاجئ في قيمة NO_3,DOC بعد اسابيع قليلة من اول تساقط مطري فعال.وبلغت قيمة DOC في المياه الجوفيةاكثر من 12 mg/L في عين القلط وعين الديوك،وهذا مؤشر على وجود خطر على صحة الانسان في حالة عملية الكلورة chlorination لغرض الشرب من المياه.

تظهر عينات المطر قيمة مرتفعة للنترات بعد اول تساقط مطر لاحقا لفترة جفاف بين فترات التساقط المطري.وتتناقص هذة القرائاتمع حدوث عملية الغسيل washout effect للملوثات في الجو.كما ان تأثير التكوين الصخري karsticوسقوط الامطار بشكل غير متماثل لمحتوى النترات معتمدا على الحالة المائية hydrological state وزمن وتركيز سقوط المطر.
الخارج من الملوثات في مياه الصرف الصحي من المشتوطنات المحيطة ، التجمعات البدوية، وكذلك الحيوانات في محيط مجرى وادي القلط كانت متباينة ومعتمدة على كثافة التساقط وطول المدة الزمنية للفترة الجفاف. وتحلل المواد العضوية كمصدر اساسي لزيادة عسورة ومحتوى المعادن في المياه.ان مؤشر النظائر للعناصر في المياه الجوفية خلال الموسم جاء متغيرا بالاعتماد على الظروف الناخية ،المكانية الزمانية.وجاء local meteoric water line (LMWL) **δ2H =7.95 δ18O + 19.75 ‰** SMOW.

تم تميز منطقتين للتغذية المياه الجوفية ؛ المنطقة الاولى ويمثلها عين فاره وعين القلط، ويتم التغذية فيها مباشرة من خلال الميا السطحية للمرتفعات الشرقية ، ومع زمن مكوث اقل من ذلك الذي في المنطقة الثانية.وتأتي المنطقة الثانية ،بالقرب من الدود الغربية لمدينة لأريحا ويتم تغذيتها بالمياه بشكل رئيسي من المياه الجوفية للمرتفعات الشرقية مصحوبا بالقليل من المياه السطحية .و باشباع اكثر ل deuterium في بدية الموسم مكأدا طول زمن المكوث للمياه التي يحصل لها استبدال بمياه جديدة مع الزمن.
النتائج السبفة مهمة و مفيدة للمساعدة في الوصول لاستخدام اكثر فعالية للمياه في المنطقة، ولهذا يجب الحرص على استخدام الاجراءات السابقة و الاحتياطية، وكما الاستفادة من المياه السطحية الجارية بالاستفادة من المناطق الاكثر تغدذية للمياة بخاصة في المنطقة الثاني التي يحصل فيها تبخر اعلى و تغذية اقل.