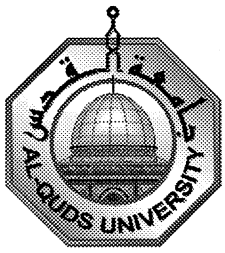
Deanship of Graduate Studies
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Evaluation of Rainfall Chemical Composition at Al Quds Rain gauge Station – Abu Dis, For the Period of 2001-2007

By:
Ruba Ibrahim Abdel-Jawad Qabajeh

M.Sc. Thesis

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Prepared By:-
Ruba Ibrahim Abdel-Jawad Qabajeh

B.Sc. Biology College of Science Bethlehem University
Palestine

Supervisor: Dr. Amer Marei

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Faculty of Science and Technology- Al-Quds University

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AL-Quds University
Deanship of Graduate Studies
Department of Earth and Environmental Sciences
Environmental Studies

Thesis Approval

Evaluation of Rainfall Chemical Composition at Al Quds Rain gauge Station – Abu Dis, For the Period of 2001-2007

Prepared By: Ruba Ibrahim Abdel-Jawad Qabajeh

Registration No. : 24011476

Supervisor: Dr. Amer Marei

Master thesis submitted and accepted, Date: May 26, 2008

Name and signatures of examining committee members are as followed:

Head of Committee:	Dr. Amer Marei	Signature:
Internal Examiner:	Dr. Ziad AL-Mimi	Signature:
External Examiner:	Dr. Saed AL- Khayat	Signature:

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Dedication

To my father who taught me the value of education

To my mother who supported me, and trust my ability to succeed

and lights up my life since my birth to this date

To my lovely husband "Iyad" for his efforts, moral

support, generosity, and endless encouragement

To my daughters "Munia, Yara, and Aya," for

the understanding during my absence,

To my brothers Abdel-Jawad, Murad, and Mohammed

And brother-in low Amer

To my sisters Ohud and Heba for their support,

Finally, to my mother and father-in low for their kindness.

With my love to them all.

Declaration:

I certify that this thesis submitted for the degree of Master is the result of my own research, except where otherwise acknowledged, and that this thesis or any part of the same has not been submitted for a higher degree in any other university or institution.

Signed: .....

Ruba Ibrahim Abd-el Jawad Qabajeh

Date: 26 May 2008

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Abstract

Chemical composition of rainfall events results for the period of 2001-2007 are presented in this thesis. This work aims to identify the characteristics of main ions Ca^{+2},Mg^{+2}, K^{+}, Na^{+}, NH_4^{+}, Cl^{-}, HCO_3^{-}, SO_4^{-2}, and NO_3^{-} in the precipitation, and try to determine the source or sources of that ions. Moreover, the influence of meteorological parameters such as the wind direction and the rainfall amount are discussed in the study. The rainfall samples are collected from Abu Dis weather Station immediately after rainfall event by the work team in the Environment Research Laboratory at Al-Quds University. The chemical analysis of main ions and physical parameters such as pH, EC, and temperature are measured in the laboratory. Titration analysis are made to Ca^{+2}, Na^{+}, Mg^{+2}, HNO_3^{-} and Cl^{-}, while the SO_4^{-2}, NO_3^{-}, NH_4^{+} are analyzed by using spectrophotometer. For the period of the study 2001-2007, 122 samples we are deal with after the ion balance results rejects five samples their error are more than 10%. The arithmetic average of EC during the period is 159.78 μS/cm. While the average of pH value is7.1, which means that the rainfall is not acidic. The relative abundance of ions in the precipitation is Ca^{+2}> Na^{+}> Mg^{+2} >K^{+}> NH_4^{+} for cations, and Cl^{-}> HNO_3^{-}> SO_4^{-2}> NO_3^{-} for anions. The arithmetic means of cations and anions concentration (meq/L) for the raining months during the hydrological year is compares to the rainfall amount. This comparison suggested that the concentrations of ions are decreasing as the amount of rainfall increasing because of the wash out from the atmosphere. However, the weighted average WA concentration of cations are calculated to find the relation between the amount of rainfall and the ions concentration during the single hydrological year, and compare it with the other hydrological year during the period of 2001-2007. The results show that WA concentration of Ca^{+2} increases when the rainfall amount decrease during the dry months such as November and April. The linear comparative between some ions such as Ca^{+2}, Na^{+}, Mg^{+2}, Cl^{-}, SO_4^{-2}, HCO_3^{-} is illustrate.

The result shows that Na^{+} and Cl^{-} shares by their sources which is mainly marine, while Mg^{+2} and Ca^{+2} have the same source, which is terrestrial source, in the beginning and the ending of the hydrological year. To determine the continental or marine sources of ions, different ratios are calculated by using Cl^{-} as tracer, and these ratios are compared to the seawater ratios. This comparison suggests that SO_4^{-2} mainly from terrestrial sources during the beginning and the ending of the hydrological year, and anthropogenic in the middle of the hydrological year. Na^{+}/Cl^{-} results are close to the seawater ratio. Moreover, there are some rain events have extremes ratio values. By investigation, it caused by the long period of dry days, sudden depletion of Cl^{-}, or unexplained enrichment of the concentration of ions. On the other hand, a correlation matrix is presented between the major ions. This matrix illustrates a good correlation by coefficient factor 0.73 between Na^{+} and Cl^{-}, which suggest that mainly they are from the same source that is marine source. While the weak correlation between Ca^{+2} and Mg^{+2} by 0.28 is presented, which suggests the influence of different sources of these ions. This thesis recommends studying the chemical composition of the rainfall in other cities in the West Bank to design a profile for the components in that period. In addition, it is recommended to study the relation of the rainfall component and the groundwater influenced by this rainwater to determine the relation between them.

الخلاصة

تعتبر مياه الأمطار المتساقطة على منطقتنا المصدر الأساسي لمخزون المياه الجوفية والسطحية، والتي تعتبرا لأساس لمجالات الحياة المختلفة. نتيجة التقدم العلمي والتكنولوجي، والذي أصبح سيفاً ذا حدين، فقد ارتفعت نسبة الملوثات في الهواء والتي أثرت مباشرة في المحتوى الكيميائي لمياه الأمطار.

لقد جاءت هذه الدراسة لتحديد المحتوى الكيميائي لمياه الأمطار المتساقطة على محطة أبو ديس الجوية للفترة الزمنية الواقعة من 2001 و حتى 2007. توجد هذه المحطة على ارتفاع 650 متراً عن سطح البحر فوق مبنى جامعة أبو ديس. وقد تم جمع العينات من هذه المحطة وتحليلها كيميائياً لأهم المكونات الموجودة فيها من قبل فريق العمل في مختبرات المياه والبيئة في جامعة أبو ديس. حللت العينات للكشف عن مكوناتها من أيونات الكالسيوم Ca^{+2}، المغنيسيوم Mg^{+2}، الصوديوم Na^{+}، والبوتاسيوم K^{+}، والكبريتات SO_4^{-2}، والبايكربونات HCO_3^-،والنترات NO_3^-، بالإضافة للأمونيوم NH_4^+ . أما بالنسبة للعناصر الفيزيائية كمستوى الحموضة pH ودرجة الحرارة والتدفق الكهربائي EC فقد تم أخذ تلك القراءات مباشرة بعد جمع العينات.

وقد وجدنا في هذا البحث أن معدل EC لفترة الدراسة كان 159.78 µS/cm ومعدل نسبة الحموضة 7.1 والذي يشير إلى أن الأمطار ليست حمضية في هذه المنطقة. أما بالنسبة للمحتويات

الكيميائية فقد كان توزيع احتوائها على النحو التالي: كالسيوم > صوديوم> مغنيسيوم> بوتاسيوم> امونيوم للأيونات الموجبة، و الكلور> البايكربونات> الكبريتات >النترات للأيونات السالبة.

أظهرت النتائج أن تركيز العناصر يتناقص كلما زادت كمية سقوط الأمطار أما العلاقة الخطية بين العناصر فقد أثبتت بأن أيونات الكلور والصوديوم هي من نفس المصدر، وهو مياه البحار. أما أيونات المغنيسيوم والكالسيوم فهي متفاوتة في المصدر وذلك حسب الفترة الزمنية للسنة المطرية فتارة مصدرها الأتربة المتطايرة من صحراء النقب و شمال أفريقيا وسيناء، وتارة مصدرها من مياه البحار. ووجد بأن تركيز الكلور عالٍ في هذه المنطقة، وهذا ما يتوافق مع الدراسات السابقة.

ومن هنا تم الخروج بتوصيات تتمثل بالقيام بدراسة تأثير الظروف الجوية مثل سرعة الرياح واتجاهها وأيضا درجة الحرارة على مكونات والتركيب الكيميائي للأمطار المتساقطة على المنطقة. وأخرى توصي بعمل دراسات مماثلة على بقية مناطق الضفة الغربية في محاولة لتكوين ملف متكامل عن المكونات الكيميائية لمياه الأمطار خلال الفترة الزمنية للدراسة. من جانب آخر تمت مناشدة الدول والمدن الصناعية بالالتزام قدر الإمكان بالمعايير المحددة لمستوى المواد المنبعثة في الجو.

Table of Contents

No.	Subject	Page
Chapter One : Introduction		**1**
1.1	Background	1
1.2	Problem Statement	4
1.3	Objectives	6
1.4	Hypothesis of the study	6
1.5	Study Overview	7
Chapter Two: Literature Reviews		**8**
Chapter Three : Methodology		**14**
3.1	Theoretical framework	14
3.2	Overview	15
3.3	Study area	19
3.3.1	Location	19
3.3.2	Climate and synoptic situation	20
3.4	Instruments	21
3.5	Sampling	22
3.6	Chemical analysis	22
3.7	Statistical analysis	23
3.7.1	Quality assurance	23

3.7.2 Determination of ion sources 23

Chapter Four: Results and Discussion

4.1 General characteristics of data 24

4.2 Data quality 24

4.3 Chemical analysis 26

4.3.1 Electrical Conductivity (EC) 27

4.3.2 Variation of pH 28

4.3.3 Ions contribution 30

4.3.4 Ions Concentrations 33

4.3.5 Weighted average of ion concentration 37

4.3.5.1 October 37

4.3.5.2 November 39

4.3.5.3 December 40

4.3.5.4 January 41

4.3.5.5 February 42

4.3.5.6 March 43

4.3.5.7 April 44

4.4 Determination of chemical sources 46

4.4.1 Ionic correlation 46

4.4.1.1 Na^{+}-Cl^{-} 46

4.4.1.2 SO_4^{-2}-Ca^{+2} 48

4.4.1.3 Mg^{+2}-Ca^{+2} 50

4.4.1.4 (Ca^{+2} + Mg^{+2}) –HCO_3^{-} 52

4.4.2	Correlation coefficient	54
4.4.3	Ions Ratio	56
4.4.3.1	Na^{+}/Cl^{-} ratio	56
4.4.3.2	SO_4^{-2}/Cl^{-} ratio	59
4.4.3.3	Ca^{+2}/ Cl^{-} ratio	61
4.4.3.4	Mg^{+2}/Cl^{-} ratio	63
4.4.3.5	K^{+}/Cl^{-} ratio	65

Chapter Five: Conclusions and Recommendations

5.1	Main conclusions	67
5.2	Recommendations	68

References **69**

List of Tables

Table No.	Table title	page
3.1	Types of the chemical analysis for Abu Dis Weather Station samples	23
4.1	Rain chemistry summary data for rainfall samples collected in Abu Dis Weather Station 2001-2007	27
4.2	Weighted average of ions concentrations (mg/m^2) for the period of 2001-2007	45
4.3	Correlation matrix between major ions concentration in mmole for rainwater samples for 2001-2007 at Abu Dis Weather Station	54

List of Figures

Figure No.	Figure Title	Page
1.1	Two types of automatic meteostation	3
1.2	The annual rainfall contours in Israel	4
3.1	Abu Dis Weather Station at 650 m above sea level	20
3.2	Instruments used for collection rainfall in Abu Dis Weather Station	21
4.1	Quality control of chemical analysis	25
4.2	Plot of Electrical Conductivity (μS/cm) for the samples.	28
4.3	Histogram of pH values of the precipitations	29
4.4	Contribution of individual ions in rainfall samples	32
4.5	Comparative between arithmetic mean of cations and anions concentration of the raining months during the hydrological year 2001-2002	34
4.6	Comparative between arithmetic mean of cations and anions concentration of the raining months during the hydrological year 2002-2003	34
4.7	Comparative between arithmetic mean of cations and anions concentration of the raining months during the hydrological year 2003-2004	35
4.8	Comparative between arithmetic mean of cations and anions concentration of the raining months during the hydrological year 2004-2005	35

4.9	Comparative between arithmetic mean of cations and anions concentration of the raining months during the hydrological year 2006-2007	36
4.10	Weighted Average of cations concentration in mg/m^2 in October 2001-2007	38
4.11	Weighted Average of cations concentration in mg/m^2 in November 2001-2007	39
4.12	Weighted Average of cations concentration in mg/m^2 in December 2001-2007	40
4.13	Weighted Average of cations concentration in mg/m^2 in January 2001-2007	41
4.14	Weighted average of cations concentration in mg/m^2 in February 2001-2007	42
4.15	Weighted Average of cations concentration in mg/m^2 in March 2001-2007	43
4.16	Weighted Average of cations concentration in mg/m^2 in April 2001-2007	44
4.17	Correlations between Na^+ and Cl^- in mmole in the rainfall for the period of 2001-2007, Abu Dis Weather Station	47
4.18	Correlations between SO_4^{-2} and Ca^{+2} in mmole in the rainfall for the period of 2001-2007, Abu Dis Weather Station	49
4.19	Correlations between Mg^{+2} and Ca^{+2} in mmole in the rainfall for the period of 2001-2007, Abu Dis	51
4.20	Correlations between (Ca^{+2} + Mg^{+2}) with HCO_3^- in mmole in the rainfall for the period of 2001-2007, Abu Dis	53

4.21	Comparison between the Na^+/ Cl^- ratio for the samples in the period 2001-2007 with the seawater Na^+/Cl^- value (0.86).	58
4.22	Comparison between the SO_4^{-2}/ Cl^- ratio for the samples in the period 2001-2007 with the seawater SO_4^{-2}/Cl- value (0.10).	60
4.23	Comparison between the Ca^{+2}/ Cl^- ratio for the samples in the period 2001-2007 with the seawater Ca^{+2}/Cl^- value (0.0.018)	62
4.24	Comparison between the Mg^{+2}/ Cl^- ratio for the samples in the period 2001-2007 with the seawater Mg^{+2}/Cl^- value (0.098)	64
4.25	Comparison between the K^+/ Cl^- ratio for the samples in the period 2001-2007 with the seawater K^+/Cl^- value (0.098).	66

Chapter 1

Introduction

1.1 Background

West Bank locates at the southeast corner of the Mediterranean Sea, so specific geographical and meteorological factors may establish distinct zones characterized by typical chemical rain compositions. The chemical compositions and the characteristics of aerosols and precipitation in the Mediterranean region, and also the factors affecting these compositions have been studied by many authors since 1980s. Some of them have shown that in a given rainy season the amount of rainfall increase with the latitude and elevation of the station decreases with distance from the coast (Steinberger , Yari 1996).

Precipitation, which is a major pathway of natural and anthropogenic species from atmosphere to terrestrial and oceanic ecosystem, is insurance mechanism for the removal of air borne gases and particles. These gases and particles concentrations are varies from atmosphere according to the amount of emissions, atmospheric, transformations and weather (Lettman 1991, Spanos 2002).

This area could be affected by two main sources of the particles: eolian dust transports from North Africa, and the pollution aerosol from Europe. But at the same time there are other sources which contribute and modify the chemical composition of rainfall, such as biogenic emissions, sea salt generation, and local anthropogenic emissions (Tuncer et al, 2002).

Mediterranean region locates under strong influence of pollutants transported from industrialization Europe countries. However, Israel is considered to be as industrial state (Guerzoni et al 1995). The current amount of pollutants in micrograms per cubic meter is between 60-76 in Tel Aviv and 47-51 in Hifa, some 65% above the new limit. Where in a Geneva press conference, the UP group announced it would push for a worldwide reduction of pollutants from 70 to 20 micrograms per cubic meter (Rinat, 2006).

The increasing worldwide industrialization influences the acid rain to be a serious atmospheric environmental problem. That caused by the combustion of fossil fuels during which sulfuric and nitrogen oxides are emitted into atmosphere. These acids will be deposited on to the earth's surface, so the receptor ecosystems will be acidified (Toros et al 2000).

There are many weather stations fixed in the main cities in the West Bank and Israel, which work in high specialize level to collect and analyze the data of the climate and the meteorological factors with there effects on the rainfall quantity and quality, specially chemical component. These stations are located in Jenin, Meithalun, Tulkarm, Nablus, Jericho, Jerusalem, Hebron, Al Arrup, and Gaza. The data of Jerusalem Station are estimated according to the data of an Israeli station, while Al Arrub Station is stopped working in October 1998 (Atlas, 2008).

These stations must have some characteristics like the location, which should be representative for the area where the measurements are important, taking into account: plant, soil, and climatic conditions. Also, the measuring instruments should be reliable,

solid and easy to maintain. Nevertheless, there is no standard layout for a meteorological station. Two types of automatic meteostation are presented in Fig.(1.1).

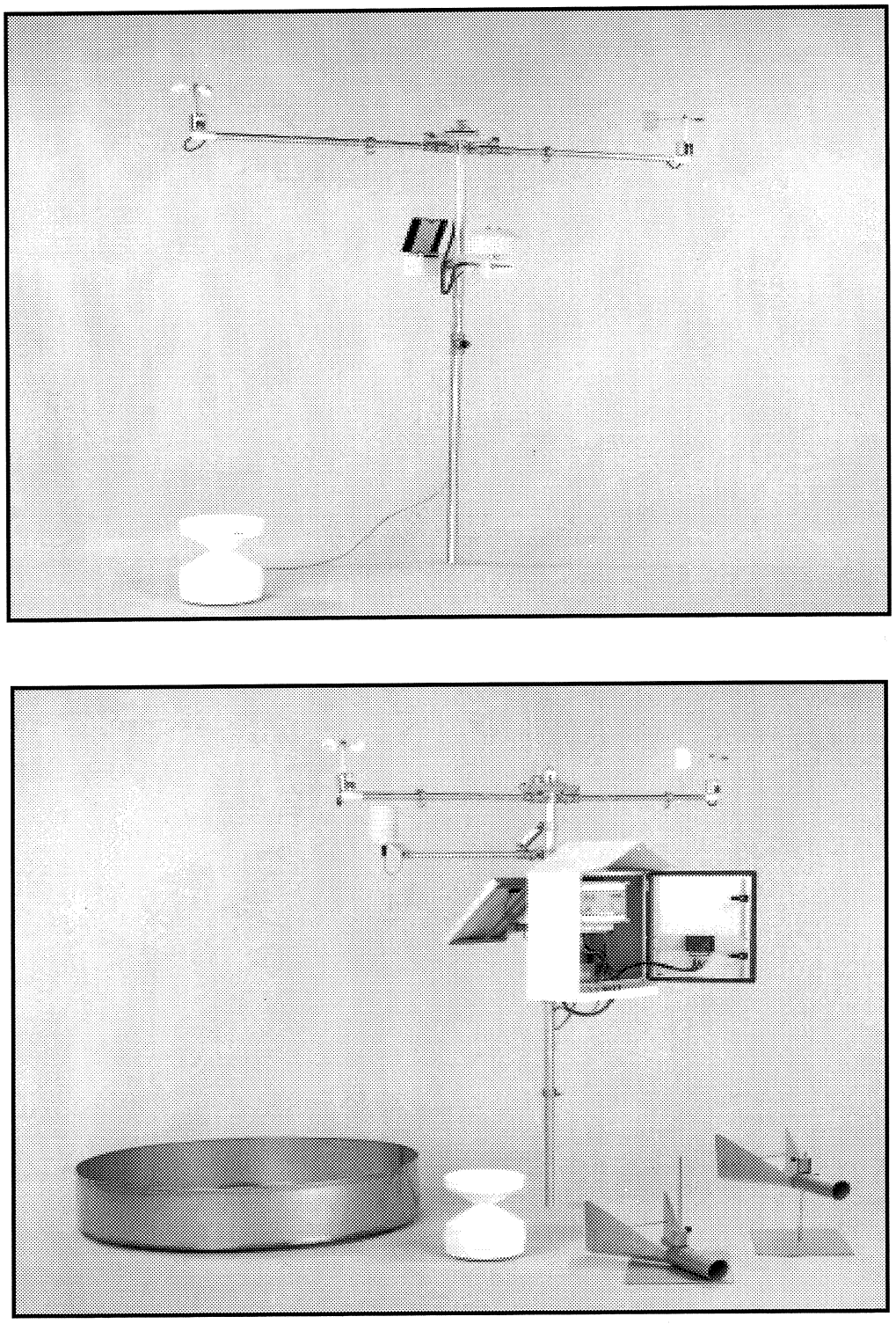


Figure 1.1: Two types of Automatic meteostation, **a-** with 8 channels, **b**- with 62 channels

1.2 Problem Statement

Water is sole of the life in general, and in our country water is the key factor for sustainable development, industry, and agriculture, which is the main source of Palestinian economy. As an area in a semi arid region, Palestine's water resources depend mostly on rainwater for ground water recharges, so the quality of the rainwater is an important factor. Palestine has different geographical sections, this geographical and meteorological situation results in extreme spatial variation of the mean annual precipitation (Fig. 1.2) (Herut et al, 2000).

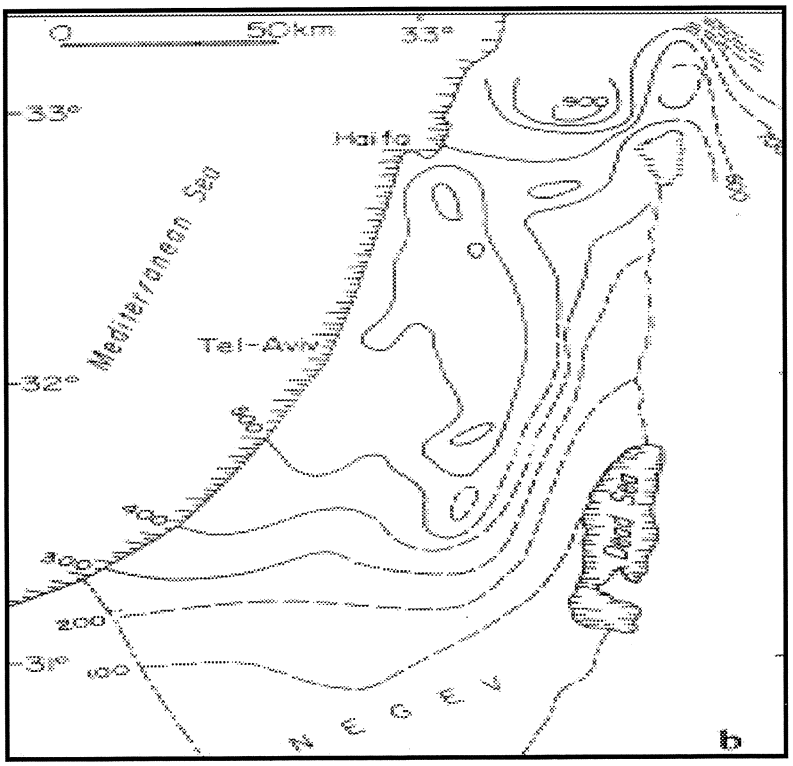


Figure 1.2: The annual rainfall contours in Israel. (Herut et al, 2000)

Yearly precipitation is critical components in the water budget of the area. The rainy season is defined as the 9-month period September-May. The total amount of rainfall during this interval is referred to as yearly or seasonal rainfall (Steinberger, Yaari 1996).

It is widely accepted that each of the major ions dissolved in groundwater originates from the three possible sources, juvenile rainwater, water-soil and water- rock interactions, and anthropogenic influences (Dafny et al 2006, Zilberbrand 1995).

Several studies describe the effect of the chemical composition on the quality of surface and groundwater. From the analysis of Golan groundwater (Dafny et al, 2006) he proof that the major ions dissolved in groundwater was originated from present rainwater according to the result of isotopes. While in the Negev, rainwater has Ca^{+2} and HCO_3^- ions dominating as well (Herut, 1994).

In contrast, in the composition of groundwater of infiltration origin the chalky sediments of the Avedate Group, the Na^+ and Cl^- are dominant (Zilberbarnd, 1995). Rosenthal (1998) they found that in western and central Negev, the saline groundwater encountered in Judea Group aquifer is derived by rock- water interaction from Karnub Group paleowater.

Both surface water and groundwater are available as water resources in the West Bank and Gaza strip. Since the occupation, Israel is forbidding the Palestinians to share them of Jordan River as a water resource. At the same time, the total annual recharge of the aquifer is estimated at 46 million cubic meters. A deficit of 50 million cubic meter/ year is observed in water balance due to over pumping (JICA, 1999). Therefore, the aquifer is replenished from the brackish or seawater, which results in a quality deterioration. As a result, many people are still suffering from water shortages, especially during the summer season.

From the previous discussion, we have to study the characteristics of the chemical composition of the rainfall that the area gets, and try from the analysis to determine the source of the ions in the rainfall. The results of the study could be helpful for other studies to understand if there is any relation between the component of the ground water and the rainfall in that station. In addition, It may be recommended to the special orientations to start with projects for collecting the rainwater in poles or artificial wells to solve the problem of water shortage.

1.3 Objectives

The general objective for this study is to evaluate the chemical composition of rainfall at Al Quds Rain gauge station- Abu Dis. In addition, there are specific objectives:

1. To evaluate the concentration of different ions in the rainfall.
2. To identify the source /s of these ions.

1.4 Hypothesis of the study

There are different hypothesis to be discussed in this study depending on these points:

- Rainfall chemistry is constant in term of different ion during the rainy seasons.
- There are different rainfall chemical composition during one rainy season, and different from one year to another.
- The chemistry of rainfall controlled through the meteorological factors (wind speed, wind direction, temperature, relative humidity, and dry weather periods).
- Each ion in the rainfall composition has one or more than one sources.
- Rainfall Chemistry depends on the trajectory sources

1.5 Study Overview

Chapter two present some of the literature reviews that are used in this thesis. Each one shows an idea or equation that could be used in the study. Some of these studies conducted in Mediterranean region discuss the chemical characteristics of wet deposition. Furthermore, the ion sources and ion ratios importance are showed in that region. Theoretical framework is given in the third chapter by discussing practical and theoretical works. Location of sampling station, sampling method, instrumentation, collection the data and analytical techniques that used are presented in the fourth chapter. The results are extensively discussed in chapter five. Data quality assurance, the characterization of rain chemistry in Abu Dis Weather Station are presented, relationships are established between the concentration of major ions, and the effects of wind direction on the composition are interpreted a function of the position of local and distant emission sources.

Chapter Two

Literature Review

The studies deal and work different issues, like the ratio between the ions, the source of that ions and how become as component of the rainwater, the effect of the geography and meteorological factors on the composition, also relationship of rainwater and groundwater component.

Artaxo (2005) described the relationship between biogenic emissions from forests of Amazon and the concentration of organic acids in rainwater and aerosols, and addressed how the anthropogenic activities are changing the concentration and deposition patterns of organic acids, carbon, and nitrogen there.

Mouli (2005) the results show that in India , soil has been considered as a major contribution of the particulate in the atmosphere owing to its dusty nature. In Indian context, both the rainwater and aerosols are mostly alkaline, which is due to low contribution of secondary aerosols SO_4^{-2} and NO_3^{-} from anthropogenic sources and high contribution of primary aerosols Ca^{+2}, K^{+} and Mg^{+2} from soil.

Bruggemann (2005) found that the nitrate and ammonium concentration in precipitation remained roughly stable, whereas the NO_x ammonia emissions were reduced by shutdown of older industrial and agricultural facilities.

Kocak (2005) found that the total dry deposition fluxes were dominate for Al, Cu, Pb where as for Zn and Cd the wet deposition fluxes are likely to dominate.

Al-Khashman (2005) found in his study that the concentration of heavy metals (Cd, Cu, Pb, Fe, Ni, Zn) that were determined in the rainwater samples were relatively low. Anthropogenic activities were the main source of trace metals in rainwater samples.

Aiuppa (2003) suggested that volcanic activity may modify the natural atmospheric fluxes of chemicals, and may have a strong impact on the local environment. Mt. Etna, the biggest volcano in Europe, is producing continuous degassing from the central craters. The study shows that the Etnean plume, which affect on the local atmosphere, continuously releases volatiles species such as S, Cl, and F.

Hu (2003) shows that local meteorological conditions influence the chemical composition to a significant extent. The pollutants in rainwater were derived from long rang and local industry and traffic sources.

Zunkel (2003) found by the statistical analysis that the rain chemistry in that area is influenced by a combination of sources. These include terrigenous, agricultural, marine and biomass burning.

Herut (2001) found in his work, long-term measurements of particulate atmospheric trace metals were carried out at two coastal sites in order to estimate the fluxes to the coast and to identify their sources.

Mosley (2001) have attempted to define the atmospheric deposition of natural trace metals (Al, Fe,Mn,Cr) and anthropogenic trace metals (Cd, Cu, Pb, Zn) to open ocean and coastal seas .

Tuncer (2001) found that the rainwater in the Mediterranean region is not acidic, because the most important characteristic of precipitation in the region is extensive neutralization of acidity, particularly by $CaCO_3$, which originates from calcareous soil in North Africa, Middle East and along the coasts of the Mediterranean Sea. In there study there was unexpected high concentration of anthropogenic ions in the precipitation at the Central Anatolia which were probably due to transport of pollutants from distant source regions.

Al- Mommani (2000) presented the volume weighed average pH, which were 6.4. High pH value in precipitation samples were attributes to neutralization processes. Results suggested that $CaCO_3$ is the main neutralizing agent and the role of NH_3 in the neutralization process is very small. The study pointed out that the precipitation at Irbid is greatly influenced by natural sources rather than anthropogenic.

Herut (2000) suggested that the higher continental components at the southern regions were related to two main factors: - first; westerly winds in south contain more desert dust, second; the deposition and removal (by rain) of large fractions of the dust in the south. The air trajectory has a dominant westerly component, which brings air from the Mediterranean Sea to north and central Israel, and the westerly wind in the south Israel has a continental trajectory over Sinai and North African deserts. In addition, Na/Cl ratio of the rainwater samples is similar to that of seawater indicating a clear marine origin of there in most rain events. $(Sr/Ca)_{nss}$ ratio indicated the dominance of chalky dust transported from the southern deserts, North Africa, Sinai, and Negev

Fillion (1999) proofed that the natural neutralization reactions can occur both in the cloud droplets and in rain droplets. In the clouds, bases have to be incorporated in cloud droplets which can occur during the transport of cloud from source to receptor site and bases are available everywhere. While in the rain, it is locale process involve basic substances that are available at the receptor region.

Al-Momani (1998) presented from chemical analysis, the ratio H^+ / (SO_4^{-2} + NO_3^{-1}) ratio is high in winter season and low during summer, due to high $CaCO_3$ concentration in atmosphere during dry summer period

Hara (1998) deal with the definition of acidity, that most public attention has been focused on the acidity of rainwater in terms of pH because the term "acid rain" has been widely spread among the public. More correctly, this should be described as "acid deposition", for it refers to the deposition of acidic materials in rain, snow and fog and directly from the air on to various terrestrial ecosystem elements such as foliage.

Rosenthal (1998) found the sources of $Ca^{+2}$and SO_4^{-2} are less clearly defined. Three processes can account for the origin of dissolved $CaSO_4$ in rainwater: 1) neutralization reaction, 2) dissolution of gypsum or anhydrite, 3) crystallization of gypsum in the atmosphere following evaporation of sea spray and consequent separation

Littmann (1997) describe the ratio of atmospheric and biogenic nitrogen inputs many widely in different environments. For example in a rocky desert ecosystem at Sede Boqer in the Negev nitrogen flux analysis showed about 90% of total nitrogen to come from atmosphere deposition .

Leviy (1996) observed that the concentration of continental components dissolved in rainwater increases by about an order of magnitude from northern to southern Israel. High values in ice nuclei, total suspended particles, and continental origin matter dissolved in rainwater were coincident with geographic location and synoptic conditions that are indicative of the presence of desert dust.

Herut (1994) suggested that each ratio had its meaning according to the ions, location, and the source. Sulfate is a major component of rainwater and amount of sea spray sulfate in the rain can be estimated from the Cl/SO_4 (or Na/SO_4) ratios in seawater and the measured concentration of Cl (or Na) in the rain or in aqueous extracts from aerosols. The influence of the geographic origin on the chemical composition of the rain was assessed by the comparison of parameters that were related to marine, terrestrial (dust), and anthropogenic sources. The sources of none sea spray (NSS) sulfate are either anthropogenic sulfur dioxide originating from oil and fossil fuel combustion, or natural biogenic reduce sulfur gases

Khwaja (1990) found that the concentration of species in precipitation depend on various factors such as: - 1) Natural and anthropogenic sources, 2) Amounts of chemical present in the atmosphere, 3) Physical and chemical transformation in the atmosphere that lead to deposition. On the other hand, free acidity in precipitation results from strong mineral acids (H_2SO_4, HNO_3, HCl), or weak organic acids (formic, acetic, oxalic), and the changes of acidity of precipitation were mainly influenced by the changes of main ionic components as sulphate, nitrate, calcium, and ammonium. Major neutralization cations for these acids were NH_4^+ and Ca^{+2} Also seasonal variations in precipitation chemistry were observed, SO_4^{-2} peaked in summer and spring, and bottomed out in the winter.

Fay (1989) observed that the concentration of SO_4^{-2} and NO_3^- are fluctuating from year-to-year about a mean value. Therefore, he assumed that these fluctuations are probably caused by variable meteorological factors, such as the frequency and direction of storm tracks and the yearly precipitation amount.

Chapter Three

Methodology

3.1 Theoretical Framework

The rainwater composition results from two series of mechanisms operating consecutively. First, "rain out": 1- condensation of vapor on aerosol to form cloud droplets, 2-attachment of aerosol particles to the cloud element, 3- incorporation of gases. Second, "washout": carrying and dissolving particles and gases along their fall (Andre, 2007).

In another study (Ayalon et al, 1998), they observed that the lowest isotopic compositions are associated with the most intense rain events, and the more isotopically enriched rains mostly occur during the early and late rainy season, whereas the most depleted values are associated with the peaked of the rainy season.

The pH level and the concentration of major ions Ca^{+2} ,Na^{+} ,Mg^{+2} ,K^{+} dissolved reactive phosphorous, and nitrate generally decreased during storm flows as a result of dilution by rainwater (Mosley, Peake 2001).

In deferent studies, the concentration of measurement ions shows both short-term (episodic) and long- term (seasonal) variations. Episodes in the concentrations of crustal ions, such as Ca^{+2}, Mg^{+2}, and K^{+} are due to episodic nature of the wind speed, which resuspend soil particles into atmosphere.

Meteorological conditions affects on concentrations. The wind speed and wind direction before and during raining periods and the precipitation events, would rather determine the origin of the air masses associated with cloud formation and therefore, the droplets composition from rainout process (Baez 2006, Asaf 2005, Herut 2000, Pio 1991).
These main ideas are the basics of our research to analysis, comparatives, and discussions.

3.2 Overview

The literature reviews present different procedures of sampling, chemical analysis, and statistical analysis. In this chapter, some of these techniques will be presented.

The rain samples were collected following the World Meteorological Organization (WMO) and United Nation Environmental Program (UNEP) protocols. Herut (2000) collected the rainwater in laboratory graded funnel bottle samplers (25 cm diameter) at an elevation of at least 100 cm above ground level. The samples were operated manually quickly as possible after the onset of rainfall avoid excessive contamination. (Marques et al, 2006) their equipment was constituted of a polypropylene funnel with diameter of 27 cm connected for an inert tube to polypropylene bottle with capacity for 5,6 liters forbidden with inert silica. The system is previously washed with deionizer water, before each use preventing contamination.

For the trace metal the total suspended particles (TSP) in air, were collected by high-volume samplers, and was carried out on four occasions during special meteorological conditions of "Hamsins" characterized by the influences of air masses from the southern desert (Herut et al, 2000).

Chemical analysis of rainwater samples was performed by standard spectrometric methods: Ca^{+2} , Mg^{+2} , SO_4^{-2} as (S) were analyzed by Inductively coupled plasma (ICP), Na^+, K^+ by Atomic absorption spectrophotometer (AA), Cl^-, NO_3^- by Ion Chromatography, HCO_3^- Potentiometric Gran titration with hydrochloric acid, pH was determined using a Metrohm pH meter.

For trace metals, analyses of Cd, Pb, Cu, Zn, Cr, Mn, Fe, Al, Ca, and Na in TSP are carried out after total digestion with HF, and then the digested samples were diluted to volume by double- distilled water. The concentrations are measured on atomic absorption spectrometer (AAS) and graphic furnace (GFAAS) (Kocak 2005, Herut et al 2000). Mosley (2001) worked the "Clean" technique are used to minimize contamination during sampling and analysis. Water samples are collected in 1-Liter polypropylene bottles dialed in special way. The nitric acid digestion used, and then the concentrations were analyzed by using (GFAAS).

The source regions of, SO_4^{-2} , NO_3^- which represent the anthropogenic component in the precipitation at the central Anatolia were investigated using the "Potential Source Contribution Function" PSCF, and measured by ion chromatography (Tuncer et al 2001). While SO_4^{-2} was analyzed using the methyl thymol blue (MTB) method by Dillon (1988). Marques et al (2006) analyzed the NO_3^- in their work, each samples had been submitted to quantified nitrate using procedures of Standard Methods through spectrophotometer UV. While Dillon (1988) used the azo dye colorimetric method following reduction with Cd, and hydrazine reduction was employed.

Aliquots were stored at -25 C for determination of the major ions. Na^+, K^+ were analyzed by flame emission, Ca^{+2}, Mg^{+2} were analyzed by atomic absorption spectrometry, SO_4^{-2} and NO_3^- and Cl^- by ion chromatography, NH_4^+ by flow injection analysis and gas diffusion. Then the result was checked by a cation-anion balance and by the comparison of the measured electric conductivity with conductivity calculated from the concentration of all ions (Avila 1996).

For use in trend analyses, weekly precipitation and chemistry observations from each National Atmospheric Deposition Program/ National Trends Network (NADP/NTN) site were accumulated into bimonthly precipitation totals and volume-weighted mean concentrations of cations and anions (Lynch, 1995). The wet deposition samples were collected on an event basis using Aerochem Metrics model 30 samplers with a Belfort recording rain gauge and an event marker (Khwaja, 1990). The Austrian precipitation-sampling network in equipped with the wet and dry only precipitation sampler (WADOS) (Puxbaum et al, 1997).

Herut et al (2000) were recognized on two main steps. First, mean chemical values were calculated for each station in which more than one sample was collected on a given date. Second, the mean chemical compositions for each region (average of all stations within the region) at a given date were calculated. Miller (1981) applied the Student-Newman-Keuls (SNK) test for multi-pair comparison, in case to test the geographical effect on the rainwater chemical composition in his work.

The correlation analysis was made using Minitab Software version 13.2 and the Volume-weighted Mean (VWM) for the pH by (Marques et al, 2006). Also Herut et al (2000) used

a Linear multi-variant model (SAS software) to predict the regional and wind direction effects on the rainwater chemical composition, and the comparison between chemical composition of rains associated with different wind direction classes was tested by the non-parametric Wilcoxson Procedure.

For the trace metal, Mosley (2001) used non-parametric statistical testes (spearman rank-order correlations), in addition median values of storm water concentrations were reported instead of means. Khawaja (1990) designed a matrix of correlation coefficient among different chemical components in precipitation. While Puxbaum et al (1998) used statistics for least-squares linear regression of ion concentrations Vs time.

The concentrations of species precipitation depend on various factors such as natural an anthropogenic sources, amounts of chemical present in the atmosphere, meteorological factors (wind speed, wind direction, amount of precipitation), and physical and chemical transformations in the atmosphere that lead to deposition.

Marques et al (2006) designed a matrix correlation between the variable (pH, NO_3^- concentration, EC, T_{rain} , precipitation volume, wind direction) verify that exist a significant negative correlation between pH and NO_3^- values of (-0.97) where how much bigger the concentration of NO_3^- the pH value will be lesser rain is more acid.

In most, the rains Cl^- and Na showed approximate marine ratios. Herut et al (2000) found that the (Na^+/ Cl^-) ratios in water soluble fraction of dust from the Negev Desert is lower than the marine ratio, and the (Ca^{+2}/ Cl^-) ratio may be used as the most significant indicator

for continental / marine ratio. The $(Sr /Ca)_{nss}$ ratio may be used as a signature of the calcium minerals dissolved by the rain

Another study made (SO_4^{-2} /NO_3^-) equivalent ratio which indicated the form of acidity in precipitation, and the result indicated that the acidity transported to the Central Anatolia was primarily in the form of H_2SO_4 rather than HNO_3 (Tuncer et al, 2001).

On the other hand Dillon et al (1988) found that the (SO_4^{-2} /NO_3^-) ratio decreased significantly, suggesting that, although NO_3^- concentration in precipitation has not increased, NO_3^- is becoming a more important contributor to the acid anion content of precipitation.

Equivalent ratio of (H^+) / (SO_4^{-2} + NO_3^-) provides information on the magnitude of neutralization of rainwater acidity (Hara 1998, Tuncer et al 2001). There were eight distinct weather regimes in the area study and the results indicated significant variability in meteorological parameters / indicators on a year- to- year basic (Dillon, 1988).

3.3 Study area

3.3.1. Location:

Abu Dis Weather Station locates at Abu Dis University roof with coordinates of 31° 45́ 22˝ N and 35 ° 15́ 39˝ E (Palestineremembered, 2008). The average elevation of Abu Dis city is 630 m a.s.l, While the station is about 650 m. Fig.(3.1) shows the station .



Figure 3.1: Abu Dis Weather Station at 650 m above sea level.

3.3.2 Climate and synoptic situations:

Abu Dis climate is related to Israel climate. With exception of Negev Desert, Israel has a Mediterranean climate characterized by a rainy winter season and a dry summer season. The rainy season occurs between October and May, the main months being December, January, and February (Levin, 1999). Winter in Israel is characterized by passing Cyprus Cyclones. In summer, it is under the Persian Gulf trough. On the other hand, spring and autumn have two main types of winds. First, Sharv Cyclone: which moves quickly a long the North African Shores. The second is The Red Sea trough, which extend from the Red Sea toward the north (Goldrecich 1995, Saaroni 2000, Kahana et al 2002).

3.4 Instruments

The Weather Station (Fig. 3.1) is designed from Eijkelkamp- Agrisearch Equipment Company, is used to collect data according to the sensors it has. The pH is measured by using pH-meter by WTW Company, while the EC is measured by EC-meter from the same company. The spectrophotometer, which is used, is HACH type. The rainfall amount is measured by using the mechanical precipitation recorder (Fig.3.2.a). The porcelain sampler container for rainfall which used for chemical analysis is presented in Fig.(3.2.b).

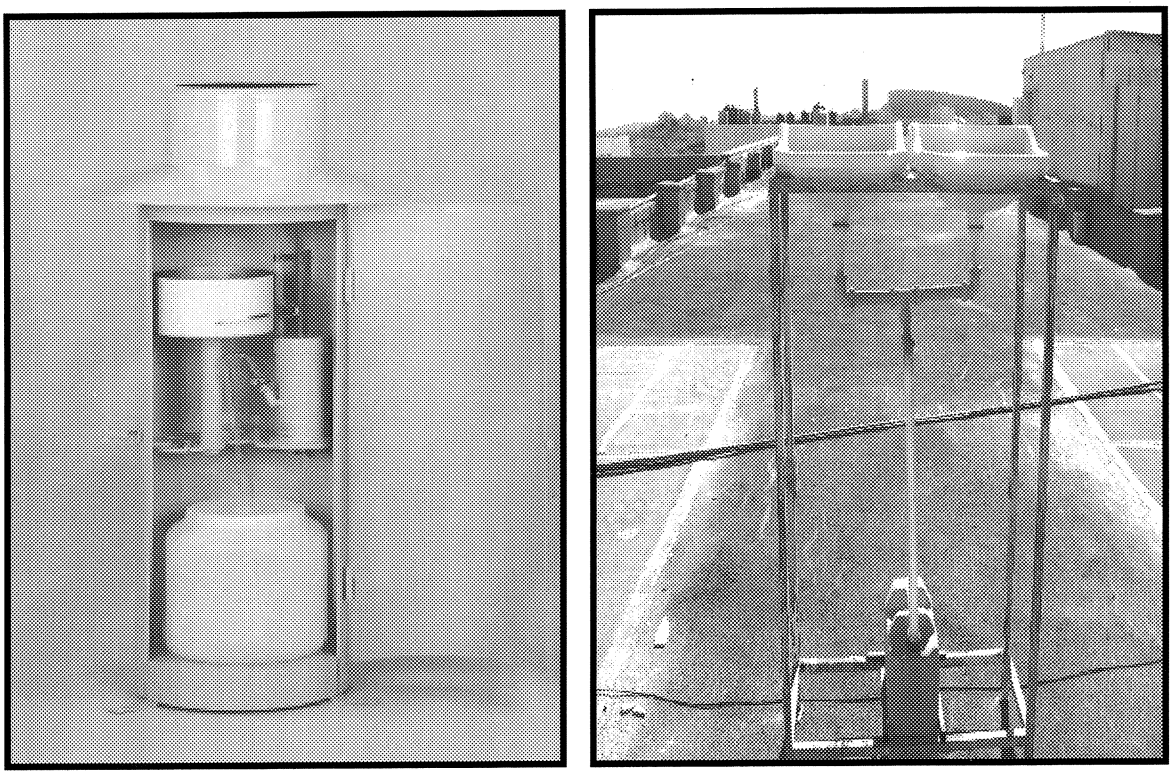


Figure 3.2: Instruments used for collection rainfall in Abu Dis Weather Station

a- The mechanical precipitation recorder using in the search.

b- The porcelain sampler container, Abu Dis Weather Station.

3.5 Sampling

For this research, the samples are collected by two porcelain poles placed on roof (top) of the building 650m (above sea level). The samples are taken for each storm.

The poles and the polypropylene collectors are washed by demonized water to prevent contamination. Then the collected rainwater is divided in smaller and clean polyethylene bottles. These samples are prepared for chemical analysis immediately, so nothing is added to the bottles.

The pH value, Temperature, and Electrical Conductivity (EC) are measured immediately. If the samples will be stored, HCl or HNO_3 is added to the sample and are stored in a refrigerator at 4 ° C.

The station has different sensors like radiation, rainfall, wind direction, and wind speed sensors. The data logger designed to take a result each 10 min, so to take the result for each storm the average of radiation, wind direction, and wind speed have been taken, while the result of rainfall rate is accumulative in the logger. These data retrieved from the data logger with laptop and processed in the office (Eijlkelkamp Hog Viewer).

3.6 Chemical analysis

For this research, Ca^{+2}, Mg^{+2}, HCO_3^-, Cl^-, NH_4^+, NO_3^-, SO_4^{-2}, and PO_4^{-3} are analyzed in the laboratory according to the type of analysis in Table (4.1).

Table 3.1: Types of the chemical analysis for Abu Dis Weather Station samples.

Parameter	Type of Analysis
Ca^{+2}, Mg^{+2}, HCO_3^-, Cl^-	Titration
NO_3^-,SO_4^{-2}, PO_4^{-3}, NH_4^+	Spectrophotometer (HACH)
p-H value	pH- meter
Electrical Conductivity	EC-meter

3.7- Statistical analysis

3.7.1 Quality assurance:

Two methods are used to check data quality and exclude samples that are questionable. Cation-Anion balance and Calculated EC-Measured EC are compared to gather as linear relationship

3.7.2 Determination of ion sources:

Correlation matrix is designed between the major ions, and resulted coefficient factor suggests the sharing of the source of that ions. In addition, weighted average concentrations of ions are calculated to study the influence of rainfall amount on the concentration of ions.

Chapter Four

Results and Discussion

4.1 General characteristics of data

One hundred twenty two (122) rainwater samples have been studied for the period between October 2001 and May 2007, with missing data for the hydrological year 2005-2006. The work team in the Water and Environment Research Laboratory at Al-Quds University collected these samples. These samples represent most of rainfall events at Abu Dis Weather Station.

The pH, electrical conductivity, and temperature are measured directly after collecting the samples. These samples were analyzed for its chemical constituents for the following concentration of (Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}, NH_4^{+}, Cl^{-}, NO_3^{-},SO_4^{-}, HNO_3^{-}, PO_4^{-3}), Table (3.1) presents methods are used. The volume weighted, arithmetic average, arithmetic mean, standard deviation, minimum and maximum values are calculated for the samples and presented in Table (4.1).

4.2 Data quality

The quality of the data is checked by cation-anion balance method, where the error should be les than 5%. That result is compared with the strength of the relationship between the measured electric conductivity EC_{mes} (µS/cm) and calculated conductivity EC_{cal} from the concentration of all measured ions.

The ratio of total anions to the total of cations (∑anions/∑ cations) is an indicator of the completeness of measured parameters. If all major anions and cations are included in the measurement, the ratio is expected to be unity. Deviation from unity indicates the exclusion of some ions (Al-Momani, 2000). These relations have fixed in Fig.(4.1) for the all research data.

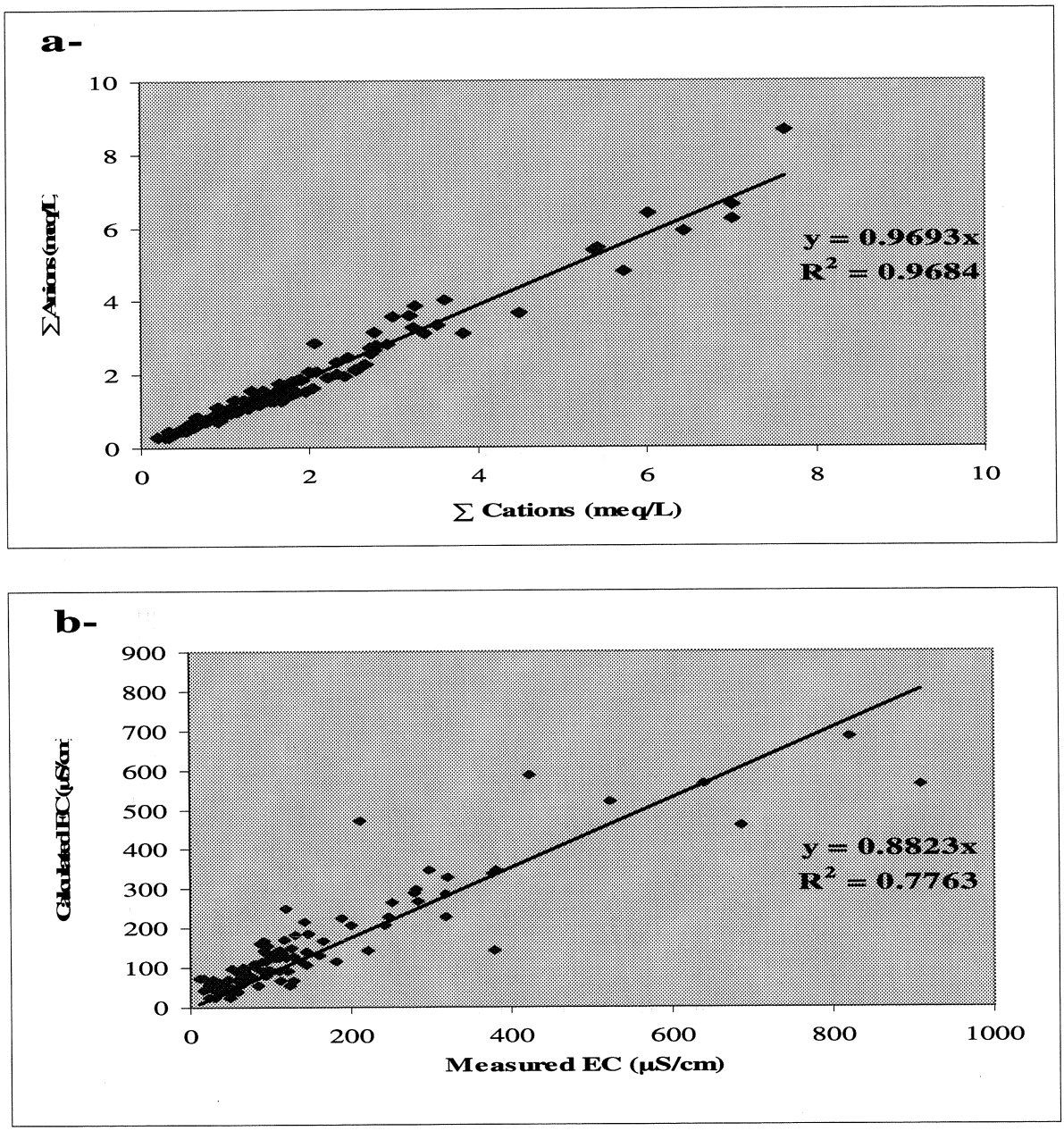


Figure 4.1: Quality control of chemical analysis for (a) the sum of cations vs. the sum of anions and (b) the calculated conductivity vs. the measured conductivity.

Fig. (4.1.a) presents the relationship between the sum of anions and cations in (meq/L), the strength of this linear relation R^2 is about 0.96 between ionic sums indicated good quality of data. Moreover, the average of anion / cation ratio is equal to 0.97. Fig. (4.1.b) shows relationship between the measured conductivity with calculated conductivity in (μS/cm), where the calculated conductivity values calculated by using equation (4.1):

$$EC_{cal} = TDS * 0.63 \qquad \text{(Eq. 4.1)}$$

where EC_{cal} is the calculated electrical conductivity in (μS/cm), and TDS is total dissolve solids in mg/L, and 0.63 is conversion factor. From Fig. (4.1.b), the relation between the calculated EC and measured EC is very good one depending on R^2 value which is 0.77, that means that the data were controlled in high percent. This means that the data, which we deal, were being controlled in high percent. However, the little difference between the R^2 values between Fig. (4.1.a) and Fig. (4.1.b) is because some samples are not analyzed, which affects on the calculated EC.

4.3 Chemical analysis

Table (4.1) presents the arithmetic average value of the measured parameters; pH, EC, and rainfall amount. The average of EC is 159.78 (μS/cm), where the minimum value is 11.64 μS/cm recorded after long rain days with short dry days. On the other hand, the maximum value is 1387(μS/cm), which recorded in the first rain event in 2003-2004 that means after long dry events. In addition, the average of pH is 7.1, which is neutral value, and the minimum value 5.98 is still over the pH of rainwater (5.6). The average of rainfall is 19.85 mm that is lower than the average that recorded in Hifa (Mamane & Gottlieb 1995).

Table 4.1: Rain chemistry summary data for rainfall samples collected in Abu Dis weather station (2001-2007)

Variable	Average	Standard deviation	Minimum	Maximum
EC µS/cm	159.78	212.94	11.64	1387
pH	7.10	0.42	5.98	8.36
Rain amount (mm)	19.85	36.52	0.02	320.40
Cl^- (meq/L)	0.71	0.81	0.00	4.66
NO_3^-	0.12	0.18	0.00	1.71
SO_4^{-2}	0.24	0.26	0.00	1.54
HCO_3^-	0.65	0.75	0.00	7.40
Na^+	0.46	0.63	0.00	3.28
K^+	0.03	0.07	0.00	0.61
Ca^{+2}	0.81	0.77	0.00	6.31
Mg^{+2}	0.44	0.55	0.00	2.43
NH_4^+	0.06	0.05	0.00	0.19

4.3.1 Electrical Conductivity (EC):

The highest EC value during the period 2001-2007 is 1387 µS/cm, which measured on 28 October 2003 as the first rain event in that hydrological year. The lowest value is 11.64 µS/cm, which measured on 16 December 2002.

In Fig. (4.2), it is clear that there are two main groups of EC values because there are two groups of high and low total dissolve solutes (TDS). First group presents the high EC values such as points a, b, and c. These values are the first rain events in the hydrological year, other are measured as rain events after long period of dry days. That because of the large amounts of dust can be accumulated in the atmosphere and washed out by rain

(Jsratat et al, 1999). Second group ranged between 11.64 μS/cm to reach around 400 μS/cm. These values present rain events during the middle of the hydrological year.

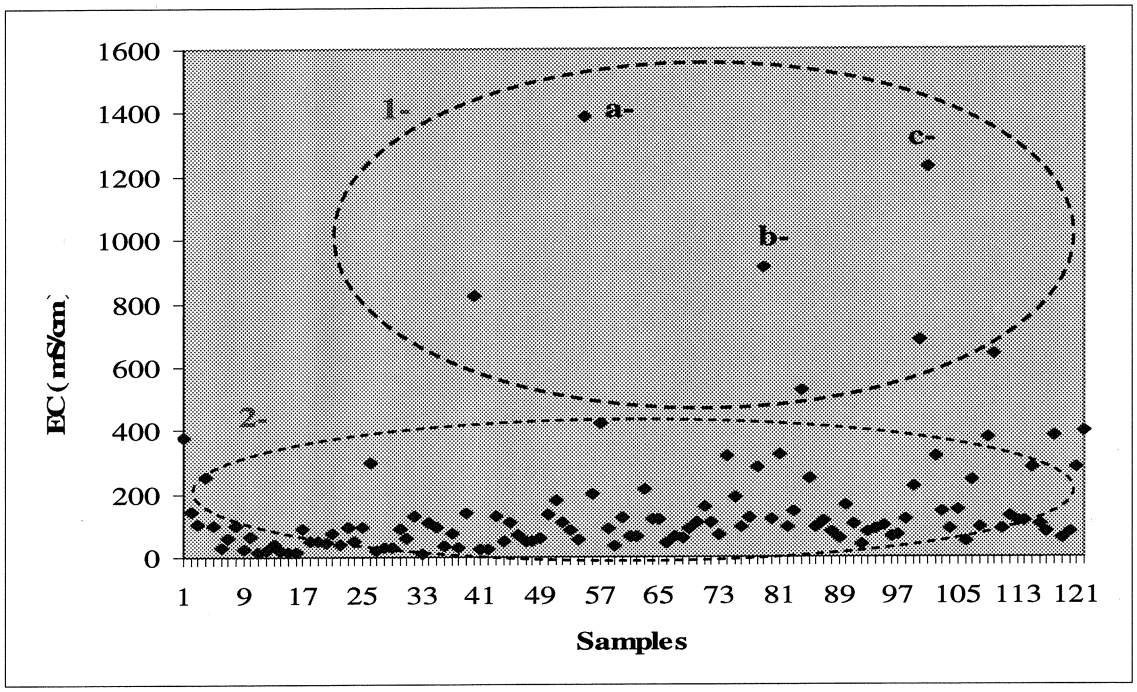


Figure 4.2: Plot of Electrical Conductivity (μS/cm) for the samples of Abu Dis Weather Station for the period of 2001-2007.

4.3.2 Variation of pH:-

Acid precipitation is an efficient removal mechanism of acidic substances such as sulfuric and nitric acids from atmosphere by wet deposition (Losn et al, 1991). pH of precipitation is a consequence of acid-base balances of chemical species from the incorporation of atmospheric gases and aerosols by in-cloud and sub-cloud scavenging (Khwaja, 1990).

The frequency distribution of pH is illustrated in Fig. (4.3). pH-values for individual rainfall events, ranged between 5.98 and 8.36 with an average value of 7.1 (Table 4.1). The

highest value 8.36 is measured on 23 November 2004, while the lowest value is 5.98 and measured on 10 December 2002.

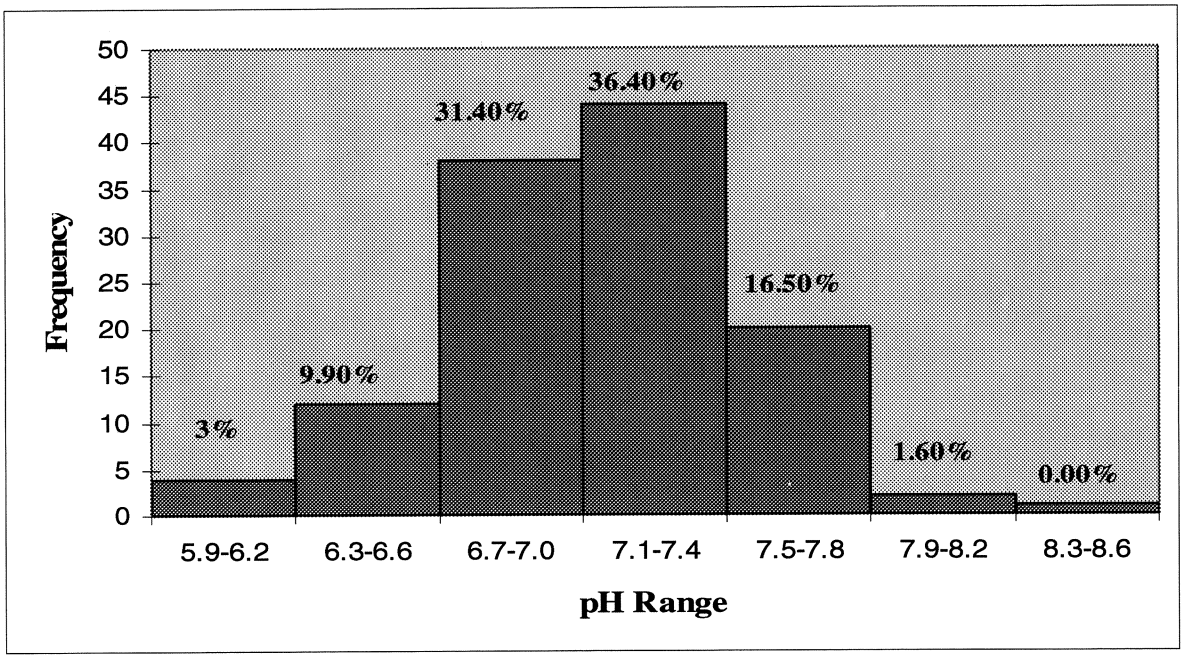


Figure 4.3: Histogram of pH values of the precipitation in Abu Dis Weather station for the period of (2001-2007).

Fig. (4.3) present the pH value for each individual sample for 122 samples, with an interval of 0.3. The (7.1-7.4) interval presents the highest percent (36.4%) of the total samples. On the other hand, the lowest percent is presented in the interval (8.3-8.6), which reaches (0.008%). The majority of pH-values (84.3%) ranged between 6.7 and 7.8, which means that the rainfall is not acidic. Only 12.9% of the samples could be considering light acid from 5.9 to 6.6. Only 1.6% of the samples locate in the basic field. All the precipitation samples have pH-value is more basic than the pH value of 5.6 corresponding to rainwater (Charlson &Rhode 1982).

The pH-value of rain control by two factors, first is the abundance of acid forming ions such as SO_4^{2} and NO_3^{-}, second is the abundance of neutralizing ions such as NH_4^{+} from NH_3 and Ca^{+2} from $CaCO_3$ (Isikdemir, 2006). The main sources of NH_3 in precipitation are fertilizer applications or emissions from barns. Fertilizer application could be the main source for neutralization in Europe. However, $CaCO_3$ is more affective in neutralization in the eastern Mediterranean. That caused by the local soil and incursions of Saharan dust (Al-Momani et al, 1997). Therefore, the pH value of the rainfall is affected by the relative abundance of these acidic and basic species, and their reaction in the atmosphere. As the pH values here are relatively high, extent of the neutralization reactions in the atmosphere is determined by computing the neutralization factors (NFs) for the alkaline species following Equation (4.2) (Singh et al, 2006)

$$NF_{xi} = X_i / (SO_4^{-2} + NO_3^{-}) \qquad \text{(Eq. 4.2)}$$

where Xi is the chemical species expressed in μeq/L. According to our result, the NF_{Ca}, NF_{Mg} and NF_{NH4} are 2.25, 1.2, and 0.16 respectively. From this point, it could be noted that Ca^{+2} has the highest share of neutralizing factor, which means that crustal component participating effectively in neutralization of precipitation acidity.

4.3.3 Ions Contribution:

Table (4.1) is evident that the average relative abundance of various ionic species (meq/L) in precipitation is $Ca^{+2} > Na^{+} > Mg^{+2} > K^{+} > NH_4^{+}$ for cations, and $Cl^{-} > HCO_3^{-} > SO_4^{-2} > NO_3^{-}$ for anions.

The mean percent contributions of individual cations in precipitation are presented in Fig.(4.4). It is to noticed that Ca^{+2} contribute to about 46% of the total cationic strength (Fig. 4.4.a), whereas among the anions, Cl^- made up about 41% of the total anionic strength (Fig. 4.4.b). The overall mean ionic representation is in Fig. (4.4.c), which presents that Ca^{+2} contributes is the highest (23%) followed by Cl^- (20%), then HCO_3^- (18%).

These results are compared to results of other conducted in different area in Israel. Mamane, 1995 in his study for Hifa chemical composition of rainwater found that the order of cations is $Na^+ > Ca^{+2} > Mg^{+2} > K^+ > NH_4^+$ and for anions is $Cl^- > SO_4^{-2} > HCO_3^- > NO_3^-$. Asaf, 2005 who take Ashdod , which is industrial city in Israel as a case study, and found that $Cl^- > SO_4^{-2} > HCO_3^- > NO_3^-$ and $Na^+ > Ca^{+2} > K^+ > Mg^{+2} > NH_4^+$. Both studies were taken place on costal area of the Mediterranean, which explain why Cl^- and Na^+ are the dominants ions. Herut B, 2000, found that the abundance of ions in southern Israel is $Ca^{+2} > Na^+ > Mg^{+2} > K^+$ and $HCO_3^- > Cl^- > SO_4^{-2} > NO_3^-$, where Ca^{+2} and HCO_3^- were dominated.

The results of this study show that the high concentrations (0.65 meq/L) of bicarbonate and calcium of (0.81 meq/L). This related to the dissolution of carbonate for main minerals such as limestone $CaCO_3$, dolomite $CaMg(HCO_3)_2$, and gypsum $CaSO_4.2H_2O$, that originate from the terrestrial system and prevailing in atmospheric dust derived from the Negev, Sinai, and mountain edges (Herut 2000, Asaf 2005, Loye-Pilot 1986, Levien 2005, Kubilay et al 2000).

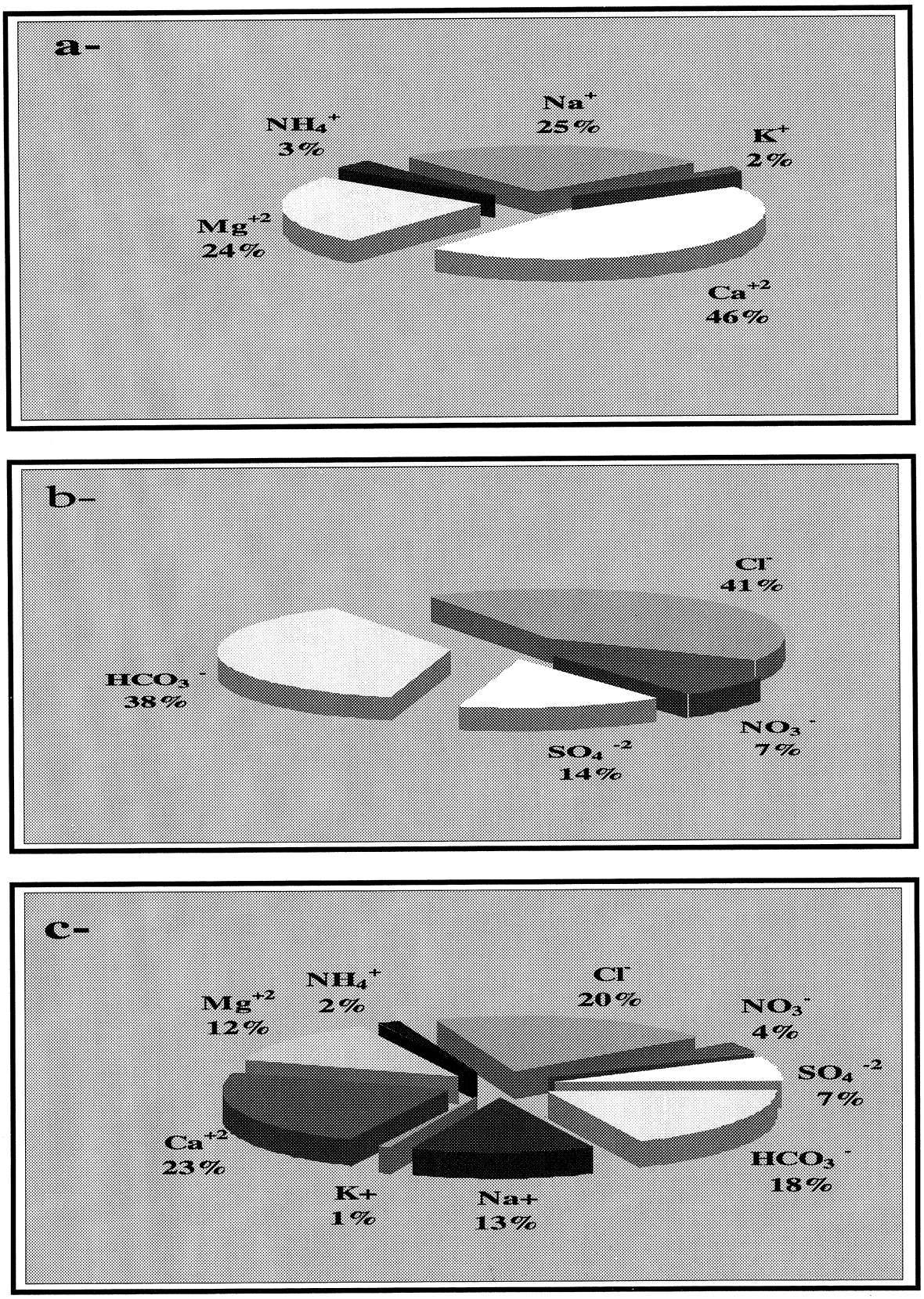


Figure 4.4: Contribution of individual ions in rainfall samples for the period of 2001-2007 at Abu Dis Weather Station.

4.3.4 Ions Concentration:

Figures (4.5), (4.6), (4.7), (4.8), and (4.9) present a comparative between the arithmetic average concentration of major cations Ca^{+2}, Na^{+}, Mg^{+2}, and K^{+} and major anions Cl^{-}, SO_4^{-2}, HCO_3^{-}, and NO_3^{-}. The concentration of these ions is in (meq/L). To compare the different concentrations with rainfall, each graph has a bar represent the rainfall intensity (mm). These graphs represent a hydrological year starting from October and end on May. Fig. (4.5), is clearly present that the largest value of Ca^{+2} 1.2 meq/L is in November 2001, and in May 2002 where both months have fall rainfall and both months represent the beginning and the end of winter season. The lowest Ca^{+2} concentration is during December 2001 until April 2002. In January the Ca^{+2} concentration is 0.3 meq/L, while the rainfall amount reach 217.8 mm. In contrast, with low rainfall- like October 2001 and May 2002, the Ca^{+2} concentration is high. This means that the concentrations of ions are controlled by the "wash out" effect. That means during the summer, the atmosphere is full of ions, particles, and dusts, when the rainfalls start these ions will be washed particularly from the atmosphere. Figure (4.6) represent the Ca^{+2} concentration for October 2001 and April 2002 were 1.2 and 1.0 meq/L respectively. On contrast, these concentrations 0.3, 0.5 meq/L are measured in February and March respectively. This could be caused by the number of dry days and the type of winds that affected the concentration of ions according to the total sources.

The relationship between rainfall and ion concentration, through the same hydrological year conclude that when the rainfall increase, the concentration of ions decrease because of atmospheric washing. This relation is applied to all samples that collected, as shown in Figures (4.5), (4.6), (4.7), (4.8), and (4.9).

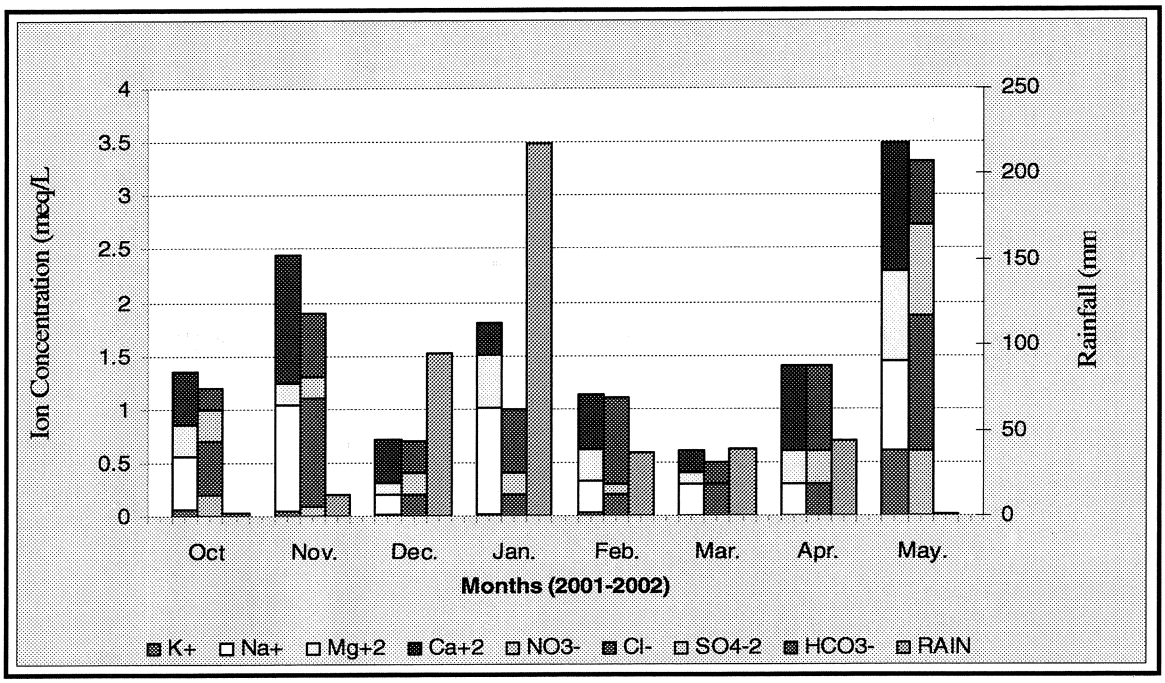


Figure 4.5: Comparative between arithmetic mean of cations and anion concentration for raining months during the hydrological year 2001-2002.

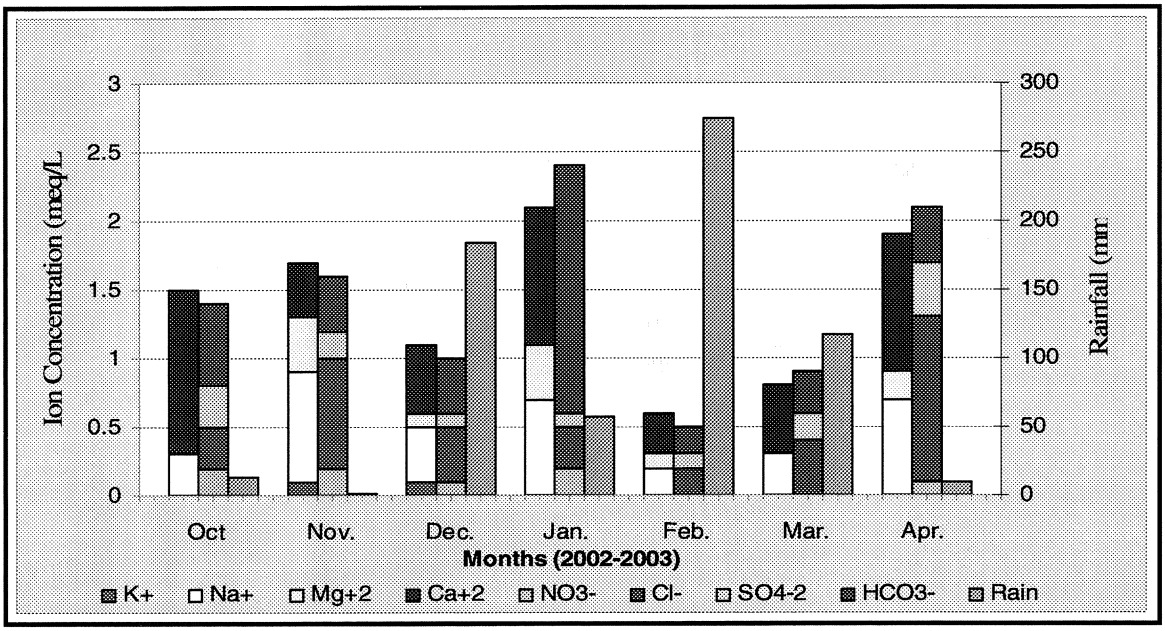


Figure 4.6: Comparative between arithmetic mean of cations and anion concentration for raining months during the hydrological year 2002-2003.

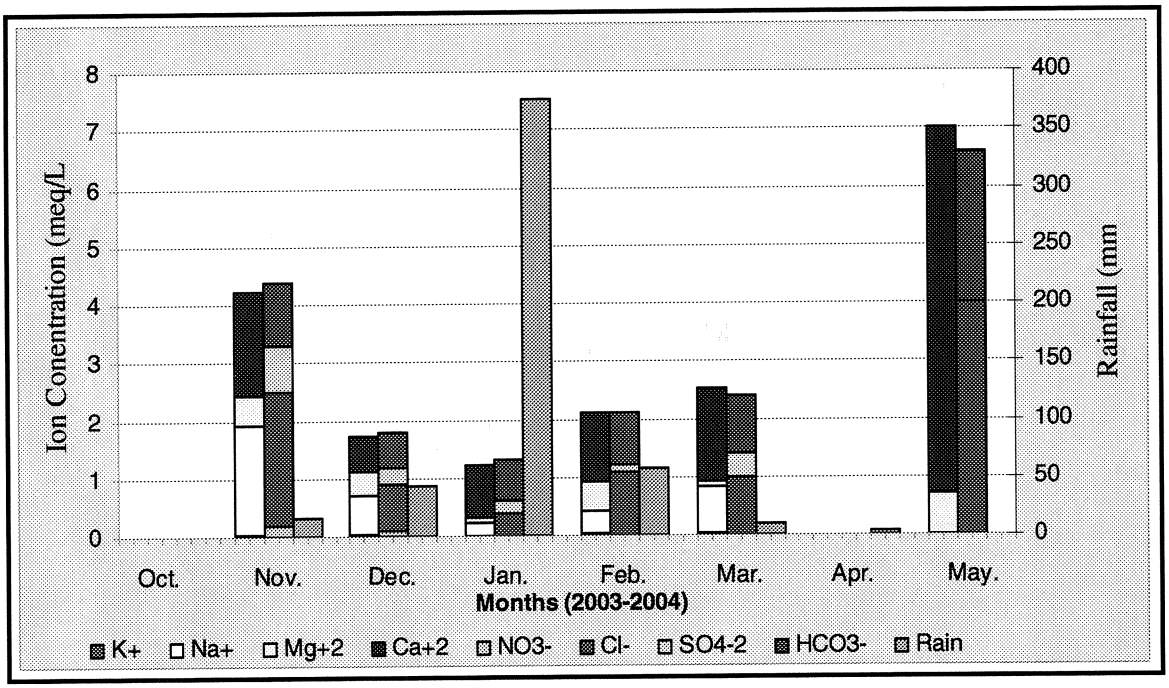


Figure 4.7: Comparative between arithmetic mean of cations and anion concentration for raining months during the hydrological year 2003-2004

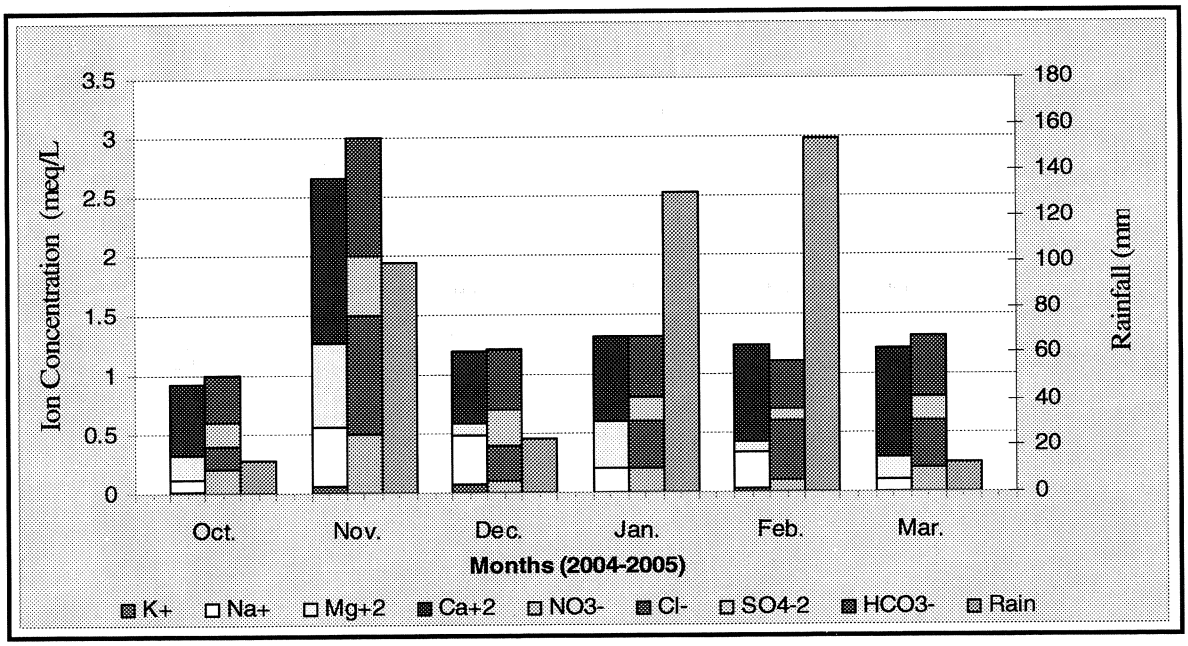


Figure 4.8: Comparative between arithmetic mean of cations and anion concentration for raining months during the hydrological year 2004-2005

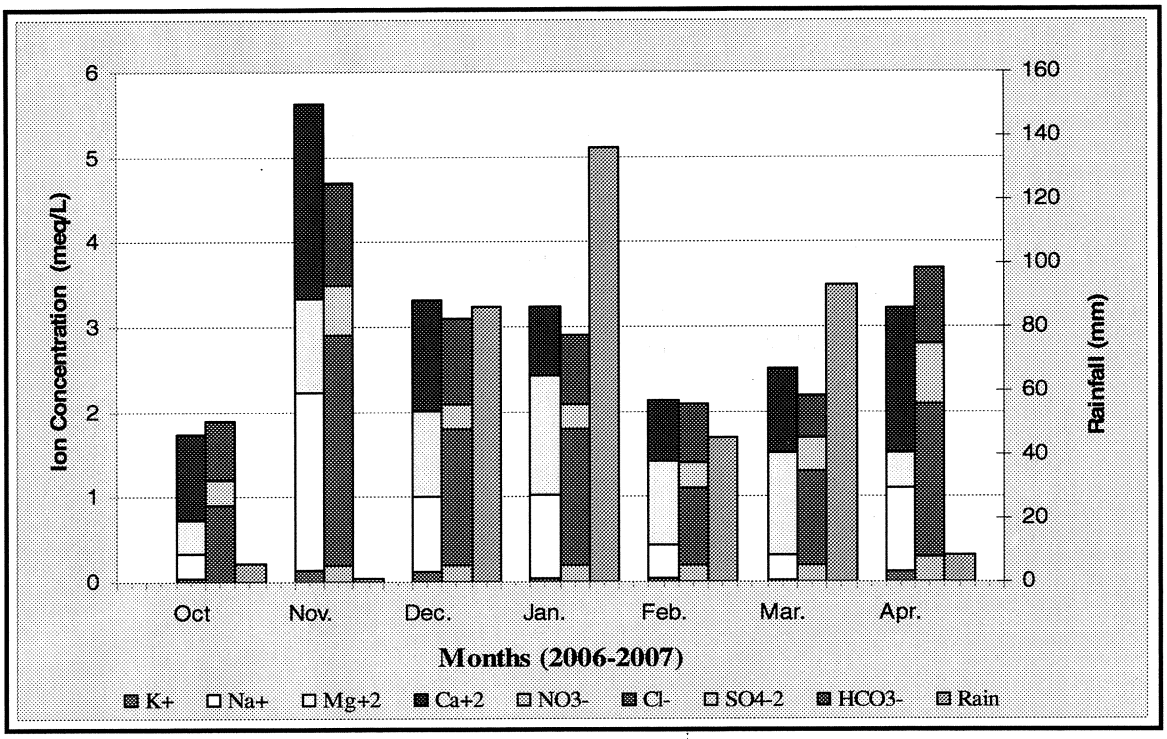


Figure 4.9: Comparative between arithmetic mean of cations and anion concentration for raining months during the hydrological year 2006-2007.

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Figures (4.5), (4.6), (4.7), (4.8), and (4.9) illustrate very clear relation between the amount rainfall and the ions concentrations. That the increasing of rainfall amount causes a decreasing in the ion concentration. When the rainfall amount is high, ion concentration decrease and vise versa.

The height of each bar, which presents the sum of cations and sum of anions for each month, is closed in most of cases. That is significant because of the balance of the data, where the value of the error lower than 5%.The dominant anion is Cl^- in all months followed by HCO_3^- and in this agrees with other result concluded by (Mamane, 1995).

4.3.5 Weighted Average of Ion Concentration:

The weighted average (WA) give the knowledge of the concentration of ions related to specific rainfall amount. We calculate WA for each ion in each rainfall event. The arithmetic average at each month in the same hydrological year has been taken by Equation (4.3) (Avila 1996, Isikdemir 2006)

$$C_p = (\sum (C_x * P_x)) / (\sum P_x) \qquad \text{.(Eq.4.3)}$$

Where C_p is the concentration as volume weighted average in mg/m^2, P_x is the precipitation amount of day x in mm, C_x is the concentration of ions in the day x in mg/L. Figures (4.10), (4.11), (4.12), (4.13), (4.14), (4.15), and (4.16) present the relation between the WA concentration of the main cations Ca^{+2}, Mg^{+2}, Na^{+}, and K^{+} for specific month through the all period of research. These figures give the knowledge of the total sum of cations, so the quantity of each cation could be compared to the total of cations. Moreover, that graphs have the number of dry days. In parallel to each figure of WA, there is a histogram of the rainfall amount in that period for month.

4.3.5.1 October:

In October 2002-2003, calcium ion is the dominate cation with 24 mg/m^2 with total precipitation of 13.2 mm (Fig. 4.10.a). In October 2004-2005 the Ca^{+2} is the dominate too with 12 mg/m^2 where the total precipitation is 14.4 mm (Fig. 4.10.b). The highest total sum of cations is determined in 2006-2007, where the Ca^{+} is dominating by 20.8 mg/m^2 with

rainfall volume 5.6 mm. There are no values in 2003-2004, because the samples for this month did not analyze.

On the other hand, Mg^{+2} presents the highest value about 4.86mg/m^2 in 2006-2007, while Na^+ gets the highest WA 13.0 mg/m^2 in 2001-2002. K^+ records the highest value (2.8mg/m^2) in 2001-2002.

It is noticed that Ca^{+2} and Mg^{+2} have the highest value in the same year 2006-2007, which measured 5.6 mm of precipitation. While K^+ and Na^+ have the highest value during that period in 2001-2002.

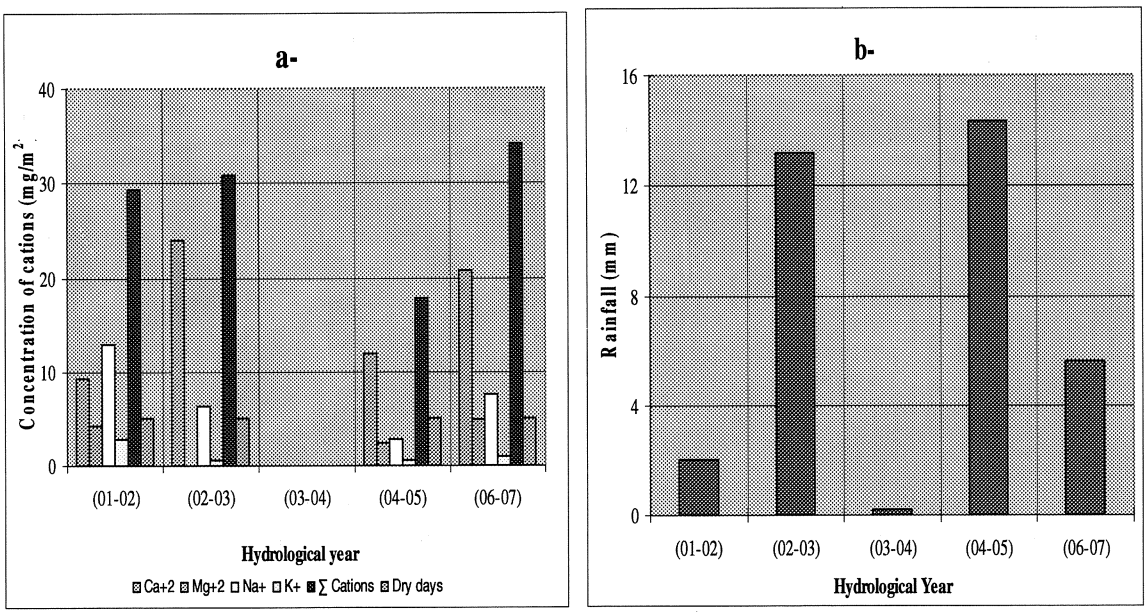


Figure 4.10: a- Weighted Average of cations concentration in mg/m^2 in October 2001-2007 b- Rainfall histogram in mm in October for the period 2001-2007 for Abu Dis Weather Station.

4.3.5.2 November:

Total sum of cations is higher than October, to reach 113.1 mg/m^2 in 2006-2007. The highest concentration of Na^+ is 48.7 mg/m^2 in 2006-2007 with precipitation amount of 1mm. The Ca^{+2} concentration is highest in 2006-2007, to reach 45.9, but the Ca^{+2} is dominated in 2001-2002, 2003-2004, and 2004-2005. In general, the concentration is higher from October, which caused by the washing out of ions from atmosphere.

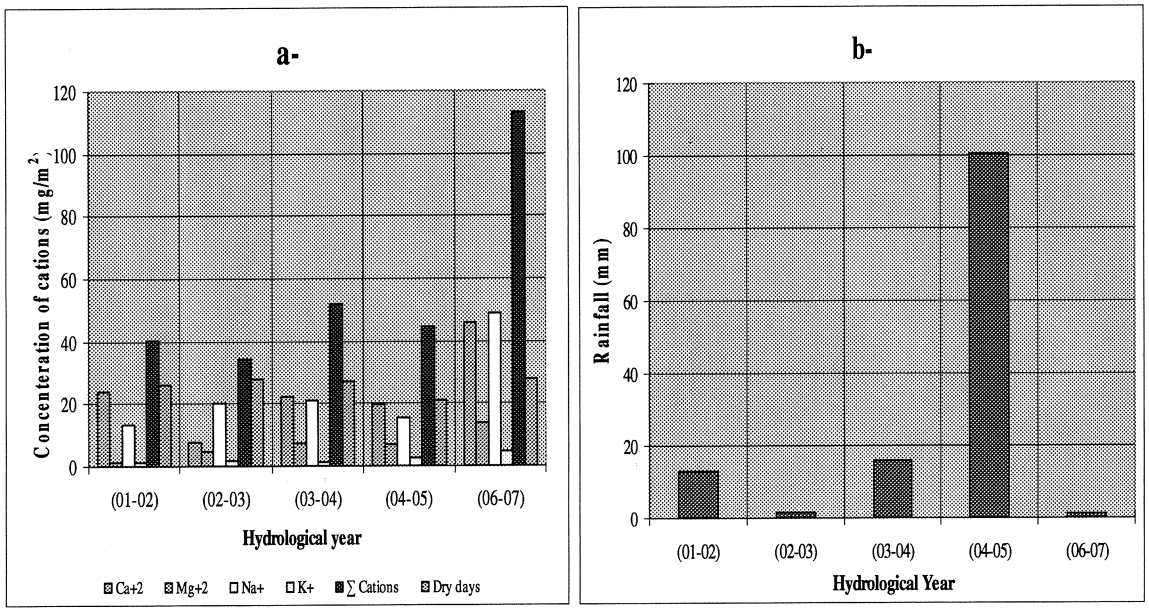


Figure 4.11: a- Weighted Average of cations concentration in mg/m^2 in November 2001-2007 b- Rainfall histogram in mm in November for the period 2001-2007 for Abu Dis Weather Station

In addition, this high concentration may be affected by the kind of winds. Herut (2000) mentioned in his study that there are two types of winds affected the area, northwest affected to central Israel, and southwest affected south Israel. The southwest came from North Africa and over Sinai. Therefore, the air is considerably drier and after contains

large amounts of desert dust and mineral ions (Ganor 1991, Yaalon 1979). Therefore, this could explain why those cations had higher concentration in this month.

4.3.5.3 December:

Fig. (4.12.b) shows higher precipitation intensity than November. However, the concentrations of cations in December for each hydrological year become lower than their concentration in November. Ca^{+2} is the dominated in all period with highest value reach 7.1 mg/m^2 in 2006-2007 with precipitation volume 86.2 mm. This may affected by the washing of the mineral ions from the atmosphere by the end of November.

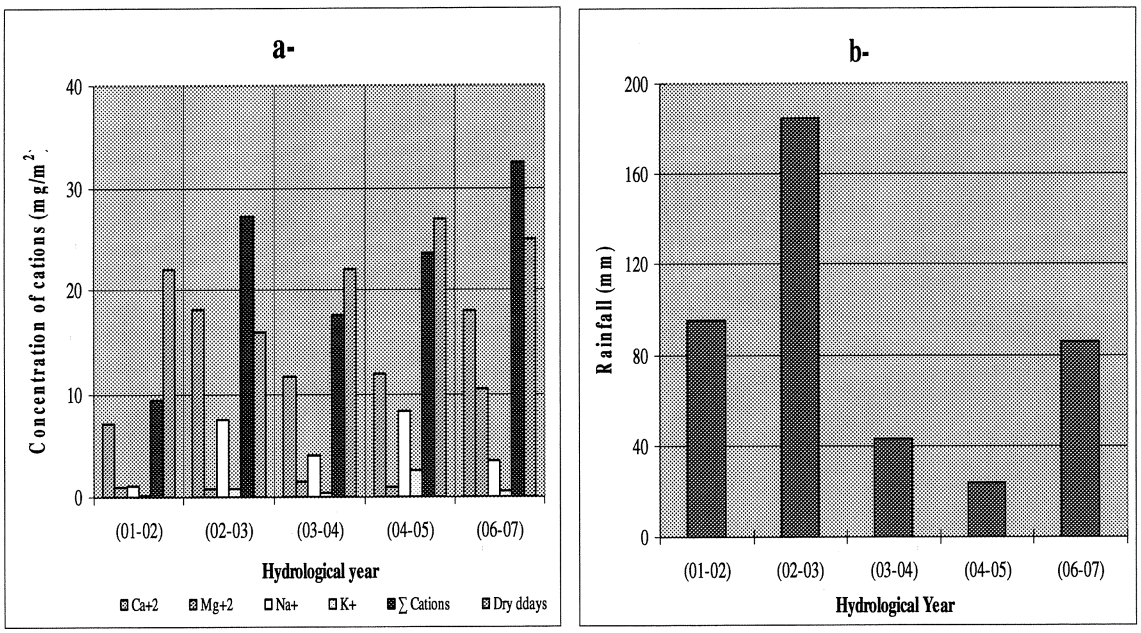


Figure 4.12: a- Weighted Average of cations concentration in mg/m^2 in December 2001-2007 b- Rainfall histogram in mm in December for the period 2001-2007 for Abu Dis Weather Station

4.3.5.4 January:

Fig.(4.13) shows that Ca^{+2} concentration 4.9 mg/m^2 in 2001-2002 is lower than the concentration of Ca^{+2} in December at the same hydrological year. On the other hand, the other cations concentration becomes higher in this month. That could be related to the increasing in rainfall amount in this month (217.8 mm) and decreasing the dry days that affected on the Ca^{+2} concentration.

At the same time, the previous reason caused the increasing of concentration of Mg^{+2},Na^{+}, and K^{+}, where their sources in this time is marine instead of continental depending on the wind direction. In January 2006-2007, Na^{+} is dominating by 31.8 mg/m^2 followed by Mg^{+2} of 21.6 mg/m^2, which may support the idea of their marine source mainly.

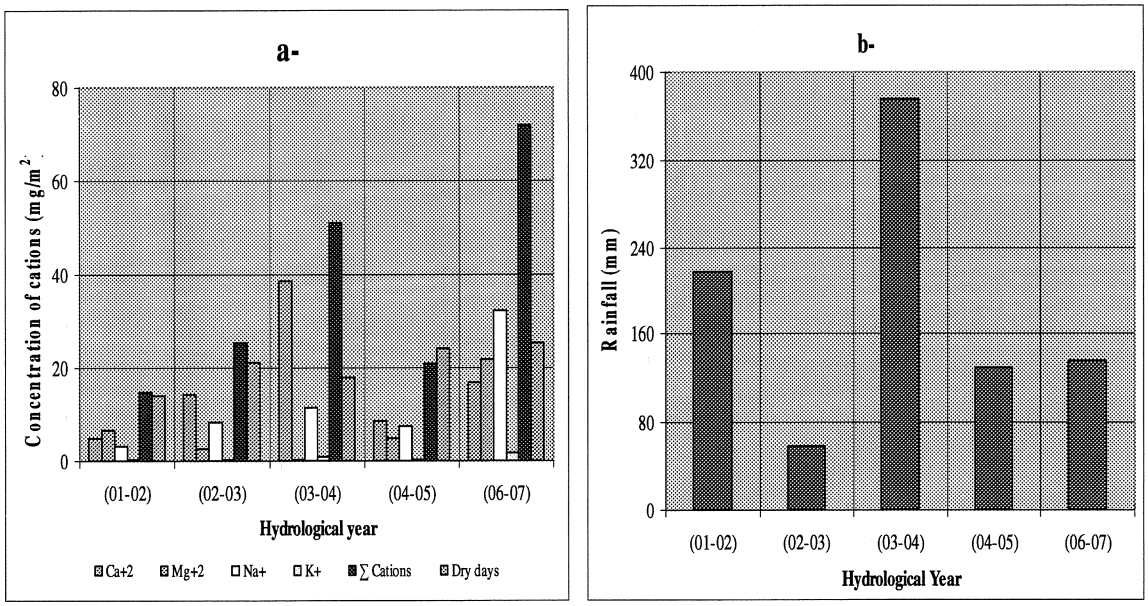


Figure 4.13: a- Weighted Average of cations concentration in mg/m^2 in January 2001-2007 b- Rainfall histogram in mm in January for the period 2001-2007 for Abu Dis Weather Station.

4.3.5.5 February:

Fig. (4.14) presents the WA of cations in February for different hydrological year. Calcium ion is still the dominant in 2001-2002 by 6.7 mg/m^2 with lower rainfall amount 37.2 mm than January. The concentration of the other ions expected to be lower, depending on decreasing the rainfall if the ions came from marine. Nevertheless, opposite result appears. This could be related to increasing of the number of dry days, which start affecting on the rainfall contents at this time of hydrological year.

In February 2002-2003, the rainfall amount is 274.2 mm, which is more than the rainfall of January 2002-2003. That decline the Ca^{+2} concentration to reach 4.8 mg/m^2, where Na^+ is dominate by 5.5 mg/m^2.

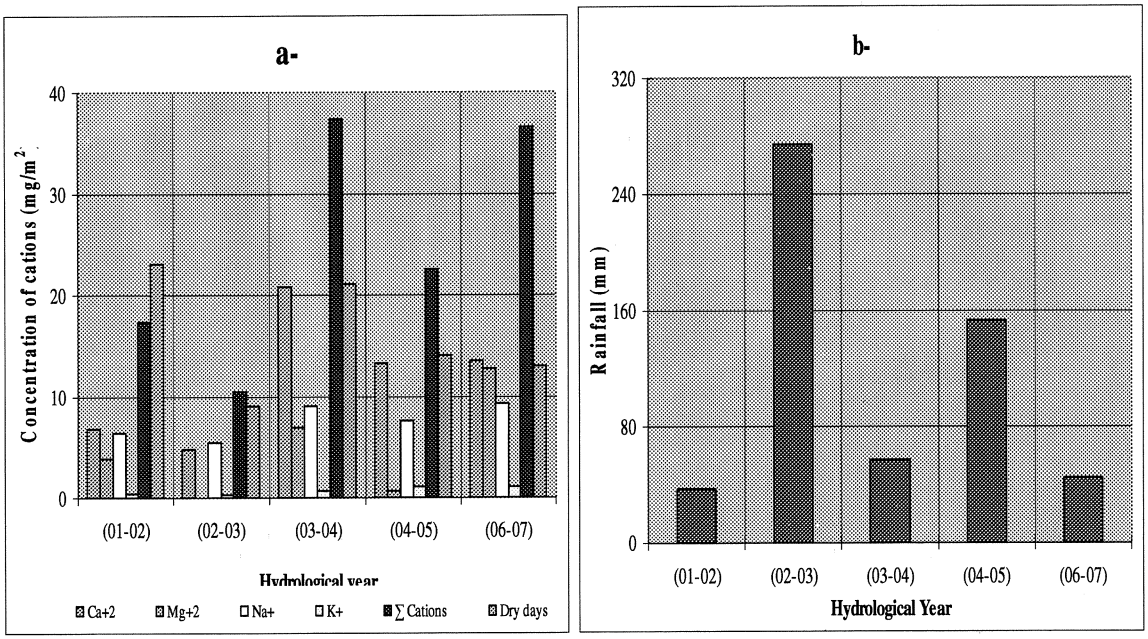


Figure 4.14: a- Weighted average of cations concentration in mg/m^2 in February 2001-2007 b- Rainfall histogram in mm in February for the period 2001-2007 for Abu Dis Weather Station

4.3.5.6 March:

In March 2001-2002, the dominant cation is Na^{+} of 7.6 mg/m^2 with little increasing of rainfall intensity to reach 39.2 mm (Fig.4.15.b). While Ca^{+2} concentration decreased than February 2001-2002 to reach 3.4 mg/m^2.

On the other hand, the March rainfall amount decreases for 2002-2003, 2003-2004, and 2004-2005 compares with February. This decreasing, affects mainly on Ca^{+2} concentration. As the rainfall amount decrease and number of dry days increase, the Ca^{+2} concentration increases. However, in March 2006-2007 the rainfall intensity increased compare to February 2006-2007. Therefore, the Ca^{+2} concentration decline to reach 8.2 mg/m^2. Which the other ions concentrations are fluctuated, this could be caused by the interference between the sources of these cations.

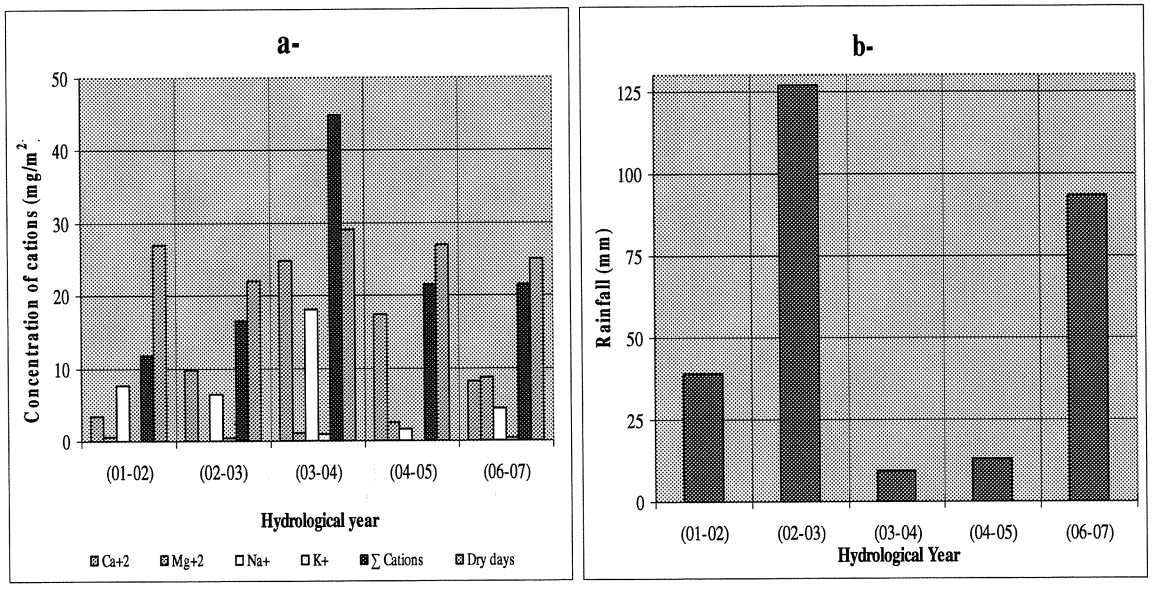


Figure 4.15: a- Weighted Average of cations concentration in mg/m^2 in March 2001-2007 b- Rainfall histogram in mm in March the period 2001-2007 for Abu Dis Weather Station

4.3.5.7 April:

Fig. (4.16) presents the results of ions WA for the beginning of spring season. In this month, the dominate cation is Ca^{+2}. The climate in this month become drier and the area affected by the Khamasieeni, Red Sea trough, and Sharv winds depending on the wind direction, which increasing the mineral ions concentration.

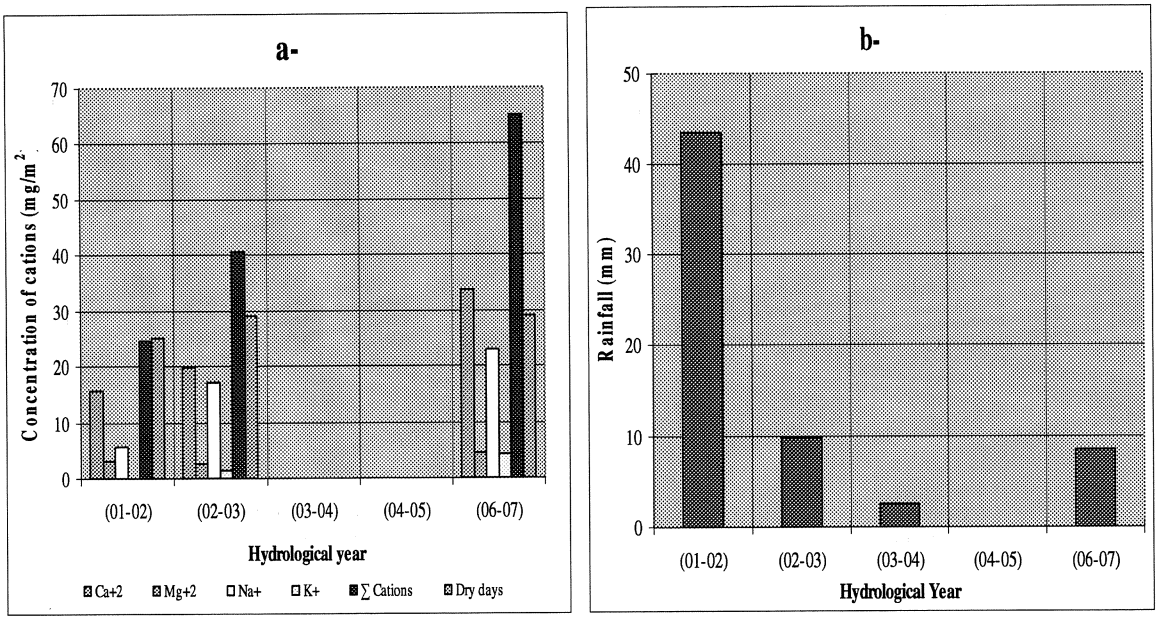


Figure 4.16: a- Weighted average of cations concentration in mg/m^2 in April 2001-2007 b- Rainfall histogram in mm in April to the period 2001-2007 for Abu Dis Weather Station

This WA of ions concentrations for the all period is presented in Table (4.2) as annual summation for each cation. The table shows that the dominant cation is Ca^{+2}. The highest values of WA of cations concentration are measured in 2006-2007. This hydrological year also have the lowest rainfall amount and the highest dry days. This reason may explain the highest WA values, where the dry days influence the increasing of terrestrial cations in the

atmosphere. However, the washout of these cations by low amount of rainfall, present the high value of WA. In addition, Table (4.2) shows the amount of each cation that precipitated in the area in each hydrological year. For example, the amount of precipitation of Mg^{+2} in 2001-2002 is 20.6 mg/m^2 and so on.

Table 4.2: Weighted average of ions concentrations (mg/m^2) for the period of 2001-2007.

	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Dry days	rainfall mm
(01-02)	71.0	20.6	50.4	4.9	142.0	448.60
(02-03)	97.9	10.7	71.2	5.4	130.0	657.80
(03-04)	117.9	16.7	63.7	4.1	117.0	503.9
(04-05)	82.7	17.9	43.2	7.0	118.0	434.80
(06-07)	156.9	76.3	127.9	13.6	150.0	376.26

From the previous discussion, there are variations of WA concentration for the different ions during the course of a single hydrological year, which produced by different meteorological conditions that affect the chemical composition of rainwater. Moreover, monthly WA concentrations of crustal cations are higher at the beginning of the rainy season in October and November (Baez et al, 2006).

On the other hand, from the calculated data there is no clear relationship between the rainfall intensity and the WA concentration of ions in the same month through different hydrological year. Moreover, the most notable relationship is about Ca^{+2}, where the WA concentration increases when the rainfall amount decrease during the dry months such as November and April. That agrees with the result which Asman (1981) get in. While it decrease when rainfall intensity increase during January and February. That may be results

from both reasons, the washout of the below-cloud atmosphere, and the evaporation of rain droplets during the first stages of rain events (Andre et al, 2007).

4.4 Determination of chemical sources

4.4.1 Ionic Correlation:

Relationships between measured components concentration are examined through the analysis of linear correlation. These relations are between Cl^- with Na^+, Ca^{+2} with SO_4^{-2}, (Ca^{+2}+Mg^{+2}) with HCO_3^-, and Ca^{+2} with Mg^{+2}. Total samples are 122, there were some ions in that samples were not be analyzed so in the correlation we suggested to reject some of them as well be mentioned later in each case.

4.4.1.1 Na^+ -Cl^-:

Fig. (4.17) summarize the correlation results of the concentration in mmole for the period of 2001-2007. Fig. (4.17.a) and (4.17.b) presents high correlation between these ions by R^2 values 0.93 and 0.84 respectively. On the other hand, Fig. (4.17.d) and Fig. (4.17.e) have R^2= 0.50 and 0.59 respectively, which is moderate relation.

These samples were plotted in the same scatter diagram for the all-period 2001-2007 where the correlation factor R^2= 0.77. This value shows is a good relation between Na^+ and Cl^-, which means that mainly they share of the same source that is seawater. However, they still affected by other sources, which could be terrestrial for Na^+ and industry for Cl^- by the same sources of ions (Fig.4.17.f).

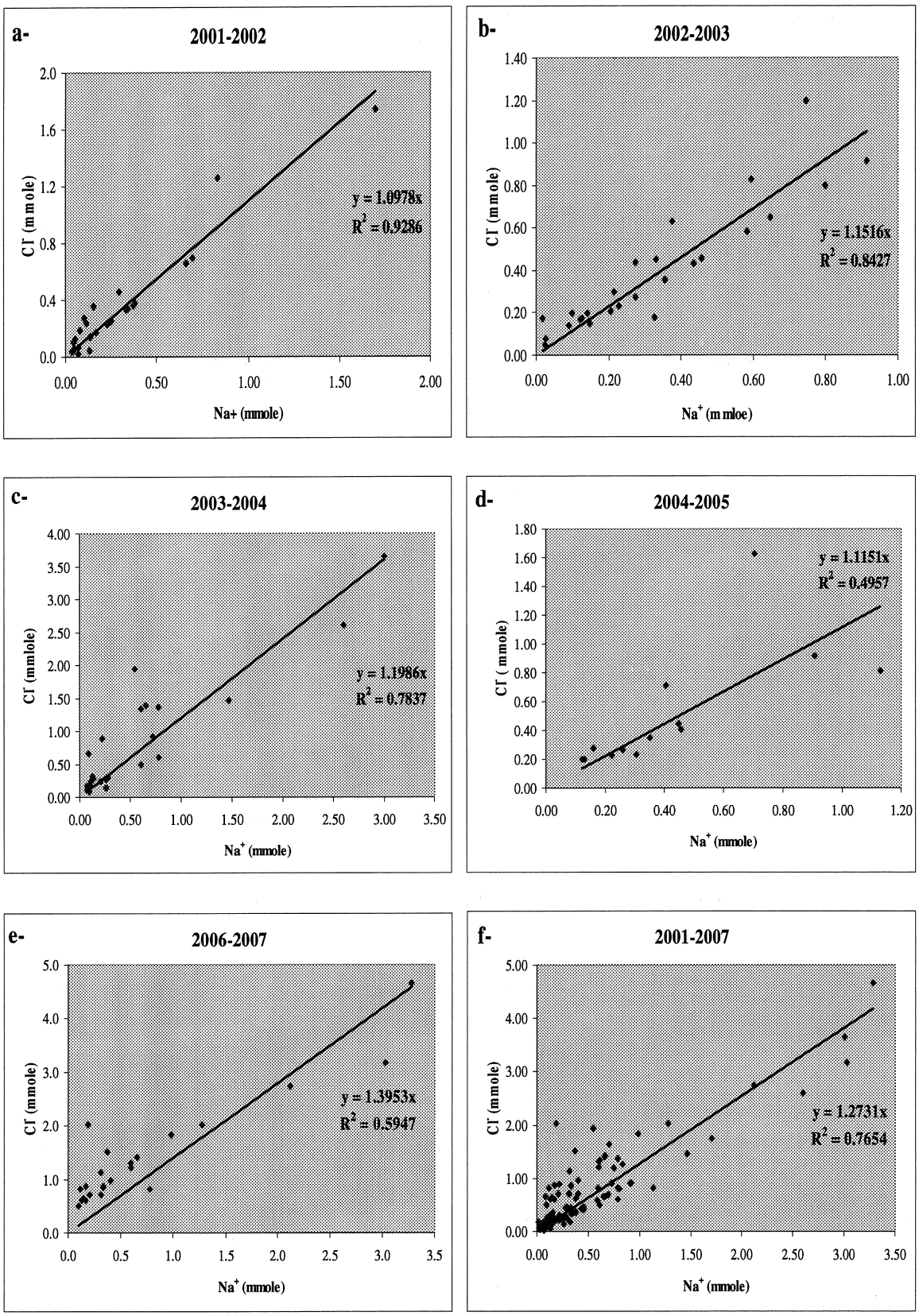


Figure 4.17:- Correlations between Na^+ and Cl^- in mmole in the rainfall for the period of 2001-2007, Abu Dis Weather Station.

4.4.1.2 SO_4^{-2} - Ca^{+2}:

Fig. (4.18) presents the relation between Ca^{+2} and SO_4^{-2} in mmole in rainwater samples during the period 2001-2007. Fig.(4.18.d) illustrates a strong relationship between the two ions with r= 0.8, which may suggest that have same source or sources. On the other hand, Fig. (4.18.b) presents a weak correlation by r=0.2. Fig. (4.18.a), (4.18.c), and (4.18.e) shows slightly moderate correlations with r= 0.4, 0.4, and 0.6 respectively. Ca^{+2} and SO_4^{-2} have weak correlation through the whole period of the study with r= 0.4, which may be caused by contributions of different sources at the same time for the ions (Fig. 4.18.f).

Singer et al. (1993) and Ganor (1991) analyzed dust materials collected during Saharan storms in Israel, which indicated that the dust is composed predominately of quarts with considerable amounts of carbonates as well as gypsum, halite and illite. The storms influence the region, so these species contribute Ca^{+2} to the rain through scavenging. The sudden decreasing in the Ca^{+2} concentration occurred in Januarys and Februarys in each hydrological year may be due to the absence of dust storms during this period, So Ca^{+2} is held to be largely terrestrial.

There are three main origins for the Ca^{+2} in rainwater Han (2006) mentioned, first is anthropogenic: human activity, traffic…etc, second is carbonate weathering: local soil and its type, less vegetation cover, and third: origin of Ca^{+2} by Long-rang transport. Although the Saharan dust has high concentration of Ca^{+2} and SO_4^{-2}, but also the area affected by north and northwest winds which came from Europe as industrial region. That means the sources of SO_4^{-2} is fluctuated between the Saharan dust and fertilizers as natural source, and pollutant from Europe as anthropogenic source. These different sources affected at different and separated times on the region

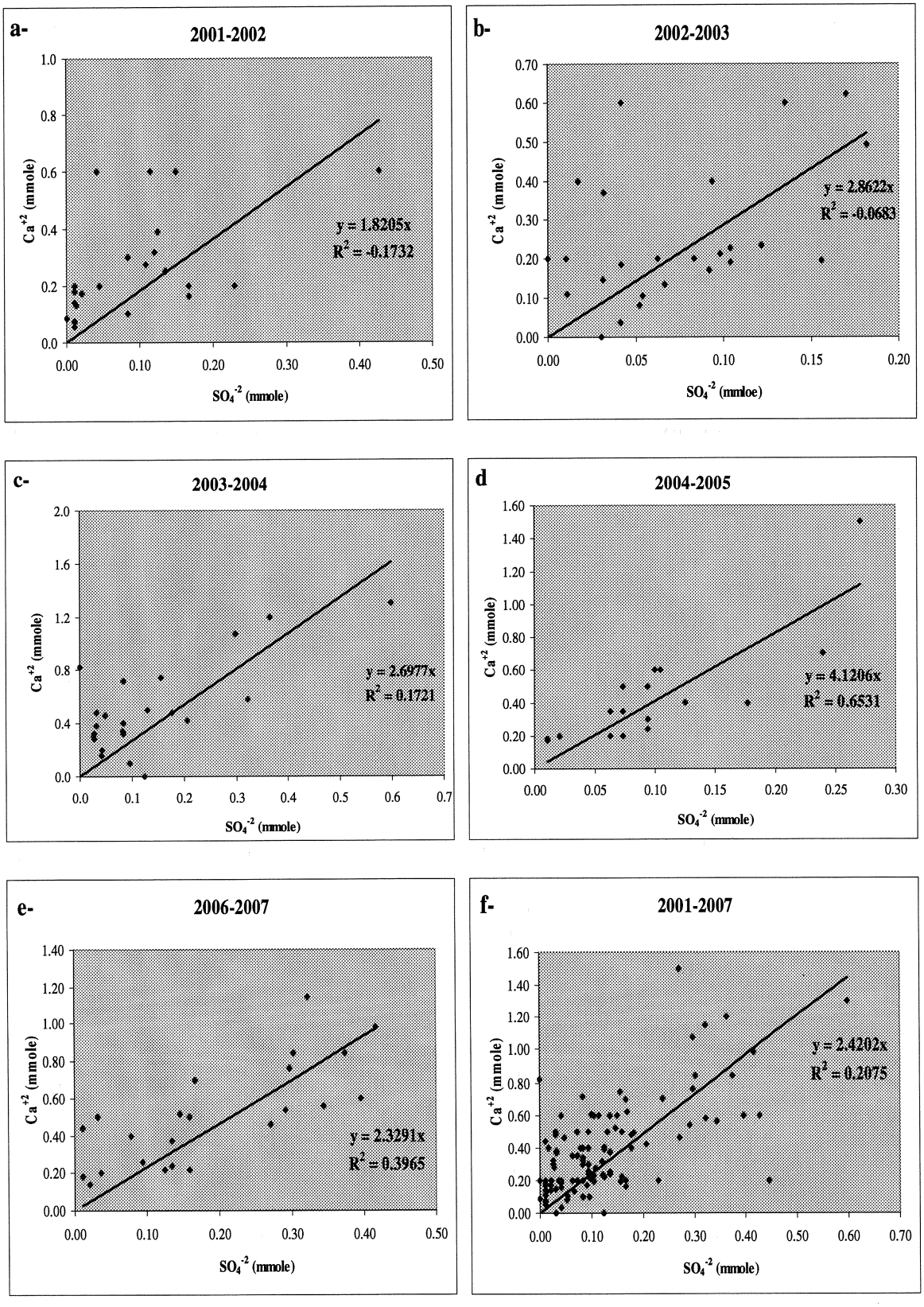


Figure 4.18: Correlations between SO_4^{-2} and Ca^{+2} in mmole in the rainfall for the period of 2001-2007, Abu Dis Weather Station.

4.4.1.3 Mg^{+2} - Ca^{+2}:-

The correlation between these ions is presented in Fig.(4.19) for the period of the research. For this section, it must be mentioned that some samples are rejected through the ion balance in this correlation, where the reminded samples are fixed in the following graphs. The highest correlation between these ions is presented in Fig.(4.19.a) and Fig.(4.19.c) with regression r=0.94 and 0.96 respectively, which may suggested to be mainly from the same source. Fig.(4.19.b) and Fig.(4.19.e) illustrate moderate correlation by r = 0.69 and 0.73 respectively. On the other hand, Fig. (4.19.d) show lowest correlation with r =0.50 which may indicate that these ions are different in source in that year.

Fig. (4.19.f) presents the correlation between Mg^{+2} and Ca^{+2} for the period of 2001-2007. Three groups can be identified in this graph with weak correlation factor r =0.58. Group 1 has high concentration of Mg^{+2} and low concentration of Ca^{+2}. The samples of this group measured either after long dry days that means that the source is terrestrial; or the samples are measured after rainy days but the wind direction were from west or northwest, and that means that the source of Mg^{+2} is marine. However, group 2 has high concentration of Ca^{+2} and low concentration of Mg^{+2}. The samples in this group measured after long dry period, which means that the source of ions is terrestrial. The third group mainly presents closed values of Ca^{+2} and Mg^{+2} concentrations, which may suggest that both are from the same source that is terrestrial.

The variation of the values suggests that the two ions have different sources. These common sources of the ions may be from natural sources that is the calcareous nature of the soil and the frequent input of Saharan soil dust, or from marine as sea sprays.

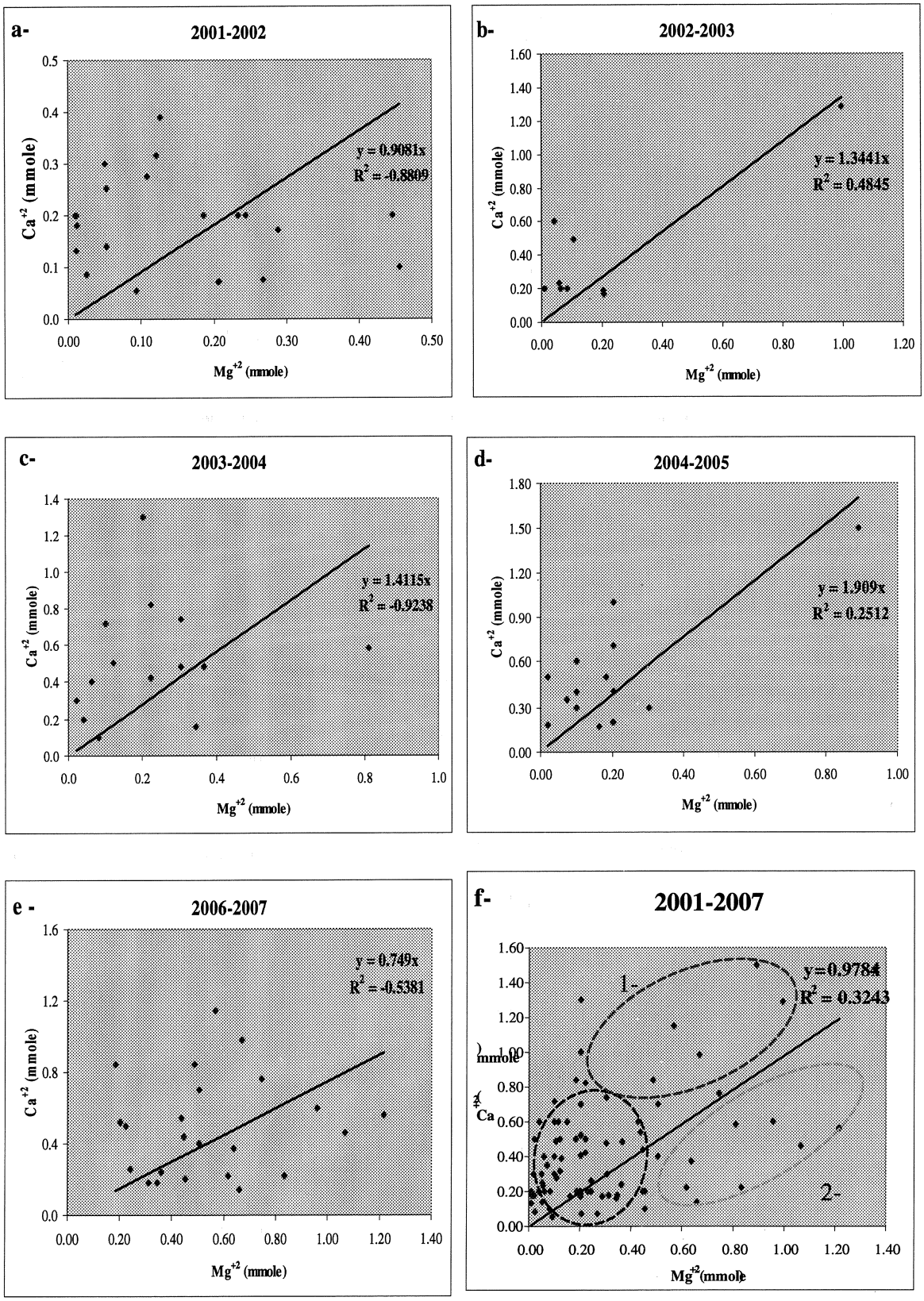


Figure 4.19:- Correlations between Mg^{+2} and Ca^{+2} in mmole in the rainfall for the period of 2001-2007, Abu Dis.

Mg^{+2} in precipitation originated commonly from sea spry and soil. However, from the previous r-values, Mg^{+2} could be contributed by marine especially during the western winds which activated in the middle of the hydrological year. At the same time, the arid climate combined with the effect of lacking a significant plant cover in the study area and the surrounding areas results in enhanced resuspension of soil and hence high concentration of elements associated with crustal material as Al-Momani mentioned in his study (2002).

4.4.1.4 $(Ca^{+2} + Mg^{+2})$ - HCO_3^-:-

As mentioned in the previous section about dealing with samples of Ca^{+2} and Mg^{+2}, this section deal with the same arrangement of that ions and compared with HCO_3^-. Fig.(4.20) represent the relation between the summation of Ca^{+2} and Mg^{+2} with HCO_3- in mmole. Fig.(4.20.c) shows the strongest correlation of r =0.88, followed by r = 0.75 presented in Fig.(4.20.d). In contrast, a bad correlation illustrated in Fig.(4.20.e) with r =0.48. However, moderate correlation with r= 0.74 is presented in Fig.(4.21.f) which presents the data for the period of 2001-2007.

Carbonate minerals such as calcite and dolomite, can dissolve at rapid rates to increase the concentration of Ca^{+2}, Mg^{+2}, and HCO_3^- and decrease the acidity (AL-Momani 2000). Therefore, from the previous r-values it could be suggested that they are from the same source and their mechanism of dissolution is the same.

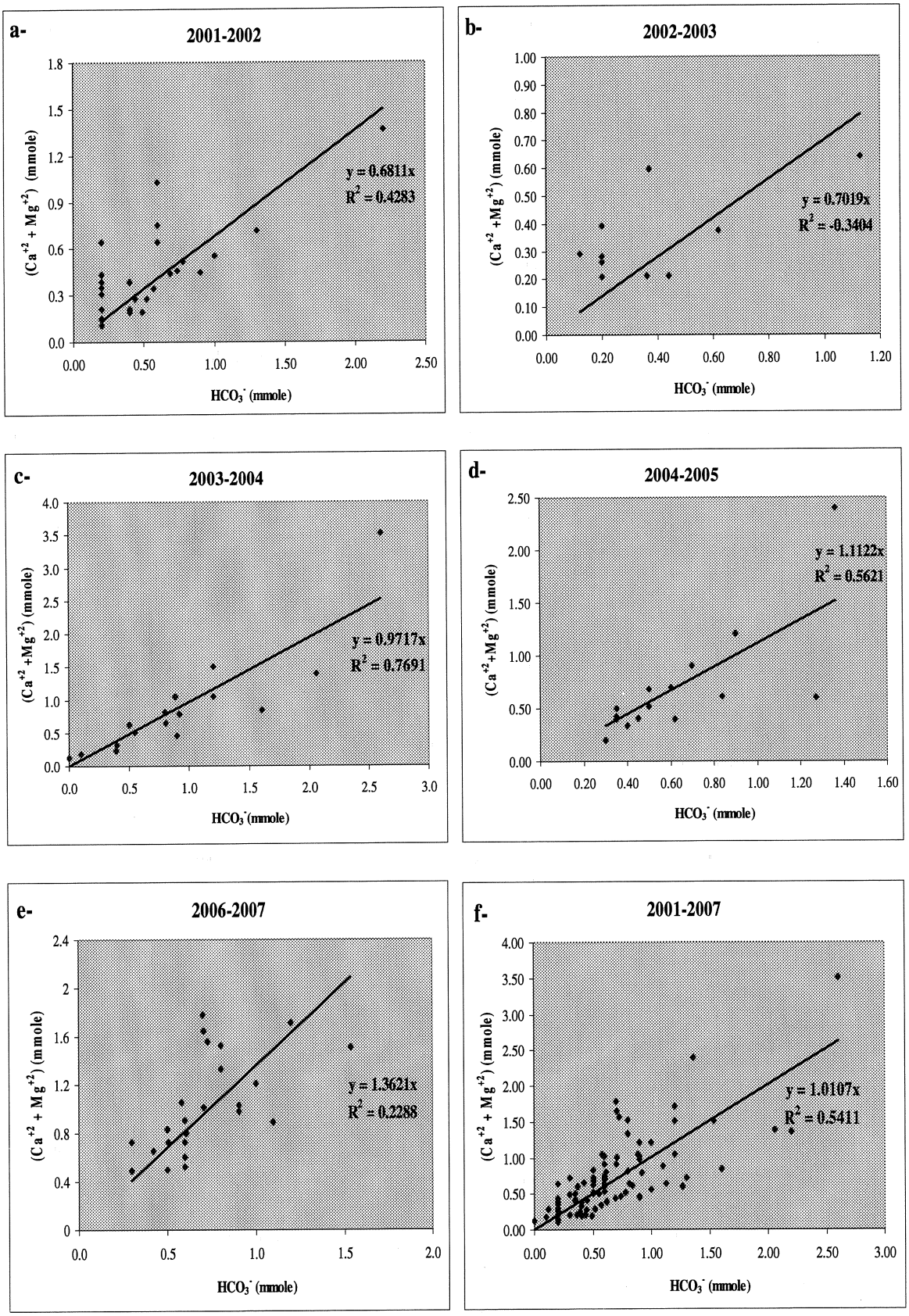


Figure 4.20:- Correlations between (Ca^{+2} + Mg^{+2}) with HCO_3^- in mmole in the rainfall for the period of 2001-2007, Abu Dis.

4.4.2. Correlation Coefficients:

In order to find possible relation between ions in rainwater samples, and the likely sources of pollutants, correlation between ions of 122 rainfall samples is calculated and presented in Table (4.3). SO_4^{-2} shows relatively similar correlation with Ca^{+2} and Mg^{+2}, with correlation coefficients of 0.42 and 0.39, respectively. This may indicate that calcium (and/or magnesium) sulfate is a compound in precipitation. NO_3^- and SO_4^{-2} shows a weak correlation r = 0.42, which not expected because both are photochemical produced and they should have good correlation (Han, 2006).

NH_4^+ generally occurs as $(NH_4)_2SO_4$ or NH_4NO_3 in the atmosphere, but depending on table (4.3) NH_4^+ has better correlation with NO_3^- by r = 0.32, while with SO_4^{-2} r = 0.21. That could support the idea that NH_4^+ is associated with NO_3^- and forming NH_4NO_3 in the area study (Kumar, 2002).

Table 4.3: Correlation matrix between major ions concentration in mmole for rainwater samples for 2001-2007 at Abu Dis Weather Station.

	Cl^-	NO_3^-	SO_4^{-2}	HCO_3^-	Na^+	K^+	Ca^{+2}	Mg^{+2}	NH_4^+
Cl^-	1								
NO_3^-	0.31	1							
SO_4^{-2}	0.55	0.42	1						
HCO_3^-	0.29	0.29	0.10	1					
Na^+	0.73	0.25	0.45	0.47	1				
K^+	0.31	0.40	0.36	0.12	0.37	1			
Ca^{+2}	0.66	0.42	0.42	0.54	0.31	0.17	1		
Mg^{+2}	0.55	0.41	0.39	0.50	0.47	0.22	0.28	1	
NH_4^+	0.10	0.32	0.21	-0.05	0.02	0.08	-0.04	0.33	1

Other relatively bad correlations are observed between the crustal elements, Ca^{+2}, K^{+}, and Mg^{+2}. For example, r-value is 0.22 between K^{+} and Mg^{+2} and 0.28 between Ca^{+2} and Mg^{+2}, and between Ca^{+2} and K^{+} it is 0.17. However, Mg^{+2} and Na^{+} have a weak correlation by r =0.47, while bad correlation between Na^{+} and Ca^{+2} with r =0.31. That may be suggested that Mg^{+2} and Na^{+} could be from same origin, which could be a marine origin. Chloride ion presents a good correlations with Mg^{+2} and SO_4^{-2} by r =0.55, and by r =0.66 with Ca^{+2}. The strongest correlation is recorded between Cl^{-} with Na^{+} r = 0.73, which indicates that they have the same source/ sources.

Table (4.3) suggests that NaCl, $CaCl_2$, $CaSO_4$, $MgSO_4$, $MgCl_2$, NH_4NO_3 are predominant species combinations, which could be formed in the atmospheric water droplets by scavenging of aerosols ad reaction of gaseous species (Al- Momani 2000).

4.4.3. Ions Ratio:

Element concentration ratios are likely to provide insight the origins of dissolved chemicals

4.4.3.1 Na^+/ Cl^- Ratio:

The arithmetic average of Na^+/Cl^- ratios for 115 samples are measured to be 0.75, there are seven samples are ignored. This value is lower than the corresponding value for seawater 0.86 because the sampling site locates 40Km from the sea. In addition, study area is considered to be as a rain shadow area, where the chemical components of the rain will differ than the sea. Fig.(4.21) presented the Na^+/Cl^- for each event in each hydrological year, compared to the seawater ratio (0.86). In Fig. (4.21), most of the rain events are close to the value of sea ratio, while others are upper or lower. That is depending on the Cl^- and Na^+ concentration. If the ratio is higher than the sea ratio, that means enrichment of Na^+ or depletion of Cl^- concentration, and vice versa.

Fig.(4.21) illustrates that the most events which had low Na^+/Cl^- ratio taken place between the end of Decembers to the end of Februarys from each hydrological year. In that period, and according to meteorological information, the winds and cold masses came from the west and northwest that means from Europe. This could be one reason to increase the concentration of Cl^- as pollutants. On the other hand, this period is the middle of hydrological year, which means that the ions like Na^+ are scavenging form the atmosphere by the rain.

Fig (4.21.a) and (4.21.b) are mainly near to the corresponding value except some events. In Fig.(4.21.b) an extreme ratio 4.69 measured on 15 January 2003. Depending on the origin data for the chemical components of this day, it seems to have extreme in the all chemicals.

By measuring the arithmetic mean concentration of Cl^- and Na^+ for each hydrological year in mmole, the Cl^- records the highest concentration 1.36 mmole in 2006-2007. However, the lowest value is 0.33 mmole in 2001-2002. While Na^+ has the highest concentration 0.7 mmole in 2006-2007, and the lowest concentration 0.28 mmole in 2001-2002. On the other hand, the highest average of Na^+/Cl^- 1.07 is measured in 2002-2003, and the lowest ratio average 0.51 is measured in 2006-2007.

The most closed value of the ratio to the seawater is founded in 2001-2002, which is 0.84. From the previous explanation and depending on r-value 0.87 in Fig.(4.17.f), this maybe suggest the Na^+ and Cl^- in 2006-2007 have the same source but it was not from the seawater, or the enrichment Cl^- may be contributed by anthropogenic source. Fig.(4.21.f) present the ratio for the samples for the all period.

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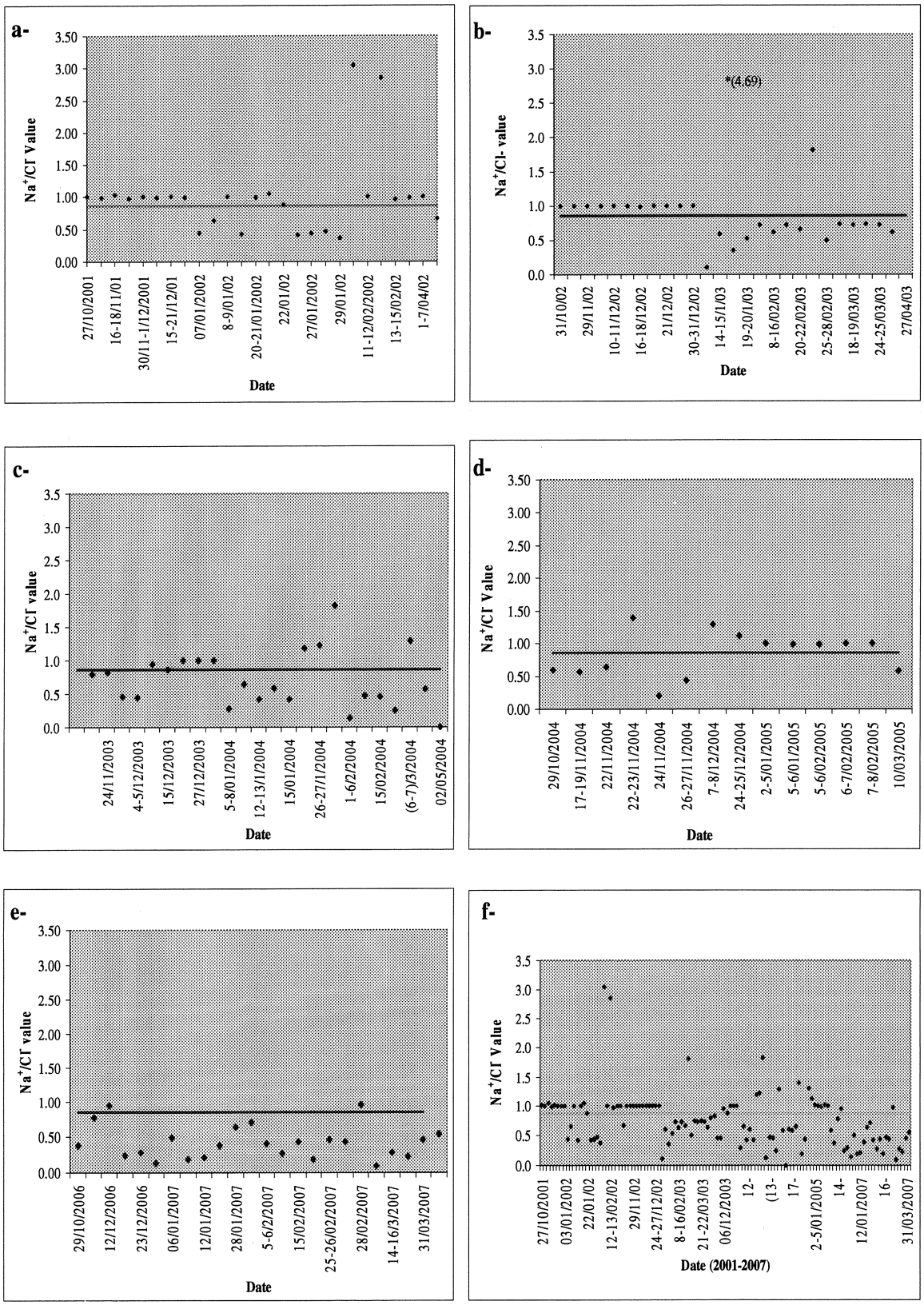


Figure 4.21: Comparison between the Na^+/ Cl^- ratio for the samples in the period 2001-2007 with the seawater Na^+/Cl^- value (0.86).

4.4.3.2 SO_4^{-2}/ Cl^- ratio:

SO_4^{-2} in rain results from two main sources, first the oxidation of atmospheric SO_2 mainly emitted from fossil-fuel combustion in industrial regions, and the second from naturally from the dust material like gypsum $CaSO_4.2H_2O$ (Herut, 1999).

Fig.(4.22) presents the SO_4^{-2}/Cl^- compared to the sea ratio 0.11. Fig.(4.22.e) shows the most close result to the seawater ratio. On the other hand, Fig.(4.22.a) shows some samples in six to eight higher for the seawater ratio. Those events are taken place in the middle of hydrological year that means after the atmosphere scavenging the calcareous ions.

The enrichment of SO_4^{-2} relative to Cl^- in rainwater can be attributed to the inputs of gaseous sulfuric acids that came by the northwest wind (Al-Khashman 2005, Han 2006). Fig.(4.22.b) and Fig.(4.22d) have extreme ratios by 1.02 and 1.09 respectively. The first point is measured on 25 March 2003, during the dry winds Khamasieeni. Second point is recorded on 19 November 2004 that means at the beginning of rainfall events.

Fig.(4.22.f) presents the ratio for the period 2001-2007. The extreme point (a) measured after strong storm affected the Middle East during 24-26 March. This storm came from Europe, which may suggest that the high value of SO_4^{-2} could be pollutants. On the other hand point (b) recorded on November with southeast wind direction, which may affected by Red Sea Trough.

In general, the SO_4^{-2}/Cl^- is mainly high. Asaf (2005) suggested that if $SO_4^{-2}/Cl^- \leq 1$ then the source of SO_4^{-2} is continental, which is Red Sea Trough. While if $SO_4^{-2}/Cl^- > 1$ the n the source is anthropogenic, such as industry or foil combustion.

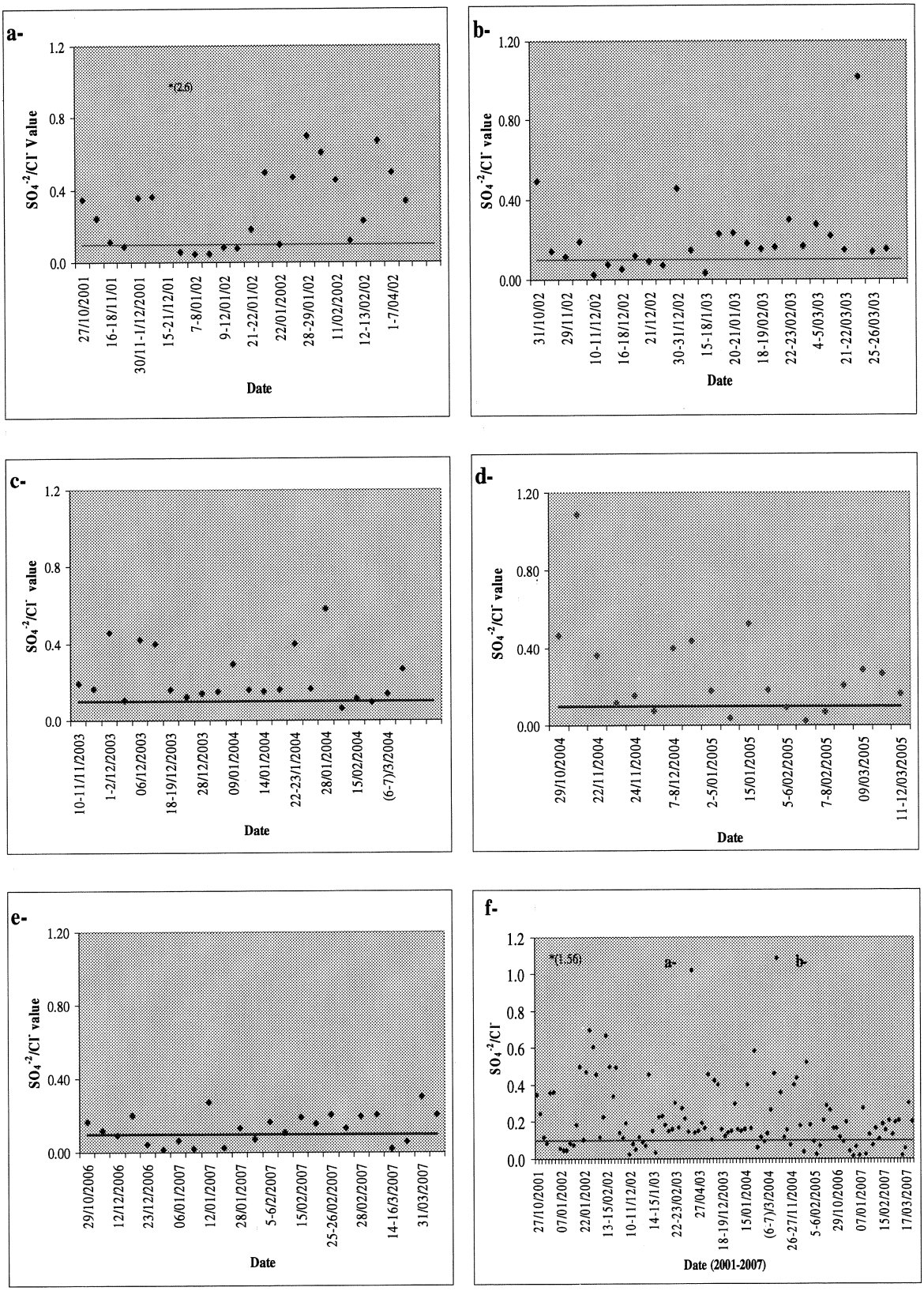


Figure 5.22: Comparison between the SO_4^{-2}/ Cl^- ratio for the samples in the period 2001-2007 with the seawater SO_4^{-2}/Cl^- value (0.10).

4.4.3.3 Ca^{+2}/ Cl^- ratio:

The Ca^{+2}/Cl^- is significant indicator for continental/ marine ratio. Fig.(4.23) present Ca^{+2}/Cl^- ratio compared to the seawater ratio 0.0189. It is very clear that in general the rainfall ratio results are higher and far from the seawater ratio. The highest ratios are observed for Ca^{+2} caused by the limestone quarry located in the surroundings of the area. Fig.(4.23.a) Fig.(4.23.b), and Fig.(4.23.c) have extreme ratios even out of the scale.

Fig.(4.23.a) shows 7.88 as extreme value, which is measured on 11 February 2002. This sample came after 11dry days, which may cause increase the Ca^{+2} concentration. However, the extreme ratio in Fig.(4.23.b) is measured on 19 January 2003 by 5.28 value. This sample is collected immediately after the strange rainfall event (15 January 2003). Fig.(4.23.c) records 6.14 as extreme ratio on 23 January 2004. This sample presents a rainfall event after three dry days and with decline in Cl^- concentration 0.08 mmole. Fig.(4.23.e) presents ratios that are slightly close to the seawater ratio, or at least they are harmonic. Fig.(4.23.f) presents the ratio for the all-period, which shows clearly that the Ca^{+2} concentration is very high according to the local soil type.

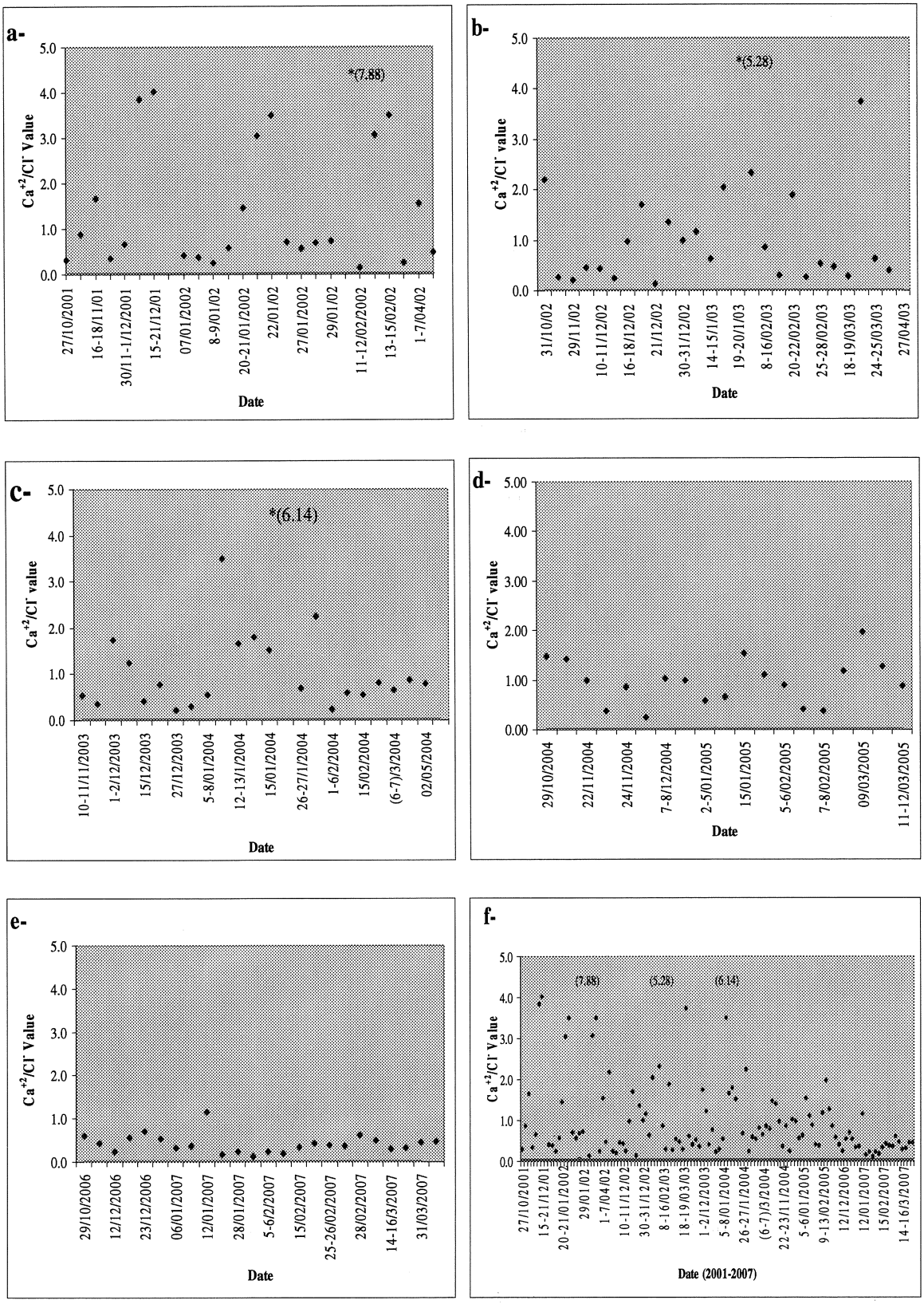


Figure 4.23: Comparison between the Ca^{+2}/ Cl^- ratio for the samples in the period 2001-2007 with the seawater Ca^{+2}/Cl^- value (0.0.018).

4.4.3.4 Mg^{+2}/ Cl^- ratio:

Fig.(4.24) presents the Mg^{+2}/Cl^- ratio for the period 2001-2007, compared with the sweater ratio 0.098. Fig.(4.24.a) illustrates very high ratios, which are very far from the seawater ratio. The arithmetic average for the Mg^{+2}/Cl^- for 2001-2002 is 1.24, which very far from the corresponding ratio. This may be related to the dusts, which influenced from the cement factory in Abu Dis in that year. Samples in 2002-2003 are near to the corresponding value, except the events at the beginning of the season (Fig.4.24.b). At the same time it shows an extreme value 1.85, which recorded on known 15 January 2003.

Fig(4.24.c) shows that most of the samples are higher than the seawater ratio. It has the extreme value 4.66, which measured on 23 January 2004. It is noticed that this ratio and the extreme ratio of Ca^{+2}/Cl^- in the previous section are taken place in the same day. That suggested that Mg^{+2} and Ca^{+2} in this event have the same source, which is terrestrial affected by the dry days. Fig.(4.24.e) shows how much the ratio is far from the seawater ratio, which may be affected by the road working in Abu Dis in that year.

Fig.(4.24.f) presents the ratio for the all-period. It is clear that the ratio is higher than the seawater ratio. This result is expected depending on the type of the terrestrial components and the direction of the wind. Those are full of dusts from Sinai, North Africa, and Negev where natural source are. However, man made such as the road working or cement factory could affect the area. Moreover, the ratios, which are closed to the seawater ratio, may suggest that the source of Mg^{+2} in that samples is marine.

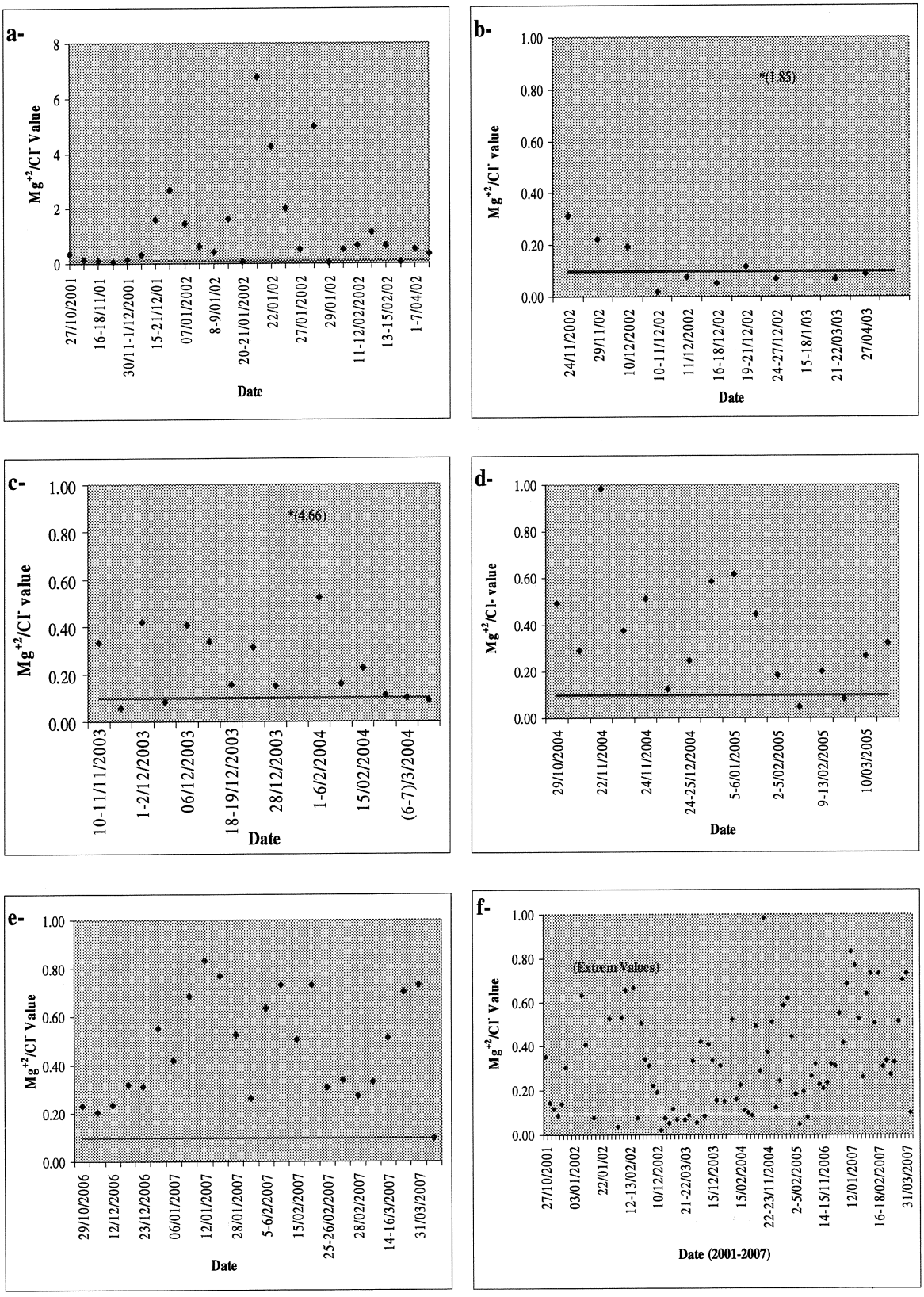


Figure 4.24: Comparison between the Mg^{+2}/ Cl^- ratio for the samples in the period 2001-2007 with the seawater Mg^{+2}/Cl^- value (0.098).

4.4.3.5 K^+/ Cl^- ratio:

Fig.(4.25) illustrates the ratio of K^+/Cl^- for the period of 2001-2007, compared to the seawater ratio 0.0182. Fig.(4.25.a), Fig.(4.25.c), and Fig.(4.25.e) show that the samples are close to the seawater ratio, with some exceptions. Fig.(4.25.a) fixed 1.42 as extreme ratio on 3 January 2003, which has 12 dry days before the rainfall event. This might suggest that K+ source in this event is territorial. Fig.(4.25.b) records 4.69 as extreme ratio on 15 January 2003. While Fig.(4.25.c) has 4.66 ratio measured on 23 January 2004, Where it discussed before (see previous section). This might be concluding that on this day the rainfall chemical components have the same source, which is natural source.

Fig.(4.25.f) presents the ratio for the all-period. This one shows that most of the samples are closed to the seawater ratio. At the same time, there are unexplained strange clusters appear in the figure.

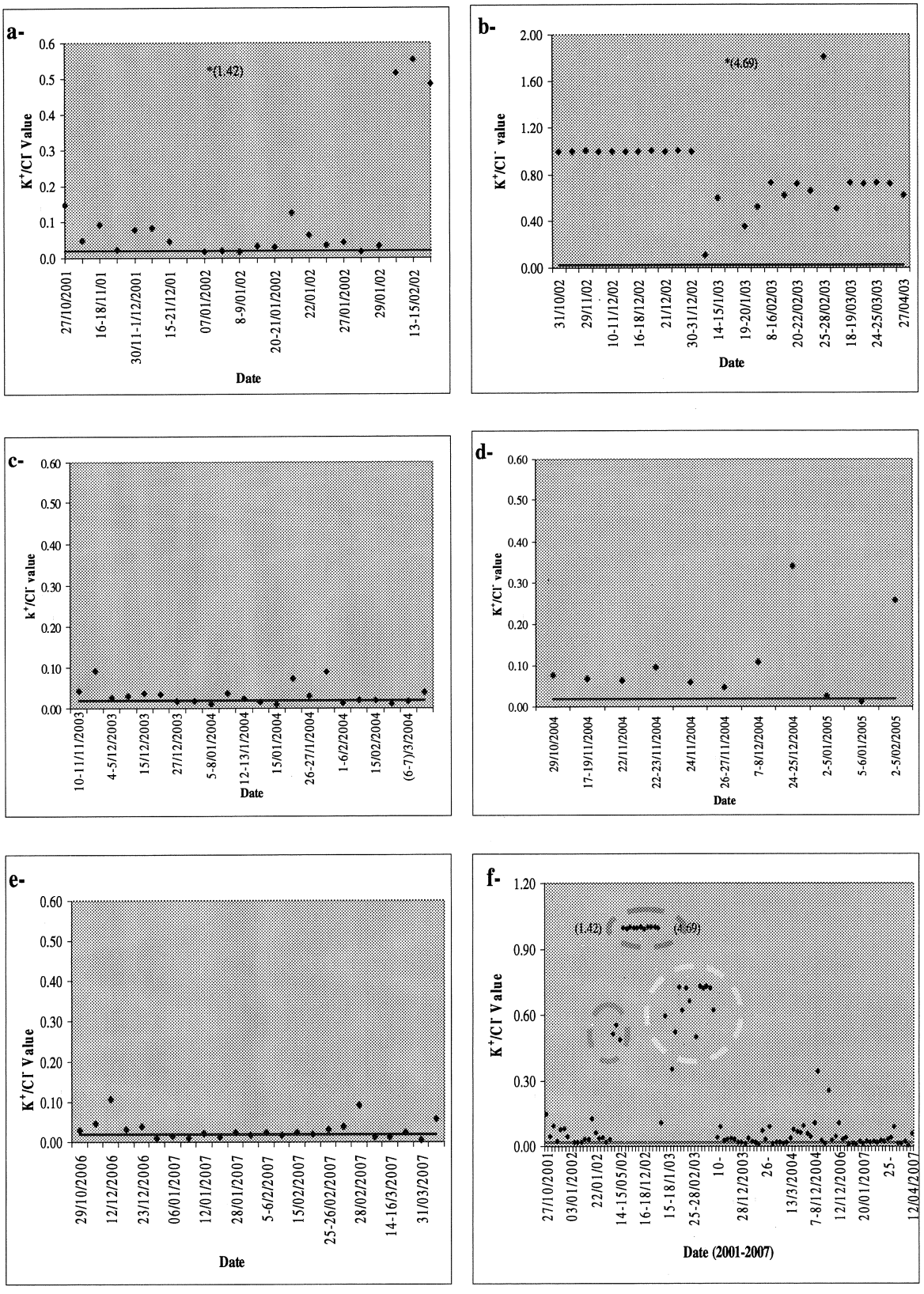


Figure 4.25: Comparison between the K^+/ Cl^- ratio for the samples in the period 2001-2007 with the seawater K^+/Cl^- value (0.098).

Chapter Five

Conclusion and Recommendations

5.1 Main Conclusions

Chemical composition of rainfall samples of Abu Dis Weather Station are analyzed for the period of 2001-2007. The main results are summarized in the following points:

- The arithmetic average for the EC is 159.78, and for pH is 7.1
- The abundance of the analyzed ions is $Ca^{+2} > Na^{+} > Mg^{+2} > K^{+} > NH_4^{+}$ for cations, and $Cl^{-} > HCO_3^{-} > SO_4^{-2} > NO_3^{-}$ for anions.
- The Cl^{-} has a high concentration value, which is agree with the results of different research in Israel.
- The dominant cation in the weighted average concentration is Ca^{+2}.
- There are variations of WA concentration for the different ions during the course of a single hydrological year, and WA concentrations of crustal cations are higher at the beginning of the rainy season in October and November.
- There is no clear relationship between the rainfall intensity and the WA concentration of ions in the same month through different hydrological year.
- The source of Na^{+} and Cl^{-} are the same, which is marine source. While the Ca^{+2} and the Mg^{+2} are sharing the same source, which is terrestrial, on beginning and the end of the hydrological year.
- The results of ratios show that Ca^{+2} source is terrestrial, while the Mg^{+2} is mainly from the marine except in the dry periods. This result is supported by the correlation factor 0.28 between both ions

5.2 Recommendations

1. We recommended studying the influence of meteorological components on the composition of rainfall on Abu Dis weather station for the same period.
2. We recommended designing the "rainfall components profile" for the West Bank for the same period 2001-2007 from the other weather station in the West Bank.
3. We recommended studying the relationship between the rainfall components in Abu Dis and the chemical composition of the groundwater which recharged by these rainwater.
4. We recommended the industrial city in Israel to apply the recommendation in Geneva conference to reduce the pollutants in the atmosphere.

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