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Hydrochemical Characteristics of Rainwater in Ramallah District

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Abstract: The hydrochemical variability of rainwater in Ramallah District in the West Bank was studied through two rainwater sampling campaigns of the rainy seasons of 2007 and 2008 in order to determine its hydrochemical characteristics. The major ions of twenty two rainwater samples: Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-}, NO_3^{-} and HCO_3^{-} were analyzed. Sodium and Potassium concentrations show increasing amounts in the Western parts more than the Eastern parts. The Nitrate concentrations is increasing in the Western parts of the study area. Sulfate shows variability, but its concentration is noticeably increasing in Western areas due to its close to the Mediterranean Sea. Three types of Rain water were found: Na-Cl, Na-HCO_3 and Ca-HCO_3. Most of the Rainwater samples fall into the normal earth alkaline water group with prevailing bicarbonate and sulfate or chloride. EC and TDS values show an increasing trend and has the linearity of TDS = 0.5 EC.

Key words: Rainwater chemistry, quality, ramallah, West Bank

INTRODUCTION

Rains are the main source of water in Palestine; it is the feeder of groundwater aquifer, surface water, valleys and flowages. Environment of Palestinian aquifers is affected by chemical composition of rainwater which is originated from the Mediterranean, Europe and the Atlantic Ocean. The Palestinian hydrological year depends on rainwater, which is the main recharge source to the Palestinian aquifers. Rains increase in the Western heights and decrease in the Jordan Valley. In general, the distribution of rainwater is strongly influenced by the topography, with higher rainwater in the hills and mountains. The average of rainwater amount falling in the West Bank varies from one area to another. The total rainwater amount falling in the West Bank varies between 2700 and 2900 Mm^3 (PWA, 2008). Rainwater is considered as the main component of precipitation in the West Bank. Rainwater in the area also shows considerable inter-seasonal variation. The rainy days in the West Bank are estimated between 40-70 days $year^{-1}$. The recorded average of Ramallah's rainfall is about 615 mm (MOA, 2010). The standard deviation of rainfall data for the period between 1994 and 2007 is 235. This is a high standard deviation and refers to rainfall fluctuations between one and another. Sources of rain in Palestine are the moisture transported through the Mediterranean, evaporation from sea surface and orographic condensation over central Palestinian mountain (Isakson, 1996). In addition, Palestine displays spatial seasonal and inter annual variability (Evans *et al*., 2004). Steinberger and Gazit-Yarin (1996) studied rainfall series in Israel during 1960-1990 for 99 stations and found out that precipitation amounts

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have decreased in the Northern, central coastal areas and in Northern mountain area. However, precipitation has increased in Southern coastal area and in Western slopes of central mountains. Trends of Rainfall were probably the outcome of changes in synoptic climate during winter in the Eastern Mediterranean region. In their study about rain spells in Israel Halfon *et al*. (2006) found a strong correlation between depth of pressure lows and rain distribution between coastal interior regions. Such a rain was affected by changes in wind speed and the penetration of the humidity inland and the orography enhancement efficiency. The research will tackle the hydrochemical patterns of rainwater in Ramallah district, which is part of the central Palestinian mountains. The objective of this research is to determine the hydrochemical characteristics of the rainwater in Ramallah District and to model the hydrochemical variability of rainwater in the study area.

MATERIALS AND METHODS

The sampling campaigns was carried out in wet seasons, starting from Nov. - 2007 to January 2009; a total of 22 samples were collected. The water samples were collected in one-liter polyethylene bottles and refrigerated in the laboratory at 2°C. Onsite tests for pH and Electrical conductance (EC) were carried out for each site using Hanna field multimode meter. Perkin-Elmer Optima 3000 ICP-OEA was used to determine calcium, magnesium, sodium and potassium. HP 8453 Diode Array Spectrophotometer was used to determine nitrate and sulfate concentrations. Hanna pH multi-meter was used onsite for the determination of pH, TDS, EC temperature. Metrohm 716 titrator used to determine chloride and bicarbonate concentrations.

Study Area

The study area is Ramallah Geographic District, which includes the cities of Ramallah and its twin Al Bireh city and it is located on a chain of Palestine central mountains in the middle part of the West Bank (Fig. 1). The chain of ridges slopes gradually toward the West but they go down in steep slope toward the east. It extends from Jerusalem district in the South to Nablus district in the North and from Jericho district in the east to the 1948 borderline between Israel and West Bank from the West. The population in the study area are about 180,000 inhabitants (PCBS, 1999). The elevation of the study area lies from 860 to 450 meters above sea level. It is highly influenced by the Mediterranean climate, which is characterized by long, hot, dry summers and short, cool, rainy winters and it has about seven rainy months (November-May). The average annual rainwater in the Western part of Ramallah district is higher than in its Eastern; it varies from 650 to 200 mm annually (Meteorological Services, 2006). Out of the rainwater, 2-13% returns to the Mediterranean sea as surface runoff, 20-26% infiltrates to groundwater aquifers and the rest is lost by evapotranspiration (Rofe and Raffety, 1963).

Temperatures are lower than other places in the West Bank. The temperature in the coldest month (January) is in the range of 6-13°C and the average temperature in the hottest month (August) was 37.5 °C during 1994/1995 (Meteorological Services, 2006). The mean annual temperature ranges between 18-20°C (ARIJ, 1996). The geological strata in the Study area are composed of thick sequences of layered limestone, dolomite, chalk and marl. The main outcrop formations belong to formations of the Albian to Turonian age (Rofe and Raffety, 1963).

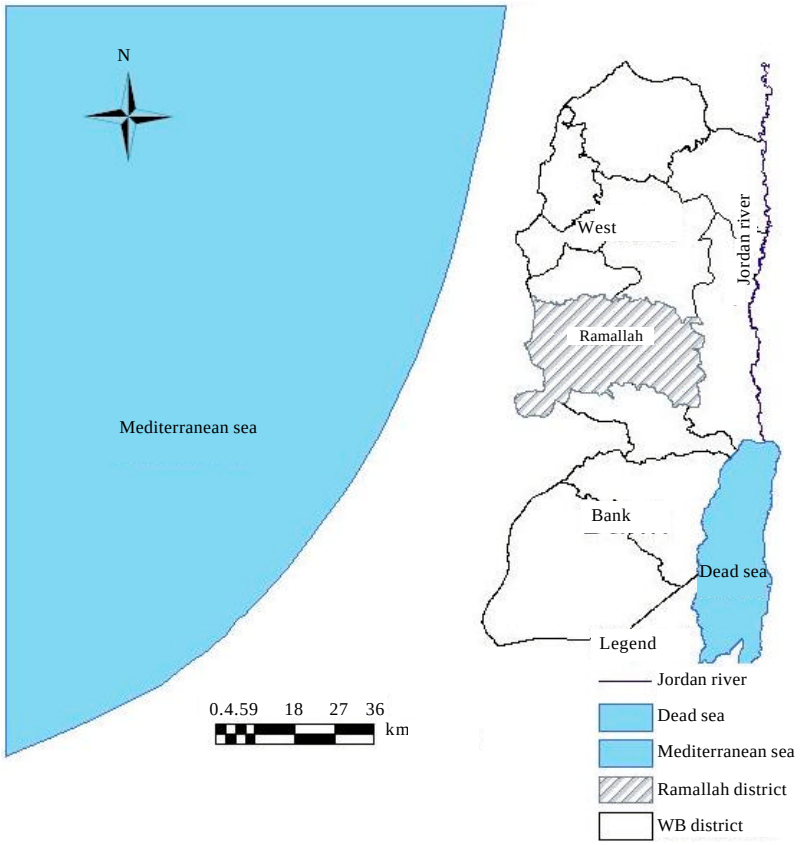

Fig. 1: Location map of the study area

RESULTS

The lack of the hydrochemical rainwater data in the West Bank makes the determination of the hydrochemical rainwater patterns more important for its overall uses. The quality of rainwater is determined through the analysis of two successive rainy seasons in the study area from Nov. 2007 to Jan. 2009 in Ramallah areas (Fig. 2). A total of 22 samples were analyzed hydrochemically. The factors controlling the chemical composition of rainwater is its distance from the Mediterranean seashore (Rosenthal *et al*., 1984).

EC has an average of 164 μS cm^{-1} and its values range between 24 and 397 μS cm^{-1}; while the TDS has an average of 82 ppm and ranges between 11 and 161 ppm. EC as well as TDS values show an increasing trend in the Western and in the Eastern parts of the study area (Fig. 3).

Both EC and TDS show a linear correlation between them in two successive rainy years of 2007 and 2008. This reveals to the equation where TDS = 0.50 EC + 0.1 in the year 2007 and TDS = 0.48EC + 0.8 in the year 2008 (Fig. 4). This could be attributed to the result TDS = 0.5 EC+C (where C is constant and depends on the yearly average of rainfall) with some differences in the coefficient of C.

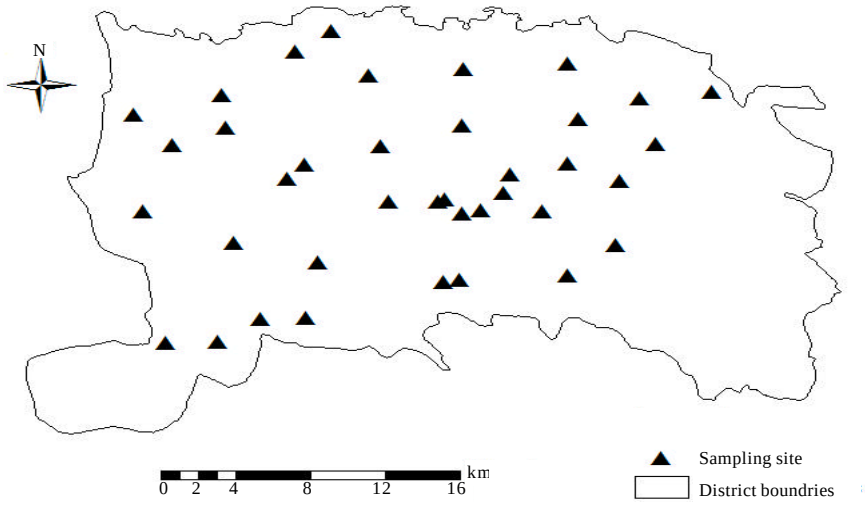

Fig. 2: Rainwater sampling sites from Ramallah district

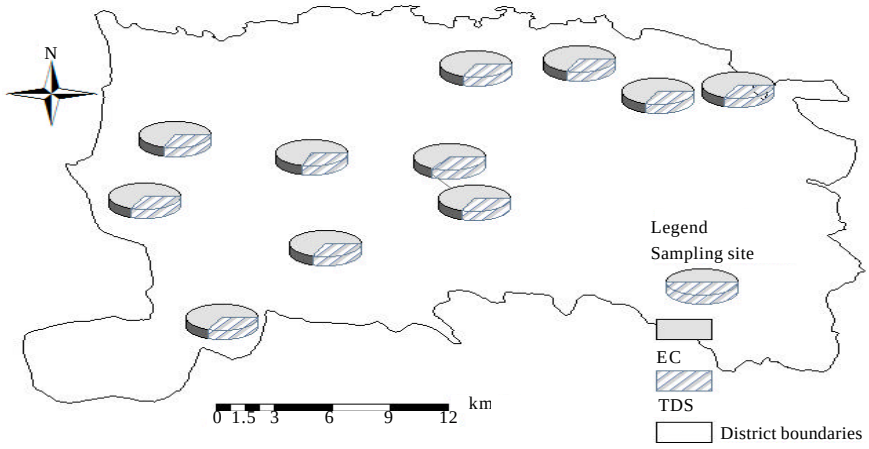

Fig. 3: Average values of EC (μS) and TDS (ppm)in rainwater samples

The pH values in the coastal regions show that rainwater is acidic with an average value of 6.5 (Mamane, 1987). The rainfall becomes richer with the bicarbonate ions in the study area originated from dust particles, which increases pH values towards neutrality and in some regions towards basic values. The pH values of samples collected in 2007 and 2009 were about 7.3±0.6, which reveals the neutral character of rainfall water over the district (Palestinian Standards Institution, 1997).

Sodium concentration in rainwater samples has an average of 11 ppm and show ranges from 1-28 ppm . Potassium concentration has an average of 5 ppm and shows ranges from 0.3-20 ppm . Sodium and Potassium concentrations show increasing amounts in the Western part of the study area more than the Eastern parts (Fig. 5).

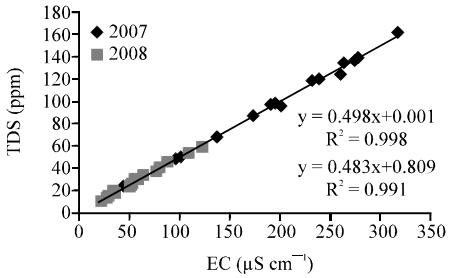

Fig. 4: Relationship between EC (µS) and TDS (ppm) for two successive years

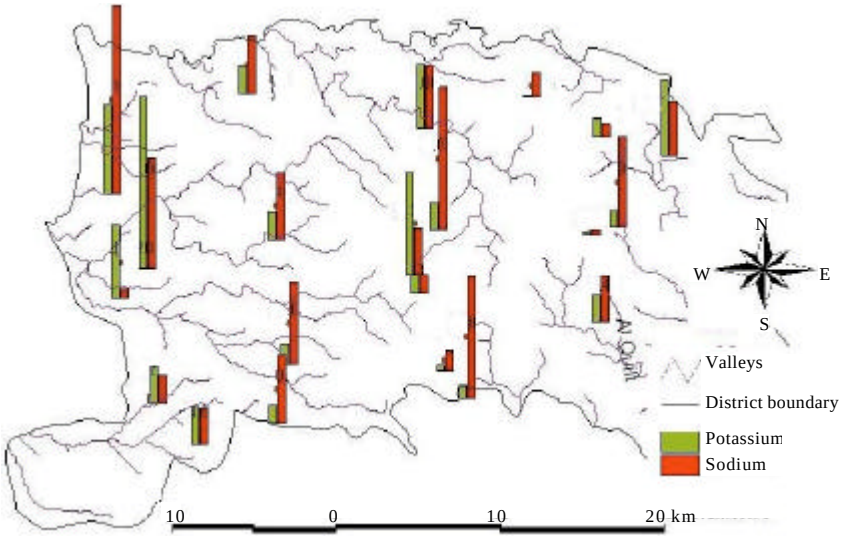

Fig. 5: Average concentrations of sodium and potassium (ppm) in rainwater samples

It is also noticed that the Nitrate concentrations is increasing in the Western parts of the study area (Fig. 6). The study area is charcterized with a huge amount of agricultural activities especially poultry and kettle farms. Nitrate concentration in the rainwater samples from the study area has an average value of 19 ppm and ranges between 2-48 ppm. But values of nitrate are exceeding the WHO standards for drinking water (WHO, 1996) in some springs in the Natuf drainage basin in Ramallah district, which are recharged by rainfall water over the district and are used as the main source of fresh drinking water for people living nearby these springs. This increase is due to the pollution caused by wastewater of the Natuf basin (Shalash and Ghanem, 2007). Therefore, the rainwater in these areas is not recommended for storage as drinking water, it can be used for agricultural and other domestic use (Fig. 6).

The main origin of chloride and sulfate is the droplets of water rich of salts from the Mediterranean Sea water which is carried through water droplets by wind and distributed over the district (Mamane, 1987); its concentration is valid upon the amount of rainwater in each area. Sulfate also shows variation from area to another, but its concentration is noticeably increasing in Western areas which are closer to the Sea (Fig. 7).

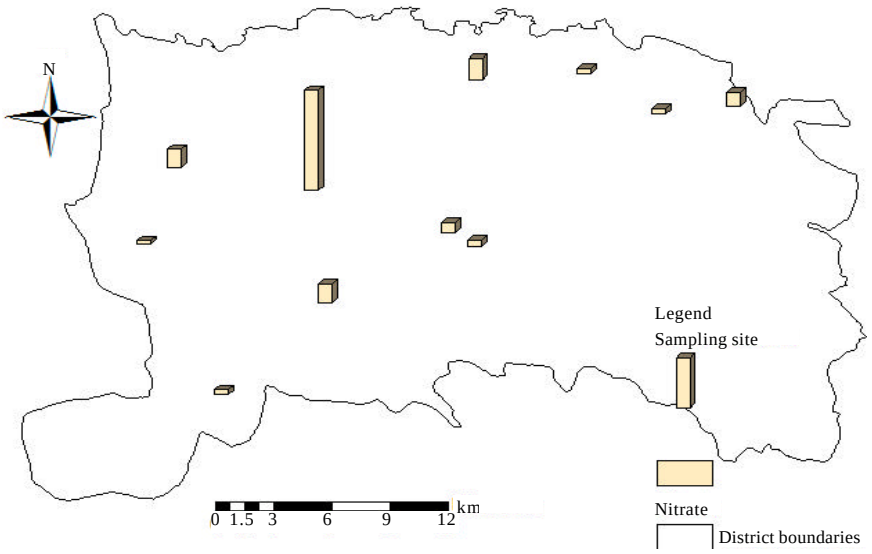

Fig. 6: Nitrate values (ppm) in rainwater water in Ramallah district

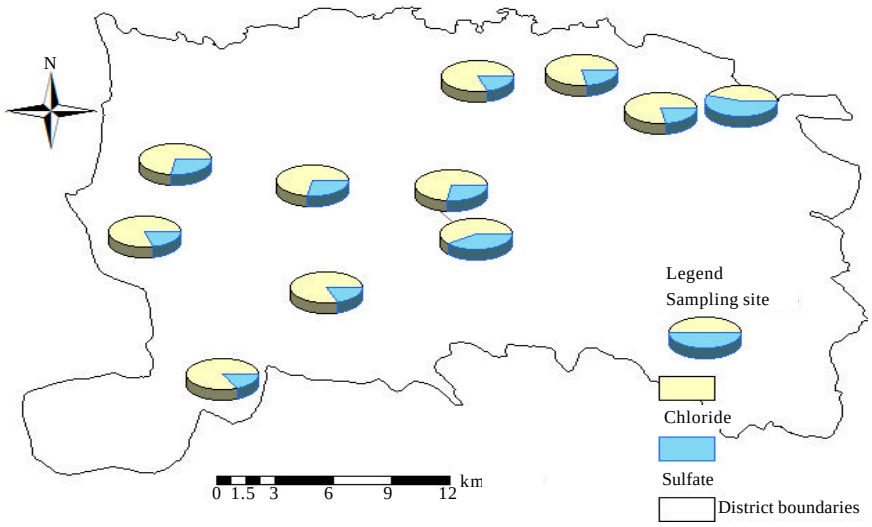

Fig. 7: Sulfate and chloride distribution (ppm) in rainwater water in Ramallah district

Three types of Rain water were found: Na-Cl, Na-HCO_3 and Ca-HCO_3. Piper diagrams were plotted for all the rainwater water samples analyzed in terms of major ions using AquaChem 5.1 software. It is clear from the graph that most of the samples fall into the normal earth alkaline water group with prevailing bicarbonate and sulfate or chloride (Fig. 8).

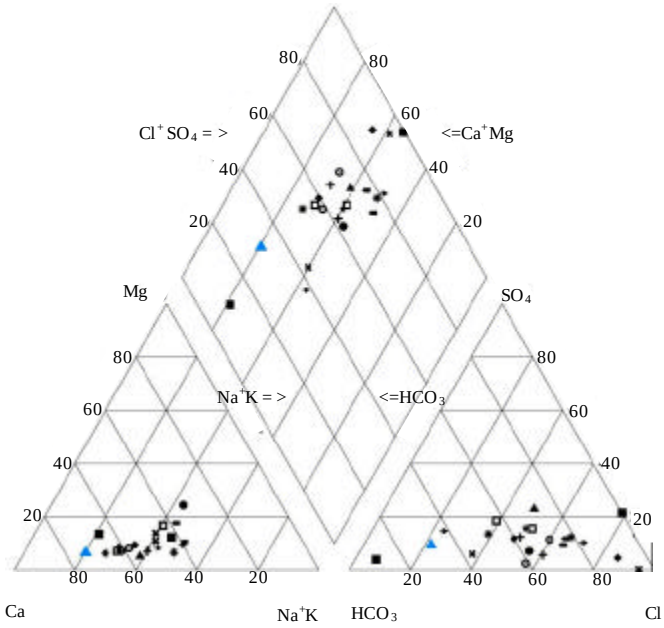

Fig. 8: Piper diagram for rainwater water in Ramallah district (symbols represent the sampling location areas)

DISCUSSION

The determination of the hydrochemical rainwater characteristics is considered to be an important indicator to the atmospheric pollution. The rainfall hydrochemical analyses of two wet seasons in Ramallah District reveals to that the rainfall is not polluted. The average of EC and TDS are 164 μS cm^{-1} and 82 ppm, respectively and reveals to the equation of EC = 0.5 TDS which matches the equations of the groundwater, that replenished from the rainfall.

The rainfall becomes richer with the bicarbonate ions in the study area originated from dust particles derives from the Mediterranean Sea. Rosenfeld *et al*. (2007); studied the inverse relationship between orographic precipitation in the mountains and air pollution and reported that Europe is the source of polluted air masses in winter toward the East Mediterranean countries. Geochemical ratios indicated that the origin of a major fraction of the carbonate minerals dissolved in rainwater is from the chalk exposed in the Sahara desert. The dust index is a valid parameter for the stratification anlyses of cloud seeding effect in Israel (Levi and Rosenfeld, 1996). The majority of rainwater had a neutral or alkaline character as a result of neutralization caused by the alkaline local dusts which contain large amount of $CaCO_3$ (Al Khashman, 2008). A comprehensive study on the chemical composition of rainwater was studied in Ghore El-Safi area Western side of Jordan nearby the Dead Sea by Al-Khashman (2008) and the rainwater samples were analyzed for major ions (Ca^{2+}, Mg^{2+}, K^+, Na^+, NH_4^+, HCO_3^-, Cl^-, NO_3^- and SO_4^{2-}) and trace metals (Fe, Al, Zn, Pb, Cu and Cd). He found that the highest concentration of elements is observed at the beginning of the rainfall season when large amounts of dust accumulated in the atmosphere scavenged by rain.

The pH in Ramallh district is found to be higher than in the Eastern side of the Dead Sea, which its average is 6.9 (Al-Khashman, 2008). Rain water quality in the Southern Jordan is

characterized by low salinity and neutralized pH and high values of pH were attributed to the neutralization by natural alkaline local dusts which contain a large fraction of calcite and dolomite (Al-Khashman, 2005).

Sodium and Potassium concentrations show an decrease trend towards the east of the gradual far distances from the Mediterranean Sea, where the majority of the Palestinian Rainfall originates. The study area is charcterized with a huge amount of agricultural activities especially poultry and kettle farms. Therefore, the rainwater in these areas is not recommended for storage as drinking water, it can be used for agricultural. The main origin of chloride is the water rich of salts and salt dusts from the Mediterranean Sea which is carried through wind and distributed according to the wind direction. The main wind directions that have water is Western or South Western directions. Sulfate increasing in Western areas and has the same original source like the chloride.

The three Rain water types of Na-Cl, Na-HCO_3 and Ca-HCO_3 that were found reflects the sources origins of rainfall and has the direct effect of the Mediterranean Sea as well as the agricultural activities in the area, especially in the Western part of the study area. In general, the results of this study suggested that rainwater chemistry is strongly influenced by local anthropogenic sources, agricultural activities, natural and marine sources. Significant chemical divergence was found between rainwater deriving from marine air masses characterized by NaCl enrichment and rainwater deriving from continental air masses which are mainly characterized by Ca-carbonate enrichment. The Western trajectory is exclusively marine originating from the Mediterranean, while the Eastern trajectory is exclusively continental and originates in the Arabian Desert (Anker *et al*., 2007). In Lebanon, rainfall chemistry is influenced by many factors. Rainwater can be affected either by the Mediterranean Sea in the coastal areas or by continental sources in the internal regions of the country (Saad *et al*., 2005). Also formation of smog in major cities, which includes air pollution caused by fossil fuel combustion, affects the precipitation chemistry in these regions.

CONCLUSION AND RECOMMENDATIONS

The determination of the hydrochemical characteristics of the rainwater in Ramallah District was studied and twenty two rainwater samples were analyzed hydrochemically. Hydrochemical analysis of rainwater water were used for understanding the hydrochemical properties of rainwater (Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}, Cl^{-}, HCO_3^{-}, SO_4 , NO_3^{-}) as well as its hydrochemical Variability in the Western and Eastern slopes of the West Bank. The relationship between EC and TDS shows linear correlation represented by TDS = 0.5 EC and the values show an increasing trend in the Western and Eastern sides. Sodium and Potassium concentrations show increasing amounts in the Western part of the study area more than the Eastern parts, due to the nearest distance to the Mediterranean Sea. The Nitrate concentrations is increasing in the Western parts of the study area. It is concluded that the rainwater water in these areas is not recommended for storage as drinking water, it can be used for agricultural and other domestic uses. Sulfate shows variation from area to another, but its concentration is noticeably increasing in Western areas which are closer to the sea. Three types of Rain water were found: Na-Cl, Na-HCO_3 and Ca-HCO_3. Most of the Rainwater samples fall into the normal earth alkaline water group with prevailing bicarbonate and sulfate or chloride.

A rainwater-runoff hydrochemical relationships should be recommended to be determined. A hydrogeochemical modeling of the groundwater and the springs water and its relations to the rainwater source as well as the runoff water.

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