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Pollution Effects of the Wastewater Flow on the Groundwater Quality in Wadi-Samen Catchment/ Hebron/Palestine

آثار التلوث بمياه الصرف الصحي على نوعية المياه الجوفية في حوض وادي السمن/الخليل/فلسطين

Submitted by:

Mohammad Zaarir

Student # (1115587)

Supervisor:

Dr. Marwan Ghanem

MSc. Thesis

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By: **Mohammad Zaarir**

Registration #: (1115587)

This thesis was prepared under the main supervision of Dr. Marwan Ghanem and has been approved by all members of the examination committee.

Dr. Marwan Ghanem ....

Main Supervisor

Dr. Hussein Rimawi ....

Member

Dr. Hijazi Abu Ali ....

Member

The findings, interpretations and the conclusions expressed in this study do not necessarily express the views of Birzeit University, the views of the individual members of the M.Sc. Committee or the views of their respective employers.

Dedication

*To my son, "**Kareem**"*

Mohammad Zaarir

March, 2017

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Acronyms and Abbreviations

°C	Degree Centigrade
µg/L	Microgram per Liter
µS	Microsiemens
µS/cm	Microsiemens per Centimeter
ARIJ	Applied Research Institute – Jerusalem
BOD	Biochemical Oxygen Demand
BOD_5	Biochemical Oxygen Demand (after five days)
CEC	Council of the European Communities
cm	Centimeter
COD	Chemical Oxygen Demand
CSO	Combined Sewer Overflow
EC	Electrical Conductivity
EHD	Environmental Health Department
ESC	Environmental Standard Committee
JMP	Joint Monitoring Programme
km/yr	Kilometer per Year
km^2	Squared Kilometer
L/capita/day	liter per capita per day
L/sec	Liter per Second
LRC	Land Research Center
m	Meter
m.a.s.l.	Meters Above Sea Level
m^3	Cubic Meters
m^3/day	Cubic Meters per Day
MDG	Millennium Development Goal
$M.m^3/Y$	Million Cubic Meters per Year
MEPA	Meteorological and Environmental Protection Administration in Saudi Arabia
mg/L	Milligram per Liter
mm	Millimeter
mm/a	Millimeter per Annual
mm/yr	Millimeter per Year
mS	Millisiemens
nm	Nanometer

NTU	Nephelometric Turbidity Unit
PCA	Principal Components Analysis
PCBS	Palestinian Central Bureau of Statistics
pThC	Presumptive Thermotolerant Coliforms
RH	Relative Humidity
RSC	Residual Sodium Carbonate
SAR	Sodium Adsorption Ratio
SPSS	Statistical Package for the Social Sciences
SSP	Soluble Sodium Percentage
SWW	Sarida Wastewater
TDS	Total Dissolved Solids
TH	Total Hardness
UWwS	Urban Wastewater System
WBWD	West Bank Water Department
WHO	World Health Organization
WQI	Water Quality Coefficient
FC	Fecal Coliform
TC	Total Coliform
CFU	Colony Forming Unit
PWA	Palestinian Water Authority

Abstract

The aim of this research is to study wastewater flowing from Kiryat-Arba settlement and the industrial zone in Hebron as a source of pollution in Wadi-Samen in terms of spring water quality. It also aims to identify the different pollutants and their potential sources, their actual impacts on groundwater sources and their effects on the socio-economic aspects on the population of the study area. Thus, identifying possible measures to improve the current situation. To achieve this, water samples for this study it was collected in two phases: the first one included six samples of spring water and five samples of wastewater in the dry season (June, 2015). On the other hand, the second period included six samples of spring water and five samples of wastewater; moreover, these samples were collected in the wet season (March, 2015).

After analyzing the results of wastewater samples using Microsoft Excel, the results showed the enormous existence of BOD_5 more than 250 mg/l and the increase of COD 400 mg/l in wastewater in the valley in dry season due to the contribution to villages of (Al-Hela, Al-Rihiya and Wadi Abu- Al-Asja) which pump wastewater toward the valley.

Because of the correlation between electrical conductivity (EC and TDS), their values may have followed similar behavior in terms of stability in the last part of the valley. In addition, phosphate concentrations (PO^{-3}_4) were not recorded to be over the limit. In contrast, the majority of TSS values have exceeded the limit of 150 mg/l. On the other hand, it was used Excel and Aquachem software packages were used to analyze springs water results that showed a slight indicators of wastewater pollution. Furthermore, in terms of physical parameters, the results showed a clear evidence of wastewater pollution of some springs in both round. This leads to the fact that all studied spring water samples appeared to be acceptable based on the World Health Organization (WHO) standards for freshwater. However, chemically, calcium (Ca^{+2}) was the dominant element, knowing that there were two samples exceeded the allowed limit of concentrations. As for bicarbonate concentration (HCO^-_3), the dry season samples showed excesses of the limits based on the World Health Organization standards. The nitrate (NO^-_3) content, was not detected or observed in spring water.

On the other hand, microbial results showed a strong evidence of spring water pollution due to wastewater; following the presence of high concentrations of bacteria FC and TC compared with results of previous tests carried out by the Palestinian Water Authority (PWA) for a number of studied springs. However, during the last ten years, a large and clear increase in wastewater was being pumped into the valley. For spring water content of the chemical micro-element, the results showed that the concentration has exceeded any of the limits permitted by the (WHO). Even so, abnormal values, especially Cd and Li, which is evident of wastewater pollution. On the other hand, all samples from both periods were categorized under the name of alkaline earth which is suitable for agricultural purposes such as irrigation.

For social survey purpose, results of the questionnaires in the study area were collected and analyzed using SPSS, which confirmed negative effects of wastewater on all aspects of life; such as health, economic and environmental. Regarding health aspects, the negative impact was clear on the overall health of the population, according to 95% of the target population sample. Economically, around 45.5% of people abandoned their agricultural lands near the valley due to the ongoing effects of wastewater. In addition, 80% of the people are convinced that their land productivity is no longer as it was before. Overall, 90% of the targeted people suffer from the negative effects of the flow of wastewater in the valley, and 20% have changed their residence. According to 80% of people of that area, the wastewater flow through the valley negatively affected the aesthetic landscape.

الملخص بالعربية

يهدف هذا البحث إلى دراسة المياه العادمة القادمة من مستعمرة كريات أربع و المنطقة الصناعية في الخليل كمصدر لتلوث وادي السمن من حيث جودة الينابيع في هذا الحوض، كما يهدف إلى تحديد الملوثات المختلفة ومصادرها المحتملة وتأثيراتها على مصادر المياه الجوفية وعلى الجوانب الاجتماعية -الاقتصادية لسكان منطقة الدراسة، وتحديد التدابير الممكنة لتحسين الوضع القائم .ولتحقيق ذلك فقد تم عمل فحوصات كيميائية وفيزيائية وبيولوجية لبعض الآبار الارتوازية والينابيع وذلك ضمن جولتين مارس 2015 و يوليو 2015 حيث تم أخذ ستة عينات من مياه الينابيع واجريت الفحوصات المخبرية لعدد من العناصر متضمنا الفوسفات، النيترايت، البيكربونات، البوتاسيوم، الصوديوم، الكالسيوم، المغنيسيوم، الكلورايد، مجموع العناصر الذائبة، الموصلية الكهربائية، درجة الحموضة، والبكتيريا القولونية.

أما بخصوص تحليل نتائج عينات المياه العادمة بواسطة تطبيق Microsoft Excel ، أظهرت نتائج التحليل وجود تجاوزات في تراكيز ال BOD_5 في عينات المياه العادمة بالإضافة لزيادة في تراكيز ال COD مع تقدم المياه العادمة في الوادي في الموسم الجاف بسبب مساهمة قرى (الحيلة و الريحية و وادي ابو العسجا) في ضخ المياه العادمة باتجاه الوادي.

وبسبب العلاقة المتبادلة بين الموصلية الكهربائية EC و TDS فإن قيمتيهما قد سلكتا سلوكا متشابها من حيث ثباتها في الجزء الأخير من الوادي، ولم تسجل تراكيز الفوسفات PO_4^{-3} ايضا أي تجاوزات عن الحد المسموح .على عكس ذلك فإن معظم قيم TSS قد تجاوزت الحد المسموح وهو 150 mg/l.

من ناحية اخرى تم استخدام تطبيقي Aquachem و Excel من أجل تحليل عينات مياه الينابيع المدروسة ، وقد أظهرت النتائج وجود دلائل واضحة على التلوث بالمياه العادمة في كلتا الجولتين لبعض الينابيع. فيما يخص المتغيرات الفيزيائية فإن جميع عينات مياه الينابيع المدروسة ظهرت مقبولة اعتمادا على معايير منظمة الصحة العالمية بخصوص المياه العذبة.

أما كيميائيا فقد لعب الكالسيوم Ca^{+2} دور العنصر المسيطر مع العلم أن هناك عينتان قد تجاوزتا حدود التراكيز المسموحة .أما بالنسبة لتراكيز البيكربونات HCO^-_3 حيث سجلت عينات جولة الموسم الجاف تجاوزات عن حدود منظمة الصحة العالمية .أما محتوى النترات NO^-_3 فلم يشهد أيضا تجاوزات في مياه الينابيع.

بالنسبة للنتائج الميكروبية فقد أظهرت دليلا قويا على تلوث مياه الينابيع بالمياه العادمة، إثر وجود تراكيز عالية من بكتيريا FC و TC بالمقارنة مع نتائج تحاليل سابقة قامت بها سلطة المياه الفلسطينية PWA لعدد من الينابيع المدروسة.

أما فيما يخص محتوى مياه الينابيع من العناصر الكيميائية الثقيلة، فقد أظهرت النتائج عدم تجاوز أي تركيز لها للحدود المسموحة من قبل منظمة الصحة العالمية .رغم ذلك فقد ظهرت قيم غير طبيعية خاصة الكادميوم Cd و الليثيوم Li والذي يعتبر دليل على التلوث بالمياه العادمة .من ناحية أخرى فقد صنفت جميع عينات الينابيع لكلتا الجولتين تحت مسمى القلويات الترابية وهي جيدة وملائمة للأغراض الزراعية مثل الري.

اما بخصوص المسح الاجتماعي فقد تم جمع نتائج الاستبيانات في منطقة الدراسة وتحليلها بواسطة برنامج الحزمة الاحصائية للعلوم الاجتماعية (SPSS) والتي أكدت الآثار السلبية لمجرى المياه العادمة على جميع مناحي الحياة والتي قسمت إلى صحية واقتصادية وبيئية .فيما يتعلق بالجوانب الصحية فقد كان التأثير السلبي واضحا على الصحة العامة للسكان وفقا ل % 95 من عينة السكان المستهدفة، ومن الناحية الاقتصادية فإن حوالي % 45.5 من أفراد العينة قد هجروا أراضيهم الزراعية القريبة من مجرى الوادي بسبب تأثيرات المياه العادمة الجارية فيها، إضافة الى قناعة % 80 من العينة بانخفاض إنتاجية الاراضي لديهم .بشكل عام فإن 90 % من العينة المستهدفة يعانون من الآثار السلبية لجريان المياه العادمة في الوادي، وما نسبته % 20 قاموا بتغيير مكان سكنهم بسبب ذلك .ووفقا ل % 80 من أفراد العينة فقد تأثرت المناظر الجمالية للمنطقة سلبا بجريان المياه العادمة خلال الوادي.

Chapter One

Introduction

1.1General background

Groundwater is an important source of potable, agricultural and industrial water supply and use (Qannam, 2003). Groundwater is considered to be the main source of water in the West Bank, so, it is essential to protect its quality from deterioration and contamination; especially when it is subjected to human activities; such as, leakage of municipal wastewater which flows down to groundwater, or depletion of groundwater because of withdrawal rates significantly exceed recharge. Groundwater contamination is a critical issue due to the importance of groundwater supply and quality in water security for basic needs. Overall, groundwater contamination has become a major concern in the recent years worldwide (Susmaq, 2002). The major sources of water pollution in the West Bank is the raw wastewater that is discharged in wadi. Sewage collection networks are limited to general big cities most of which are poorly designed and old. Therefore, leakage and flooding exist in these systems. West Bank wastewater is usually collected and discharged without any treatment into open areas in valleys area. Many contaminated wells and springs by nitrate and coliform bacteria in West Bank aquifers are no longer fit consumption use without prior treatment (Samhan et al, 2010). There are a number of increasing problems of contamination in the West Bank aquifers caused by the lack of adequate infrastructure to treat wastewater. The groundwater wells and springs in the West Bank are certainly influenced by the domestic wastewater leaching from the widespread cesspits and runoff in the rural and urban areas (Hamarshi and Al-Masri, 2012). Wadi-Samen is located over a permeable geological area which is considered as a good water catchment area that supports the eastern groundwater aquifer with harvested rainwater, thus the flow of wastewater in this environmentally sensitive area will create an environmental crises and resulted to deteriorated the ground water quality (Figure 1.1), (PWA, 2001).

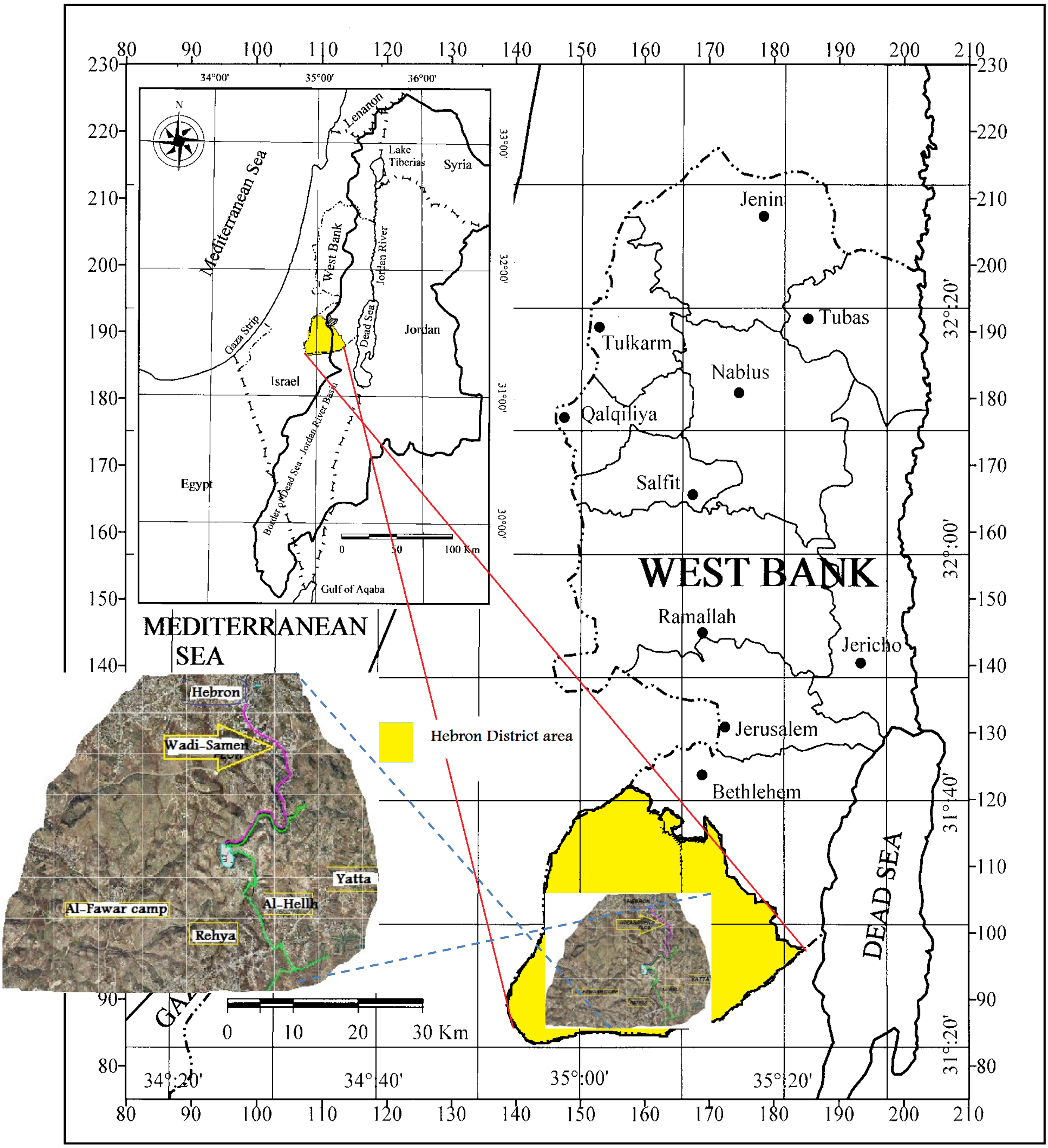


Figure 1.1: Location of the study area (Wadi-Samen) in Hebron/Palestine.

1.2 Problem statement

Wastewater flow in Wadi-Samen without treatment (Figure 1.2). And it's drained in a large area of more than twenty kilometers. Its flow is infiltrated along the Wadi and affects the groundwater in Wadi-Samen catchment. The effect of the detiorated-infiltrated water to the groundwater recharge was studied and evaluated. Moreover, the socio-economic, environmental effect of this flow to the groundwater recharge has to be determined. Wastewater flow of Wadi-Samen affects cultivated crops and soil quality. Additionally, the flow of wastewater in Wadi-Samen affects many towns and villages in Hebron governorate through creating health problems and environmental to the local residents and its surrounding areas. The flood of the sewage water affects the environmental quality of the surrounding agricultural lands. The affected agricultural lands in study area is about 5000 km^2, which is mainly cultivated with fruit trees and cultivated crops. Protecting water sources from pollution, mainly in Palestine which faces water resources scarcity, considered as an important concern. Wadi-Samen area is affected by several pollution sources. The main source of pollution by wastewater is from the nearby Israeli settlements and the Palestinian community. As a hypothesis, which present work aims to prove, the wastewater will adversely affect the surface water, groundwater and the social and economic aspects of people's life of that area.

1.3 Research objectives

1. Determining the suitability of the groundwater well's and spring's water for domestic and agricultural uses.
2. Determination of sources of pollution on Wadi-Samen and its effects on springs water and groundwater quality which are located along the area.
3. Study the water quality variations along Wadi-Samen in different stages.
4. Study the effect of wastewater on the social and economical aspects of residence life in the area.

1.4 Research motivations

1. The need for potable water for drinking, domestic use, agricultural and industrial.
2. The quality and the degree of contamination of the water in springs through chemical and microbiological parameters.
3. Ease of data manipulation and know the type and degree of contamination of water by using geographic information systems technology and Aquichem program.

1.5 Research methodology

By using mapping the existing target water resources, water sampling and measurement that to be taken during the study. Additionally, field work and field surveys which were basic modules in every aspect of this study. Research plan was carried on March, 2015 to June, 2016. Two sampling campaigns of wastewater, spring water and groundwater wells in the area will be conducted; first in March, 2015 and second in June, 2015 in order to compare wastewater effects on water resources in the study area, and data about water use and allocation will be collected. In addition, the surrounding environment around each spring will be studied. The samples were analyzed at the laboratory of Birzeit University for major (cation, anion) and laboratories of the Ministry of Health to disclose of the trace elements constituents, and some of heavy metals, by using the chemical analysis of spring water and wells (Karanth, 2008). Among of these analyses were heavy metal concentrations (Pb, Ag, Cd, Fe, Cr, Al, Co, Ni, Cu, Zn, Mn, Be, Mo, V, Sr, Ba, Li, Ga) and major, minor concentrations, chlorine, sodium, nutrients as nitrate, sulfate, carbonate, bicarbonate and phosphate as hydrochemical parameters. The physical parameters are pH, BOD_5, COD, TSS, TDS, EC and the biological parameters, total coliforms and fecal coliforms. The other part of methodology is the questionnaire that was designed for this study, seeking for representing most of the life's aspects, it consists of the three following sections:

- Socio-Economic section
- Healthy section
- Environmental section

The survey will be conducted for a random sample, which amounted to 100 persons of Al-Rehiya, Rabod and Abu-Asja citizens (Appendix 11).

The results will be analyzed through SPSS Statistics application; a software package that is used for statistical analysis. The survey results will be presented by means of tabulations, charts and graphs.

Figure 1.2: Open wastewater flow in Wadi-Samen catchment area. (Zaarir, 2017)

1.6 Literature review:

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

Study of the chemical and physical properties of Ma'in springs, waterfalls and the distribution of Blue-Green Algae types (Mahasna, 1999) showed the chemical and physical properties of water springs and waterfalls of Ma'in located east of the Dead Sea. The study aimed at measuring the chemical content and elements in springs, and defining species and varieties of algae found in that area. The chemical and physical characteristics of the water springs in the study area show that the hydrogen sulfide emissions at the top of the spring and the high rate of sulfate, which reached (350 mg/l), are the most important characteristic of that water. In addition, the characteristics show that the amount of dissolved oxygen ranging around (6.2 mg/l) and gradually decreases in running water till it reaches zero when it's 10 cm deep in muddy areas. However, the study is designed to field and laboratory work in analyzing samples and performing various measurements required for the study.

(Abed Rabbo et al., 1999) assessed the water quality of the West Bank springs from 1995 to 1997. About 400 samples were collected and analyzed. The main contaminants in springs were nitrate and coliform bacteria from sewage. The majority of the samples for microbiological analyses were found to be contaminated by infectious sources. It is likely that the contamination is due to the spring's location close to downstream from infectious sources such as sewage from cesspits, sewer network leakages, or sewage discharged directly to wadis and open ground.

In (Miqdad and Baroud, 2012) study, titled wastewater and its impact on the underground reservoir in Deir Al-Balah governorate (the study of the environment), showed the impact of wastewater resulted from: humans in Deir Al-Balah governorate, and the lack of sewage systems (where the researcher explained that the wastewater flow on the surface of the earth and the deposition of large amounts of them into the ground to reach groundwater; therefore, underground water gets contaminated and thus becomes unsuitable for drinking). This all resulted in the high proportion of salts, total dissolved solids and chloride.

In order to know the quality of water and to clarify the degree of polluted groundwater in the study area, a number of wells used for drinking in the governorate were conducted for laboratory analyzes. It also showed toxicity symptoms in humans as a result of using this water for drinking purposes because it contains high concentrations of nitrates (NO^-_3) and nitrite (NO^-_2). Furthermore, the study made clear of the contamination of areas feeding underground reservoir by human sewage and the deterioration of groundwater quality in Deir Al-Balah governorate, where the aquifer is contaminated and unsuitable for human use.

Another study was carried out by the (Qannam, 2003), based on the EC, SAR, SSP and SCR the study showed the sampled water resources are generally of excellent to good irrigation water quality. Additionally, increased portions of alkalis, chloride and sulfate in the springs and wells located near houses which caused by poorly designed cesspits and/or the infiltration of the leachates from washing the piles of animals dung, collected for agricultural purposes.

(Awadallah and Owaiwi, 2005) studied the hydrogeology and hydrochemistry of springs and groundwater of Hebron district. Extremely polluted springs and wells with nitrate and no significant salinity problem are found. The microbiological quality test of the water indicates that only 20% of the springs and dug wells are coping with the standard value. The wide distribution of cesspools and septic tanks in the West Bank cause rapid contamination of aquifer systems through karstic conduits in the area.

The chemical study of water in Natouf located in the western mountains of Ramallah (Shalash, 2006) showed the chemical properties of water in the study area. The study pointed at the natural characteristics of rocks in the region which are of limestone and calcareous dolomite. In addition, the study identified pollution sources and its impacts on the quality of the spring water; the impact of pollution on water springs. As a result, a number of water samples were collected and chemically analyzed. Afterwards, the findings were that the majority of spring water in the study area are suitable for drinking and agriculture, except that some of them contained fecal bacteria as a result of wastewater leakage to it; especially Ain Al-Alaq, Ain Ayub and Ain Musbah springs. Nevertheless, the high proportion of nitrates because it's located near population centers, agricultural activities in the region and the effect of water rocks on water elements.

In (Samhan, 2007) study, titled “The hydrogeological hydro-chemical study of Tulkarem;” located in the north-west of the West Bank, explained the environmental situation of groundwater in the study area through examining water and analyzing laboratory results. As well as, clarifying the impact of human activities on groundwater contamination. However, the study used hydro-chemical programs to find out the chemical elements percentage in the water and explained the nature of rocks of the region in the groundwater basin which is fed from the geological formations of the cretaceous period (Jerusalem, Bethlehem and Hebron). The findings of this study were: first, there is a clear evidence of the different human activities that contaminate groundwater such as agricultural activities led to the leak of some chemicals into the groundwater as a result of excessive usage of agricultural pesticides. Second, wastewater leakage due to the lack of sewage systems in the study area which showed that most wells are characterized by Alkaline/dirt wells leading to contamination of some wells with chloride and nitrate ions. Moreover, it turned out that the western part of the north-western part of the Alauajja basin is the most subject to contamination.

(Nazal and Aliewi, 2007) study showed the sensitivity of West Bank water resources for pollution in the western basin. The researcher relied on the hydrogeological side by measuring the groundwater depth, basin center, soil nature and the topography of the region. The study also relied on determining the properties of rock layers and the water flow, and relied on identifying feeding areas. However, the study aimed at producing a map showing groundwater contamination sensitivity. It was clear that the high sensitivity found in a rocky areas; especially of Jenin north of West Bank and medium sensitivity in the eastern parts of Tulkarem and Bethlehem. Whereas low sensitivity areas were found in Hebron governorate; wastewater, solid waste, industrial waste and agricultural waste turned out to be the main sources of pollution in the study area.

(Samhan et al., 2010) assessed the domestic water quality in the West Bank aquifers for major parameters such chloride, nitrate, sodium, potassium, sulfate, and other biological indicators such as T. Coliform and F. Coliform. About 90 springs and wells used for domestic purposes were analyzed. The study showed that the main sources of contamination encountered in domestic sources in the West Bank aquifers are from domestic wastewater, agriculture activities and direct discharge of wastewater in Wadis without any type of treatment.

(Easa and Abou-Rayan, 2010) after evaluating the domestic wastewater effect on the pollution of the groundwater in rural areas in Egypt. In this study, groundwater (from a well's used for irrigation and drinking) samples were taken. At different periods of time, a series of chemical analysis was carried out for water samples. The study showed the domestic wastewater which discharged into soil and aquifers without any type of treatment caused seriously dangerous on local people and plant crops.

A study of cesspits impact on spring water pollution in Natouf basin west of Ramallah was carried out by (Bader, 2011) which focused on spring water in Deir Ammar, Jamala, Der Bzaa, Ni'lin, Ein Areek, Ein Qinya and Beitillu. In order to know the impact of wastewater on water springs, examining spring water samples and distributing a questionnaire to residents of the study were carried out. Some of the study results were that some springs were polluted by wastewater from cesspits and high proportion of calcium and sulfate from agricultural pesticides leakage to groundwater. This study had to focus on the nature of the rocks in the study area and their impact on the quality of spring water in the area. In addition, develop geological maps to illustrate rock layers because the rock type in any area affects the water quality within the rock layers; therefore, it was important to have a part of the study tackles this issue.

(Hamarshi and Almasri, 2012). Study identification and assessment of potential impacts of cesspits on groundwater wells in Tulkarm district. This is achieved through using groundwater modeling on the area's water springs and wells. Results of study confirmed that the cesspits considered as one of the main sources of pollution for many groundwater wells in the study area.

(Ghanem and Abu Allan, 2013). This study highlights the environmental situation of the Al-Zarqa reserve's water quality, which is located in west Beitillo. This is achieved through chemical and physical experiments on the area's water springs, and through defining the percentages of the components/elements. The study shows that the most significant sources of pollution in the region is due to the presence of cesspit near the water of the spring specially Abu Issam and Al-bawale springs.

A study was carried out by the (Bader and Ghanem, 2013), the socio-economic impact for the spring water use in Natouf catchment/Ramallah west–Palestine**.** The study showed the effect of cesspits in contaminating groundwater and springs, and the study of socio-economic impacts in the use of spring water to human life. This study done by analyzing the results of the questionnaire, which was distributed to a number of farmers and residents in the study area, where the study showed that the pollution sources of spring water produced from solid waste dumping in the landfill near of the study area, and wastewater from Israeli settlements in these area.

In a study conducted by (Jebreen and Ghanem, 2014), hydrochemistry and isotopes of the spring water in Soreq catchment, Ramallah, West Bank. Which showed that the spring water quality is generally low, and comparing the spring water in the study area with international specifications for different uses, that showed some of the springs is not suitable for human use, such as Ein Beit Surik and Ein Albalad, but its suitable for agriculture and irrigation, except some samples which are poor due to high salinity, and is found in most of the spring water to be contaminated with Bacteria E. coli, and the high proportion of nitrates in some springs, and the reason of this pollution is wastewater leakage into groundwater in study area.

Chapter Two
Description of the Study Area

2.1 Location and topography

Hebron city located 36 km south of the Jerusalem city, in the southern part of the West Bank. It is bordered by the Bethlehem governorate to the north and the occupied territories in all other directions (Figure 2.1).

Total area of the Hebron governorate 1,067 km^2, these areas are divided into:

Palestinian areas, Israeli settlements, closed military areas, forests, natural reserves and cultivated areas.

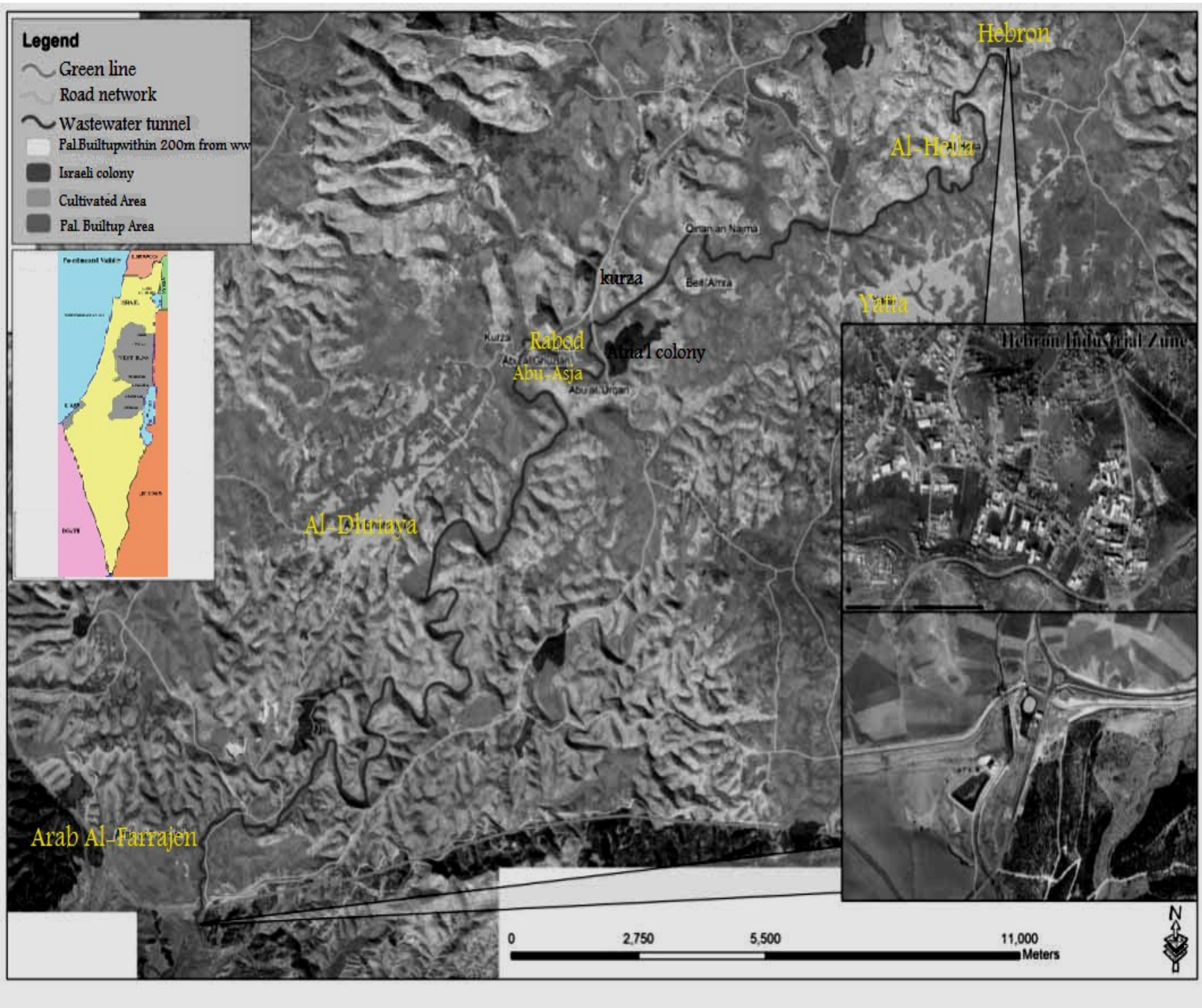
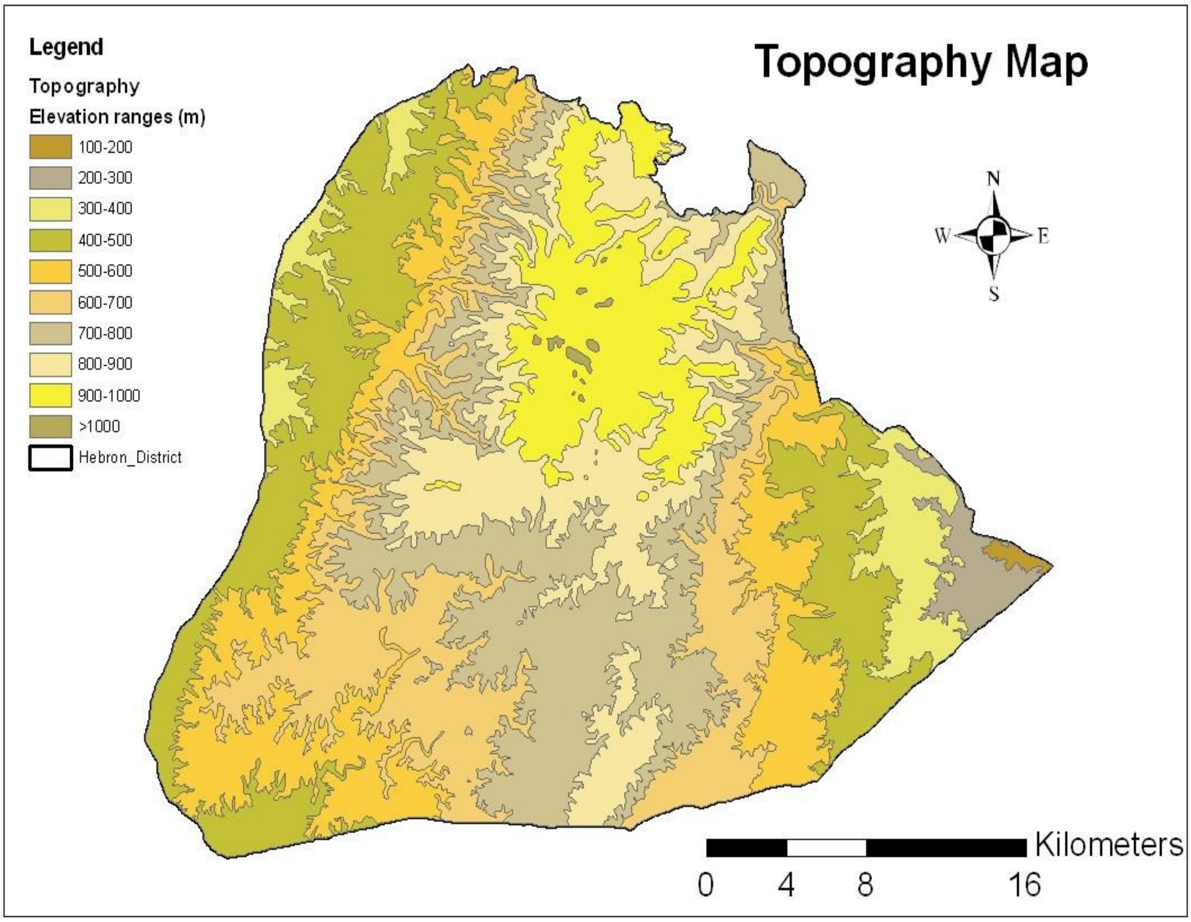


Figure 2.1: Location and borders of Hebron governorate (Palestine Technical University-Kadoorie, 2012)

The features of the Hebron area are characterized by a big difference in its topography and altitude (Figure 2.2). In Eastern side of the governorate are the Jordan Rift Valley. Its elevation varies between 140 m below sea level and 1,014 m above sea level. The highest point is Halhul with the elevation of 1,014 m above see level, and is also the highest point in the West Bank. The lowest elevation is 140 m below see level at Ar Rawain area.



Fiugre 2.2: Topography of Hebron governorate (Arij, 2009)

2.2 Soil

Despite the small size of West Bank, it have variety of soils. The major causes of this variety are: climate change, variable geology, different topographic circumstances and physical weathering. Terra Rossa stemming, brown and pales rendzinas. This soil association dominates the hilly and mountainous areas (Figure 2.3). The brown rendzinas are dark to very dark brown, parent materials are mostly from marl and chalk. According (PWA, 2012), terra Rossa has a reddish brown color and its depth varies between 0.5 m at the mountainous areas and up to 2 m at the hilltops. Also, pH of this soil ranging from (7.5-8).

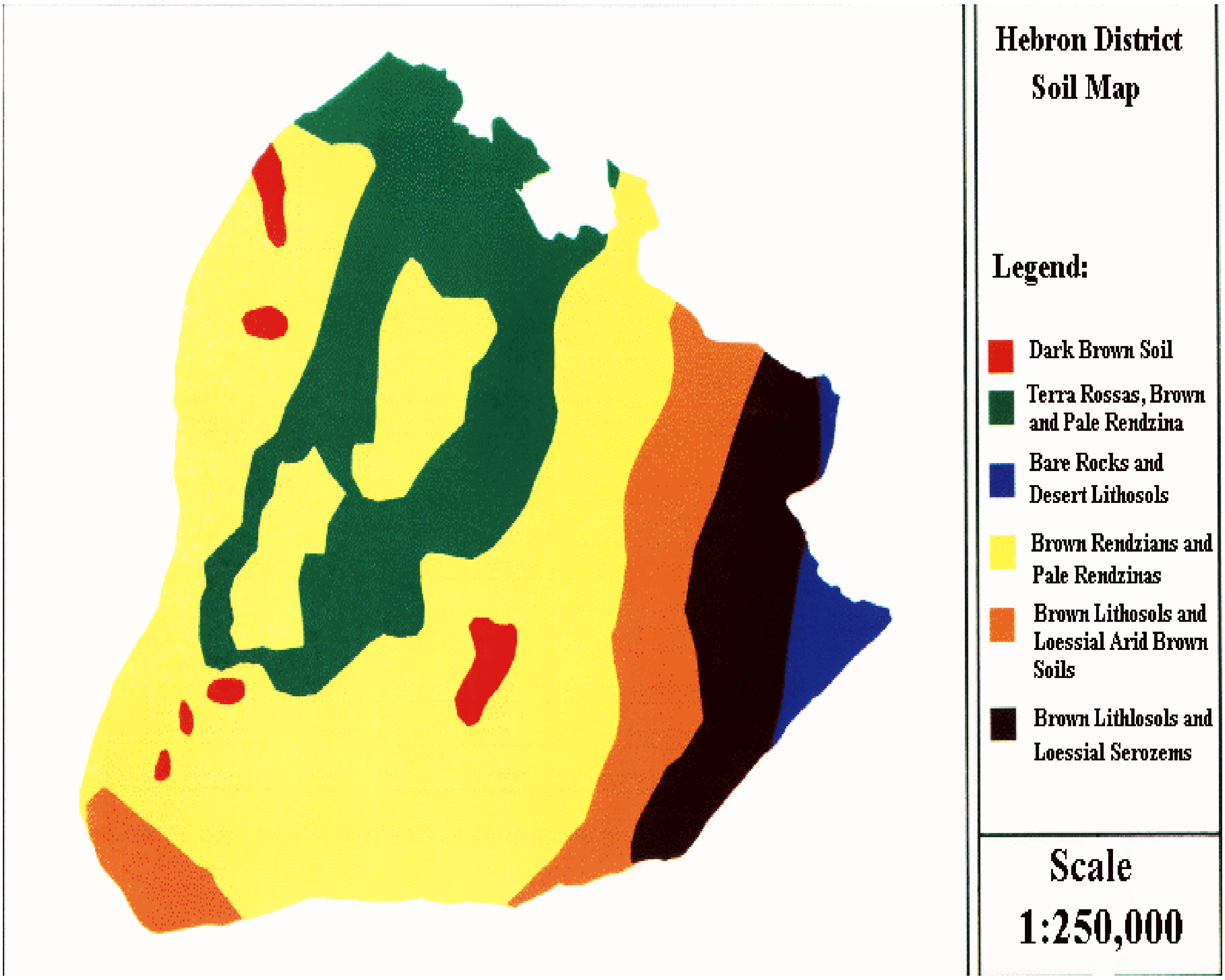


Figure 2.3: Hebron district soil map (Arij, 1995)

2.3 Land use

Wadi-Samen basin surrounded by all or part of seven Palestinian communities, Hebron, Yatta, Al-Rihiya, Al-Fawwar Camp, Dura, Al-Dahriah, Al-Samu' and parts of 3 Israeli settlements: Qriat Arb', Bet Hajay and A't nae'l. In this area could be identified various land use activities (Figure 2.4).

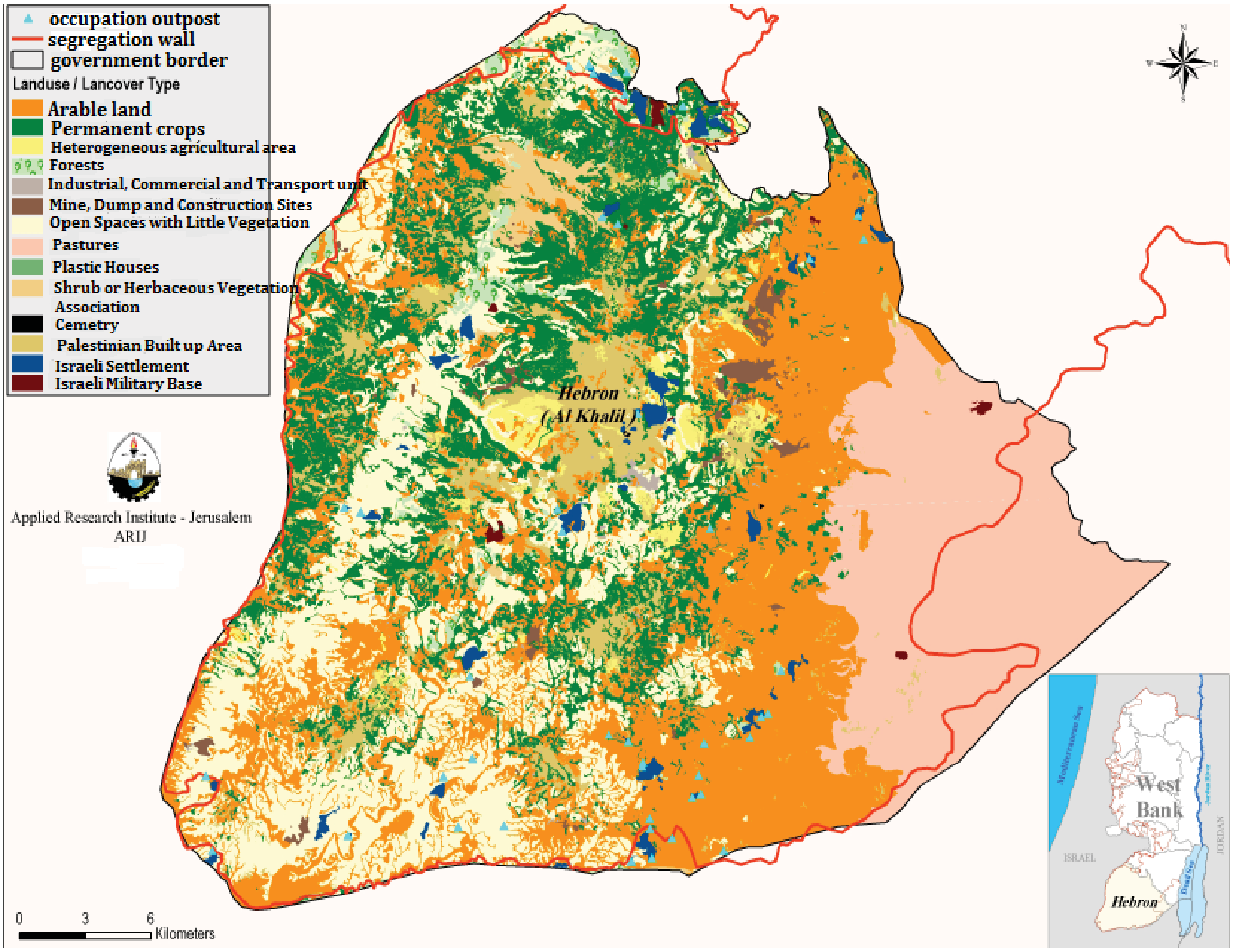


Figure 2.4: Land use/Land cover in Hebron governorate (Arij, 2009)

2.4 Population

According to (PCBS, 2016), Palestinian population of Wadi-Samen basin was about 25,850 inhabitant; 7700 in Al-Fawwar Camp, 1050 in Kurza, 2900 in Raboud and Abu al-Asja, 4670 in Al-Rihiye, 3400 in Zif, 1870 in Al-Hella.

2.5 Meteorology

2.5.1 Climate

According to (PWA, 2012), climate in study area are highly influenced by the Mediterranean climate, which is characterized by long, hot, dry summer and short, cool, rainy winter. Rainfall is mostly between winter and spring months, between November and March; summer is completely dry. Hail and snow, may fall in the area especially over the highland, Halhoul, Hebron and Dura (Arij, 2009).

2.5.2 Rainfall

The nature of the climate in the Hebron governorate trend to semi-arid and as Mediterranean (dry sub-humid). The winter season as the wet season, influenced by the Mediterranean climate. Precipitation ranging from heavy to light.

Annual average rainfall is 540 mm were about 75% of the annual rainfall that fall between November and March. In April the precipitation are generally decrease, while in May, June, July and August are almost without rain (Figure 2.5). Rain falling heavily just in December and January (PWA, 2013).

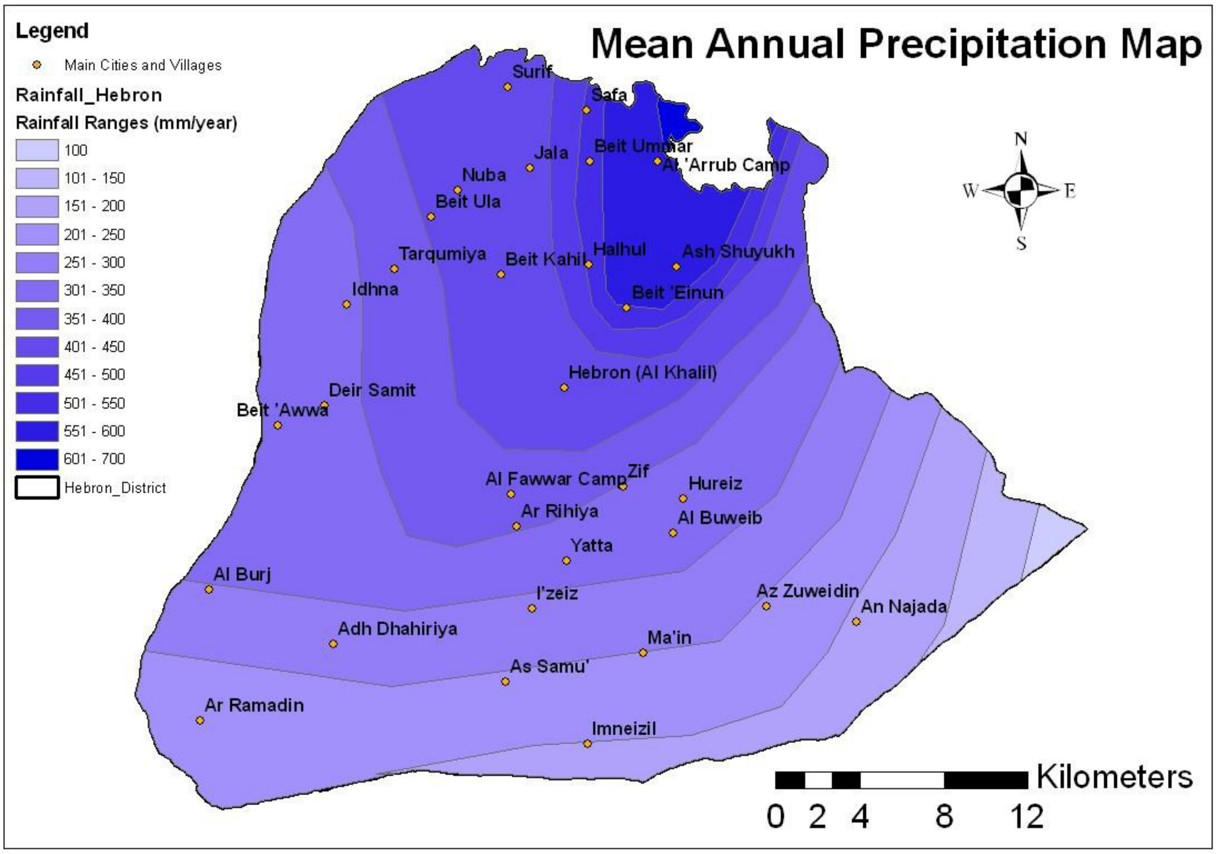


Figure 2.5: Mean annual rainfall (mm/y) in Hebron governorate (Arij, 2009)

2.5.3 Temperature

The mean annual temperature in the study area varies from 19 ^{0}C to 21 ^{0}C, and decreases to 15 ^{0}C at mountainous regions. At these mountainous area, the average temperatures vary slightly from one part of the region to another depending on the altitude. Lower temperatures characterize Hebron and Halhuul areas, which include mountainous areas with elevations exceeding 1,000 m above sea level. The average monthly air temperature in the study area was 8 ^{0}C in winter and 26 ^{0}C in summer, a maximum average monthly temperature of 38 ^{0}C and a minimum temperature -3 ^{0}C.

2.5.4 Runoff and surface catchment area

All the drainage systems in Hebron district area originated from the inland Hebron mountains and are largely controlled by a few streams flowing. Therefore, almost all the water flowing to Hebron district watersheds coms from the relatively high rainfall areas of the mountains.

The major drainage systems, which flow westwards in study area are, from north to south, Wadi Al-Qadi, Wadi-Samen and Wadi El Dore. Wadi Nar is flowing to the south, but they change their direction to the west after crossing the border of Hebron district.

2.6 Geological setting

2.6.1 Stratigraphy and lithology of the West Bank

The lithology and stratigraphy in the West Bank includes of several formations (Qannam, 2003), which were formed during different geological ages (Figure 2.6). These rock formations of the west bank are:

1. Albian – lower cretaceous formations includes of regional west bank groundwater system (Yatta formations and Beit Kahil). These formations are composed mainly of limestone, dolomite, marl, chalk and clay. The thickness of the groundwater 500-970 m (PWA, 2013).

2. Upper cretaceous formations includes regional west bank groundwater system (Hebron, Jerusalem formations and Bethlehem). These formations are composed mainly of hard limestone, dolomite, marl, and conglomerate. The aquifer thickness in this area ranges from 190-490 m (PWA, 2013).

3. Senonian age rocks are consisted mainly of chalks and marls. The aquifer thickness in this area ranges from 0-450 m (PWA, 2013).

4. Pleistocene to Eocene age rocks overlay the senonian age rocks in the northeastern and northern area of the West Bank, the rocks are composed mainly of limestone, chalks, chalky limestone, siltstone and marls, which are of limited thickness and extent (PWA, 2013).

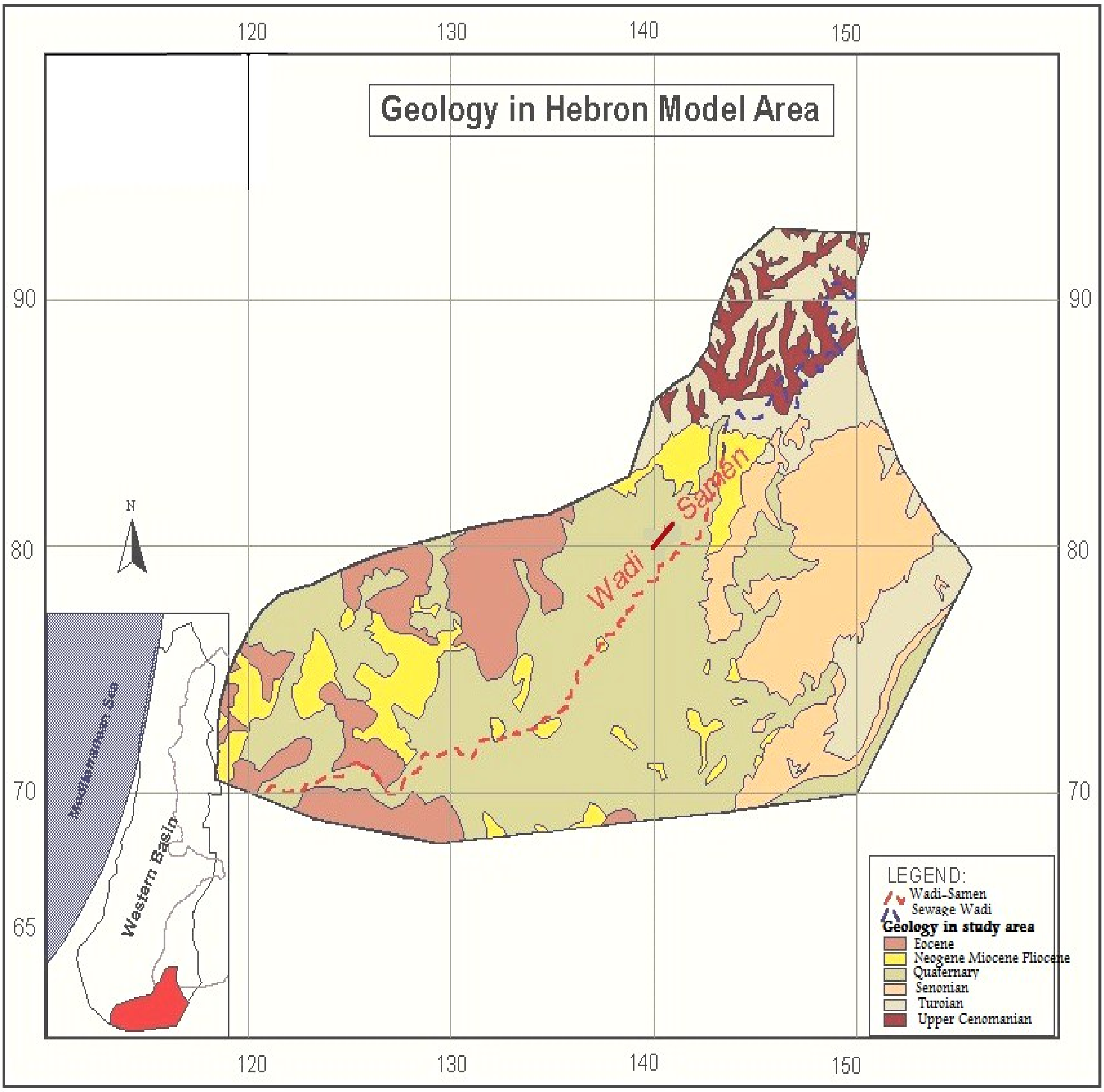


Figure 2.6: General geological and structural map of Hebron (Susmaq, 2002)

2.6.2 Geology and stratigraphy of Wadi-Samin drainage basin

According to (Rofe and Raffety 1963), the geological structure of the study area is composed of sedimentary carbonate rocks of Albian to Eocene age. The oldest formation were exposed along the Hebron anticline and the formation become younger westward and eastward (Figure 2.7). The floors of the study area covered by quaternary alluvial deposits (Susmaq, 2002). The following sentences give an a detailed explanation to the general lithostratigraphy of the Hebron district that build up the aquifers in the study area (Figure 2.8).

1. Kobar formation (Aptianto Albain).

Kobar formation is expected to be exposing near jala village and to the west of Halhoul town. It composed mainly of limestone, marl and marly limestone. In some location it consist of intercalation of marl and limestone.

2. Yatta formation (Lower Middle Cenomanian).

The main structure of Yatta formation are contains fin to medium crystalline dolomite and limestone, yellowish and brown. In some places it composed of marly limestone, usually highly enriched with fossilized fauna. The thickness between 50-130 m.

3. Hebron formation (Upper Middle Cenomanian).

The formation of Hebron district composed of hard and massive dolomite or limestone it's Hebron area combination. It is highly karstic. The thickness ranges between 20-120 m.

4. Alluvial formation (Quaternary).

Alluvial deposit and other unconsolidated sediments, such as clay, silt, gravel and conglomerate are deposited in the floors of the study area with thickness reaches 10's of meters. The red color of the alluvium is due to its origin from limestone.

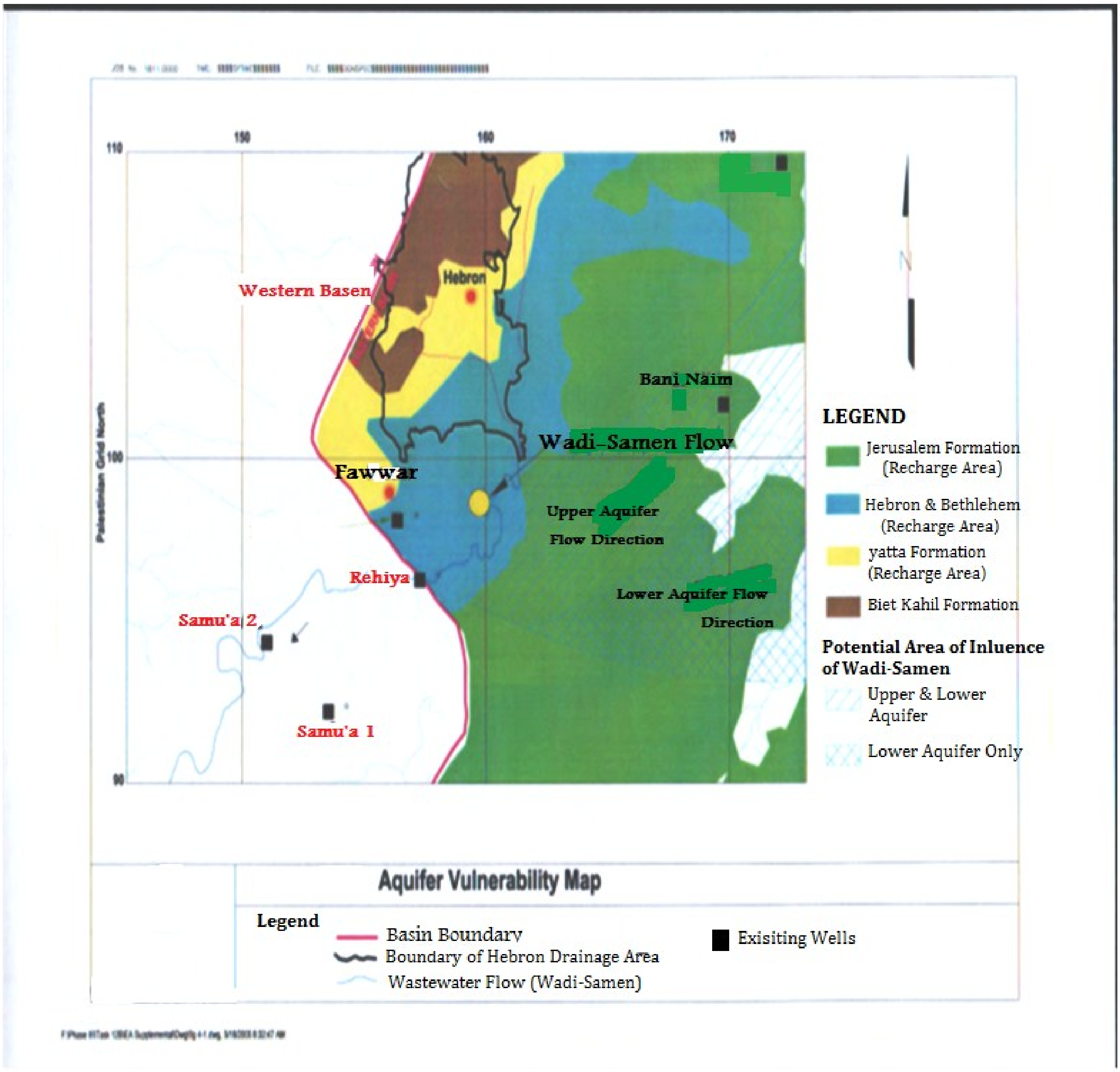


Figure 2.7: A geological and structural map of Wadi-Samen drainage basin (USAID, 2005).

Period	Age	Typical Lithology	Formation (West Bank Terminology)	Sub-Formation	Group	Symbol		Formation (Israeli Terminology)	Hydro-stratigraphy	Typical Thickness (m)
Quaternary	Holocene	Nari (surface crust) and alluvium Gravels and fan deposits	Alluvium		-	Qh-a		Alluvium	Local Aquifer	0 - 100
	Pleistocene	Thinly laminated marl with gypsum bands and poorly sorted gravel and pebbles	Lisan			Qp-l		Lisan\Kurkar Group	"Aquitard"	10 - 200
Tertiary – Neogene	Miocene Pliocene	Conglomerates, marl, chalk clay and limestone	Beida			Tmp-b		Saqiye Group	Local Aquifer	20 - 200
Tertiary – Paleogene	Eocene (Lower - Middle)	Nummulitic reefal Limestone	Jenin	Jenin 4	Jenin	Te-j	Te-j4	'Avedat Group	Aquifer	90 - 670
		Nummulitic bedded Limestone		Jenin 3			Te-j3			
		Nummulitic Limestone,Chalk		Jenin 2			Te-j2			
		Chalk ,Nummulitic Limestone		Jenin 1			Te-j1			
	Paleocene	Marl,Chalk	Khan Al-Ahmar		Nablus	Ks-n	Ks-ka	Mt.Scopus Group	Aquitard (Local Aquifer)	40 - 150
Cretaceous – Upper – Senonian	Maastrichtian Danian	Chalk ,Marl								
	Campanian	Main Chert ,Phosphate	Wadi Al-Qilt				Ks-aq		Aquiclude	10 - 120
	Coniancian-Santonian	Chalk and Chert	Abu Dis				Ks-ad			0 - 450
Cretaceous – Upper	Turonian	White Limestone ,stilolithes	Jerusalem	Upper	Ramallah (West Bank)	Kc-j	Kc-ju	Bina	Upper Aquifer (Mountain Aquifer System)	40 - 190
		Limestone and Dolomite		Middle			Kc-jm			
		Yellow thin bedded Limestone		Lower			Kc-jl			
	Cenomanian	Dolomite,soft	Bethlehem	Upper		Kc-b	Kc-bu	Weradim		50 - 210
		Chalky Limestone,Chalk		Lower			Kc-bl	Kefar Sha'ul		
		Karstic Dolomite	Hebron			Kc-h		Amminadav		65 - 160
		Yellow marl	Yatta	Upper		Kc-y	Kc-y2	Moza	"Aquitard"	50 - 125
		Lime & Dolostone,Chalk,(Clay)		Lower			Kc-y1	Beit Meir		
Cretaceous – Lower	Albian	Reefal Limestone	Upper Beit Kahil	UBK2		Ka-ubk	Ka-ubk2	Kesalon	Lower Aquifer (Mountain Aquifer System)	10 - 20
		Dolomite Limestone, interbedded with Marl		UBK1			Ka-ubk1	Soreq		60 - 130
		Dolomite	Lower Beit Kahil	UBK2		Ka-lbk	Ka-lbk2	Giv'at Ye'arim		40 - 90
		Karstic Limestone		UBK1			Ka-lbk1	Kefira		100 - 160
		Marl ,marly nodular Limestone	Qatana		Kobar	Ka-q		Qatana	Aquitard	42
		Marly Limestone and Limestone	Ein Qinya			Ka-eq		Ein Qinya	Local Aquifer	55
	Aptian	Shale	Tammun			Ka-t		Tammun	Aquiclude	300+
		Shale and Limestone	Ein Al-Assad			Ka-ea				20+
		Marly Limestone,sandy	Nabi Sa'id		Kurnub	Ka-ns		Hatira	Aquifer	20+
	Neocomian	Sandstone	Ramali			Kn-r				70+
		Volcanics	Tayasir			Kn-t				35
Jurassic	Oxfordian	Marl interbedded with chalky limestone	Maleh	Upper Maleh	-	Jo-m	Jo-um	'Arad Group	Aquitard	100 - 200
		Dolomitic limestone, jointed and karstic		Lower Maleh	-		Jo-lm		Aquifer	50 - 100

Stratigraphic Section of the West Bank

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LEGEND

Dolomite
Limestone
Marl
Conglomerate
Megafauna
Flint concretions
Chalk
Nari
Sandstone
Volcanics
Relatively Permeable
Relatively Impermeable

Figure 2.8: Stratigraphical columnar section of the West Bank (USAID, 2005).

2.6.3 Geological structures of Hebron district.

1. **Folds**.

Five main folding structures are distinguished in the study area. These are Hebron anticline, Surif monocline, Bani Na"im anticline, Shaikh Kalifa anticline and Um Daraja suncline. Hebron anticline is considerd as the main fold structure in the southern part of the West Bank. It trends north-south and passes from Jerosalem to the south of Hebron (Rofe and Raffety, 1963).

2. **Faults**

Faults in the study area either trend north-south or north, west-south, east (Figure 2.9 and Figure 2.10). The falt that forming the Surif monocline is the main falt in the study area and trends north-south. In many cases, falts change their direction from one place to another (Rofe and Raffety, 1963).

3. **Joints**

The rocks in the study area are highly affected by joints and fractures. This is due to the intensive structure history of the region. Joints are developed and associated with the forming of folding and folting structures or sharking of limestone rocks by dolomitization process. Karestic caves structures are dominated and mainly affected the limestone and dolomite rocks of the study area (Rofe and Raffety, 1963).

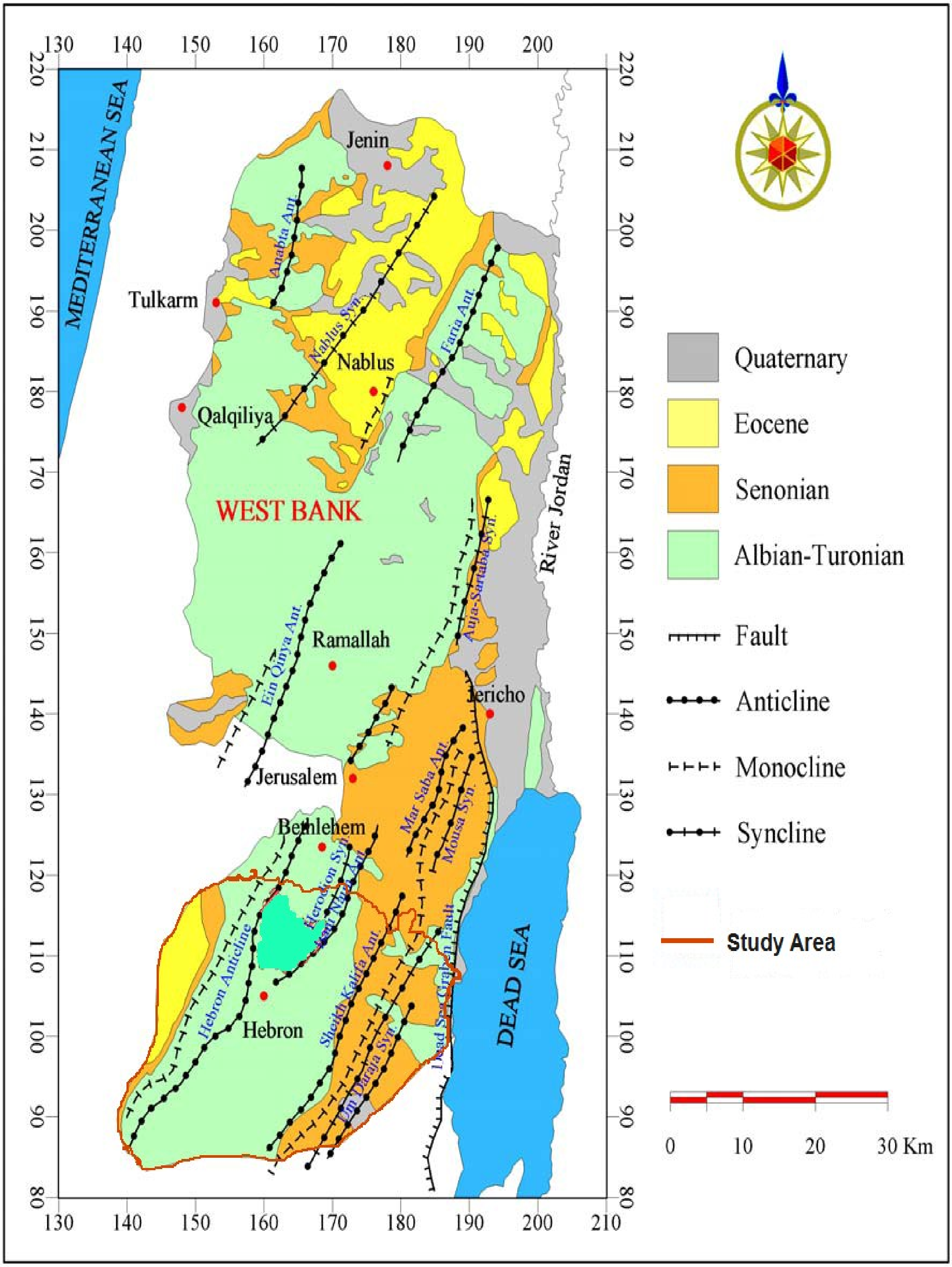


Figure 2.9: A geological structure of West Bank (Qannam, 2003).

2.7 Hydrogeology of Hebron district.

2.7.1 General

The major source of fresh water supply in the West Bank is the groundwater, derived from shallow and deep water bearing formations of the mountain aquifer. According to the direction of hydraulic drainage of the aquifer, it was divided to three main groundwater basins; north-eastern, eastern and western basin (Figure 2.10). The groundwater basins are recharged directly from rainfall on the outcropping geologic formations in the West Bank mountains, and most of these aquifer rocks formations are comprised of carbonate rocks mainly limestone, dolomite, chalk, marl, and clay (Hantash S. et al, 2007).

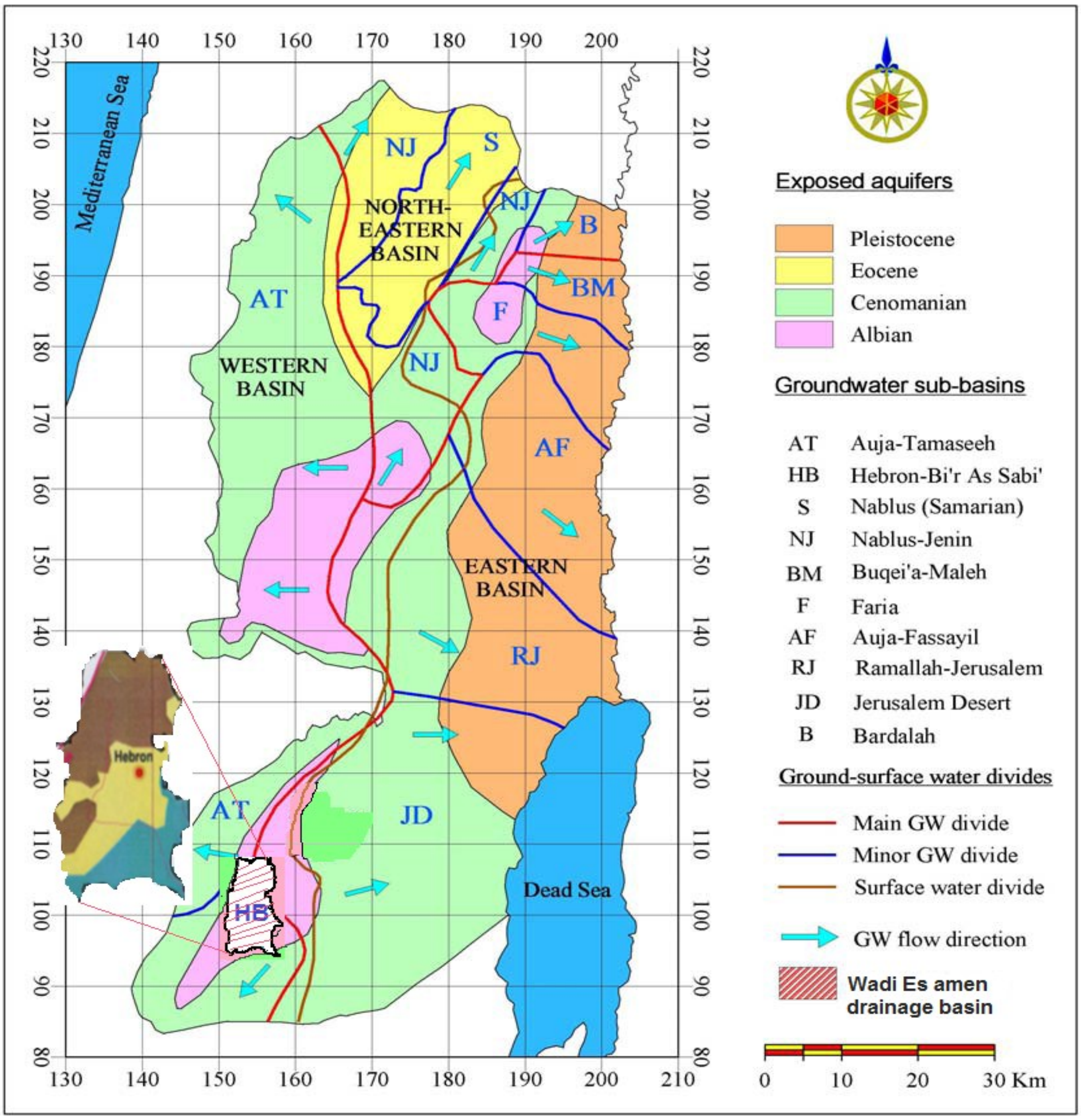


Figure 2.10: Groundwater basins and exposed aquifers in the West Bank/Palestine (Qannam, 2003).

2.7.2 The West Bank aquifer system, is classified to:

1. Western basin

The recharge area of this basin are 1800 km^2 of which 1400 km^2 are in the West Bank, while 2500 km^2 of its storage area, lies completely in Israel occupation (Sturm et al. 1996). According to (Gvirtzman, 1994) the potential yield of this basin to be 360 M. m^3/y, while (Wolf, 1995) estimated it by 320 M. m^3/y, most of water in the West Bank is utilized by the Israelis occupation, while the Palestinians is utilized of 20 M. m^3/y, from wells in addition to 2 M. m^3/y, from springs near Nablus. The water from this basin is discharged by the springs of Ras Al-Ayin, which feeds Al-Timsah springs and Al-Auja River (Qannam, 2003).

2. North-Eastern basin

This basin lies almost within the boundaries of the West Bank. The recharge area of this basin has a total area of 700 km^2 out of which 650 km^2 are in the West Bank (Sturm et al., 1996), while (Elmusa, 1996) estimated 500-590 km^2. The direction of the water flow of this basin is northeastwards along the plunge of Nablus-syncline. The Palestinians is utilized of 25 M. m^3/y, around Jenin and 17 M. m^3/y, from east Nablus springs, while the rest is utilized by the occupation (Qannam, 2003).

3. Eastern basin

This basin lies almost entirely in the West Bank. The recharge area of this basin are 2200 km^2 and the storage area over 2000 km^2 (Gvirtzman 1994). The 172 M. m^3/y are utilized as follows: 24 M. m^3/y utilized by the Palestinians from wells, 30 M. m^3/y utilized by the Palestinians from springs, 40 M. m^3/y used by the occupied Palestine and 78 M. m^3/y. The direction flow of this basin is the Dead Sea and eastwards toward the Jordan River (Qannam, 2003); (Figure 2.11).

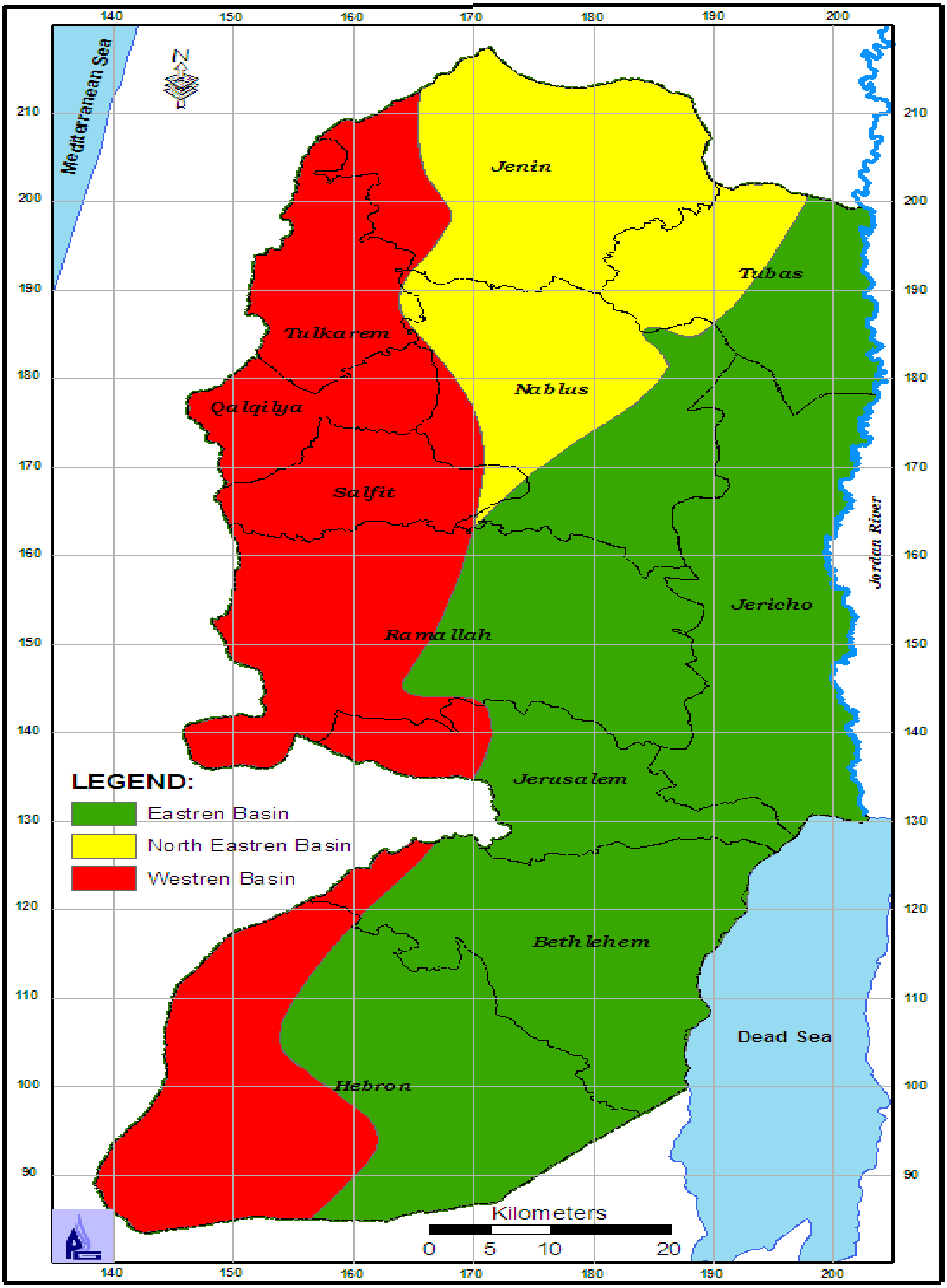


Figure 2.11: Groundwater aquifer basin in West Bank (Qannam, 2003).

2.7.3 Description of the main aquifer that were distinguished in the study area is stated in the following paragraphs

Albian lower cenomanian aquifer

According to (Guttman and Zuckerman, 1995) Albian lower cenomainian aquifer is composed of four formations; kobar, upper Beit Kahil, lower Beit Kahil and Yatta (Table 2.1). The four formations contain many marl and chalk beds intercalated within the bedded limestone. The presence of the marl beds between fractured limestone, dolomite and dolomitic limestone prevent the movement of water and allow the springs to emerge at the unconformity contact between marl and/or chalky beds and the fractured limestone, dolomite. Perched water of the Albian lower cenomanian. Three perched aquifers are distinguished in the Albian lower cenomanian (Table 2.2). These are:

1. The lower Beit Kahil local perched aquifer, which is situated in lower part of the lower Beit Kahil formation.
2. The upper Beit Kahil local perched aquifer, which is situated between the lower and middle parts of upper Beit Kahil formation.
3. The Yatta local perched aquifer, which is situated in middle part of Yatta formation.

1. Upper middle cenomanian-turonian aquifer

According to (Millennium Engineering Group et al. 2000; Guttman and Zuckerman 1995) upper middle cenomanian-turonian aquifer consists of Hebron, Bethlehem and Jerusalem formation. Hebron formation is composed of dolomite and limestone. Its rocks characterized by karstification and strong jointing that make them an excellent aquifer. Bethlehem formation consists of limestone beds at the bottom overlay by dolomite beds, which are overlay by marl bed at the top of formation. Jerusalem formation consists of well-bedded limestone and hard limestone, dolomite and marl intercalated with each other (Table 2.1).

Table 2.1: Hydrogeological formations at Wadi-Samen drainage basin and its surrounding area (Qannam, 2003).

Formation name Palestinian	Thickness (m)	Simplified lithology	Classification
Jerusalem	90-130	Hard limestone, some dolomite and marl.	Aquifer
Bethlehem	70-200	Dolomite and some limestone	Aquifer
	10-70	Soft limestone, chalky limestone and marl	Aquitard
Hebron	20-120	Dolomite and dolomitic limestone	Aquifer
Yatta	10-20	Limestone, marly limestone, marl and clay at the bottom	Aquiclude
	40-110	Limestone, dolomite and	Aquifer
		Marl at bottom	Aquiclude
Upper Beit Kahil	10-80	Limestone, dolomite	Aquifer
	30-140	Dolomite with marl	Aquifer
Lower Beit Kahil	20-80	Limestone, dolomite and marls	Aquifer
	100-200		Aquifer
Kobar	30-50	Marl, sandstone and clay	Aquiclude

2. Perched water of the upper middle cenomanian-turonian aquifer

Tow perched aquifer are distinguished in the upper middle cenomanian-turonian aquifer (Table 2.1). These are:

1. Hebron local perched aquifer, which is situated in lower part of Hebron formation.
2. Bethlehem-Jerusalem local perched aquifer, which is situated between the upper part of Bethlehem formation and the lower part of Jerusalem formation.

3. Alluvial aquifer

Neogene to quaternary alluvial deposits are mainly found in Wadi beds and terraces, but also occur as fans and piedmont cones. The caliche weathering crust, called Nari, is a prominent feature on the carbonate rocks of almost all formations within the study area (Table 2.2).

Table 2.2: A description of the main aquifer and the perched aquifer that were distinguished in the study area (PWA, 2012).

Spring-well name	Type	Location	Emergent formation	Aquifer
Al-Alaqah Al-Foqah	Deep well	Al-Alaqah/Dura	Yatta	Yatta local perched aquifer
Al-Alaqah Al-Tahta	Deep well	Al-Alaqah/Dura	Yatta	Yatta local perched aquifer
kurza	Spring	Kurza/Dura	Hebron-Bethlahem-Jerusalem formation	Upper Middle Cenomanian-Turonian perched aquifer
Al-Baiarah	Dug well	Al-Fawwar	Alluvial	Eocene-Alluvial aquifer
Al-Fawwar	Deep well	Al-Fawwar	Turonian	Upper Middle Cenomanian-Turonian aquifer
Al-Rihiya	Deep well	Al-Rihiya	Turonian	Upper Middle Cenomanian-Turonian aquifer

2.8 Description of the springs

Because of the scarcity of water in the West Bank, especially in Hebron area and because of the lack of water networks, therefore people look for other sources to fill their needs of water, such as springs and wells such as Al-Fawwar and Al-Rihiya were still the main source of drinking water. Spring and wells such as Al-Alaqah Al-Tahta, Al-Alaqah Al-Foqah, Al-Baiarah and Qurza spring, which are utilised from herdsmen and farmers (Table 2.3). Generally, most of water of springs and wells in study area are consumed for domestic purposes except drinking. The discharge of the raw wastewater in Wadi and cesspits lead to endangering water quality of these resources (PWA, 2012).

Table 2.3: Clarification of the springs and wells in study area (PWA, 2012).

Spring-well name	Type	pollution	Surrounding landuse	Catchment	Water use
Al-Alaqah Al-Foqah	Deep well	Polluted	Agriculture	Hebron	Animal and irrigation
Al-Alaqah Al-Tahta	Deep well	Polluted	Agriculture	Hebron	Drinking, Animal and irrigation
khursa	Spring	Polluted		Dura	Animal and irrigation
Al-Baiarah	Dug well	Polluted	Agriculture	Hebron	Animal and irrigation
Al-Fawwar	Deep well	Polluted	Urban and Agriculture	Hebron	Drinking
Al-Rihiya	Deep well	Polluted	Wastewater flow	Hebron	Drinking

- **Al-Alaqah Al-Foqah**

Al-Foqah well is roofed by concrete wall and located in Wadi Al-Alaqah to the south of Dura town. This well is used for animal breeding and plant irrigation (Table 2.3). The water well is dangerous because of pollution by the surrounding human activities such as the presence of cesspits, and extensive use of fertilizer and insecticide (Arij, 2009).

- **Al-Alaqah Al-Tahta**

Al-Alaqah Al-Tahta well is roofed by concrete wall and located in wadi Al-Alaqah to the south of Dura town, its below Al-Alaqah Al-Foqah about 300 m, the flow of this spring is strong in winter and low in summer, The water of this well is used for drinking, animal breeding and plant irrigation (Table 2.3). But this well is in danger of pollution by surrounding human activities such as the extensive use of fertilizer, insecticide or as a result of cesspits (Arij, 2009).

- **Qurza spring**

Qurza spring is located in Qurza village, about 2.5 km to the south of Dura town. Its roofed by concrete and it has a concrete tank of 60 m^3 and the amount of water produced from the spring is a little. The water of this spring used only for animal breeding and plant irrigation (Table 2.3). Its endangered because it is close to the flow of wastewater Wadi-Samen and human activities (Arij, 2009).

- **Al-Baiarah well**

According to (Arij, 2009) this well is located in Al-Fawwar camp area. Al-Baiarah well is located within the built up area of the camp in an agricultural land and its water is used for plant irrigation (Table 2.3).

- **Al-Fawwar well**

According to (Arij, 2009) this well is located in Al-Fawwar camp area. Hebron municipality are responsible to distribution of water that withdraw from well. The well is located in agricultural land and close to Wadi-Samen wastewater. This condition is affects to water quality, the water of this well is used for drinking (Table 2.3).

- **Al-Rehiah well**

Al-Rehiah well located to the west of Yatta town. West Bank water department are responsible on distribution of water in it. It is endangered because it is very close to the flow of wastewater of Wadi-Samen (Arij, 2009).

Chapter Three
Hydrochemistry

3.1 Introduction

In this section were clarified and submitted the general characteristics of the water quality, genesis and suitability of the water resources for domestic and agricultural purposes. Also discuss the wastewater samples that has collected from study area. On the other hand, highlighting on different types of pollutants and impacts on the groundwater resources in the Wadi. Therefore, it's necessary to conduct chemical, physical and bacterial analysis of groundwater to determine its suitability for different purposes. To reach these purposes samples were taken from the, deep wells, dug wells, springs, rain water and wastewater flowing along the stream of study area which were collected and analyzed between 2015 and 2016. Six samples from selected springs and dug wells were measured. The wells and springs samples which were analyzed for the major and minor ions, trace elements, fecal and total coliform bacteria. Also the wastewater samples which were analyzed are TSS, BOD_5, COD, EC, pH and TDS.

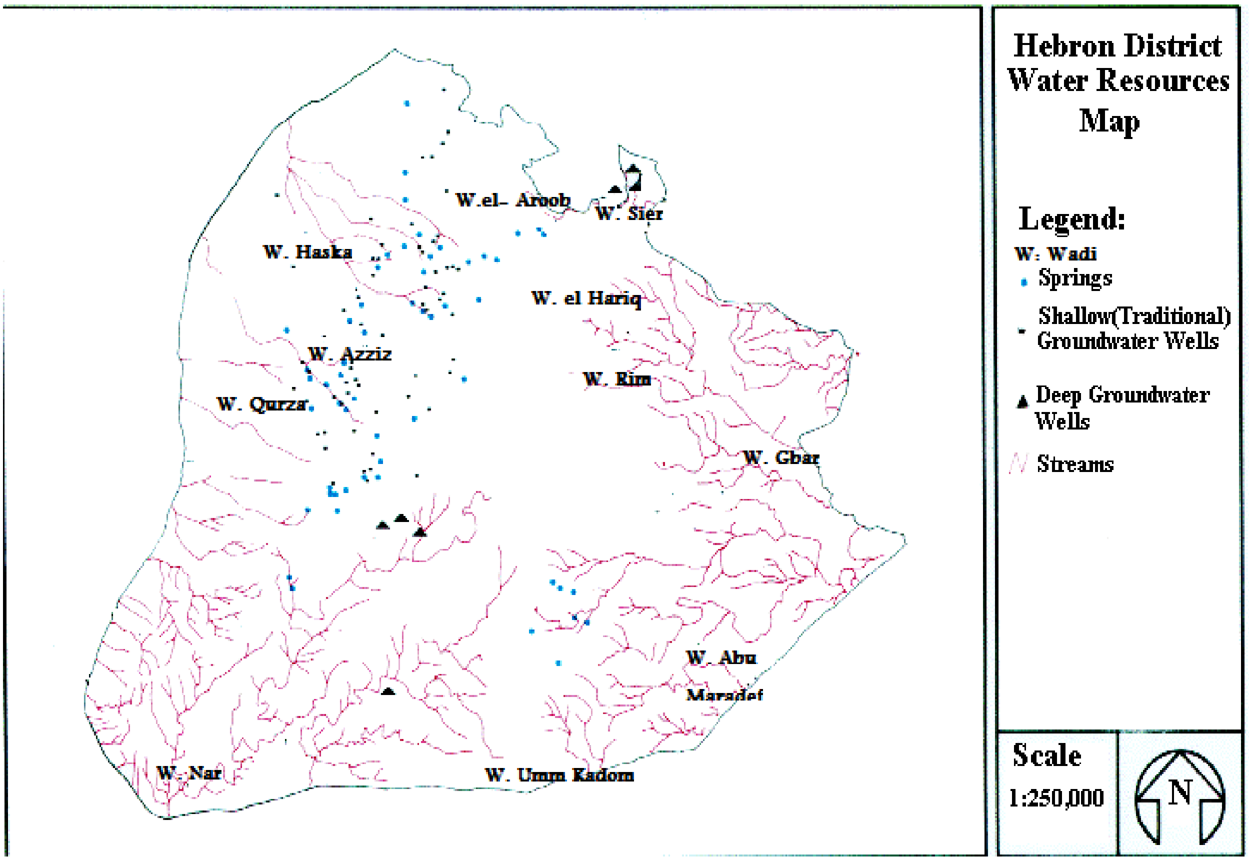


Figure 3.1: Hebron district water resources map (Arij, 1995).

3.2 Wastewater hydrochemistry

The quantitative factor for each of wastewater sources which showed the amount of wastewater that drainage from Qariat Arba' settlement, Kharsena and Aatniel colony’s and Hebron municipality (PWA, 2012). The qualitative factor is not less important, due to its sever effects when it exceeds the standards levels. For this, a simple comparison has been conducted between the two origins in order to determine the reasons behind the different qualities between the both sources.

The average values of the two round parameters for Wadi-Samen wastewater were calculated and analyzed in order to find the quality of wastewater sources. The results showed the values for Wadi-Samen wastewater in terms of pH (6.7), Total Dissolved Solids (TDS) (908 mg/l) and Electrical Conductivity (EC) (1800 µs/cm) for Wadi-Samen.

3.3 Variation of parameters along Wadi-Samen

In order to realize the quality condition of the wastewater flow of Wadi-Samen, a clear understating framework is required to clarify all elements that affect directly and indirectly, the Wadi from its origins (Hebron municipality and Qariat Arba' colony) to its end point (Wadi Al-Nar) in Hebron.

3.3.1 Chemical parameters

The Biological Oxygen Demand (BOD) refers to organic load in any water body (wastewater in this case), and has been defined as a 'five days incubation standard' and considered the best parameter to estimate water quality (dissolved oxygen) relating to the presence of organic matter either suspended form or dissolved (Ahipathy and Puttaiah, 2006). Whenever, the organic matter content increased in wastewater, the microorganisms’ activity increases in order to oxidize the organic matter biochemically which increase the BOD values. All samples of the study area exceed the standard of the raw wastewater, which is (250 mg/l). However, there are opposite trends between the wet season round results and dry season round results related to BOD_5 values which showed a better results for the wet season (March, 2015) by time with more wastewater flow rates after direct recharging season than the dry season (June, 2015). Therefore and rationally, the increasing in BOD values downstream the

Wadi in June period, due to the effect of the wastewater contribution of Hebron municipality and Qariat Arba' colony. Another reason for such increasing is represented by organic wastes of livestock and industrial activities that is disposed into Wadi. On the other hand, the wet season results indicated and confirmed the significant role of the spring's dilution effect. There is abnormal high value of BOD, along the Wadi path the sample of wet period (March, 2015) which may be attributed to runoff act of the surrounding organic materials such as livestock animal wastes and industrial activity such as (tanning) or dead plants towards the Wadi, which in turn, increase the organic content in the wastewater, especially in the case of open channel. This interpretation can be logical when regarded to March because of the precipitation activity compared to the dryness of (June, 2015) in this year. Through (Figure 3.2) show increasing in amount of BOD in both region El-Hella and Rehiya than another regions in study area because they are located at outlet of wastewater pipe.

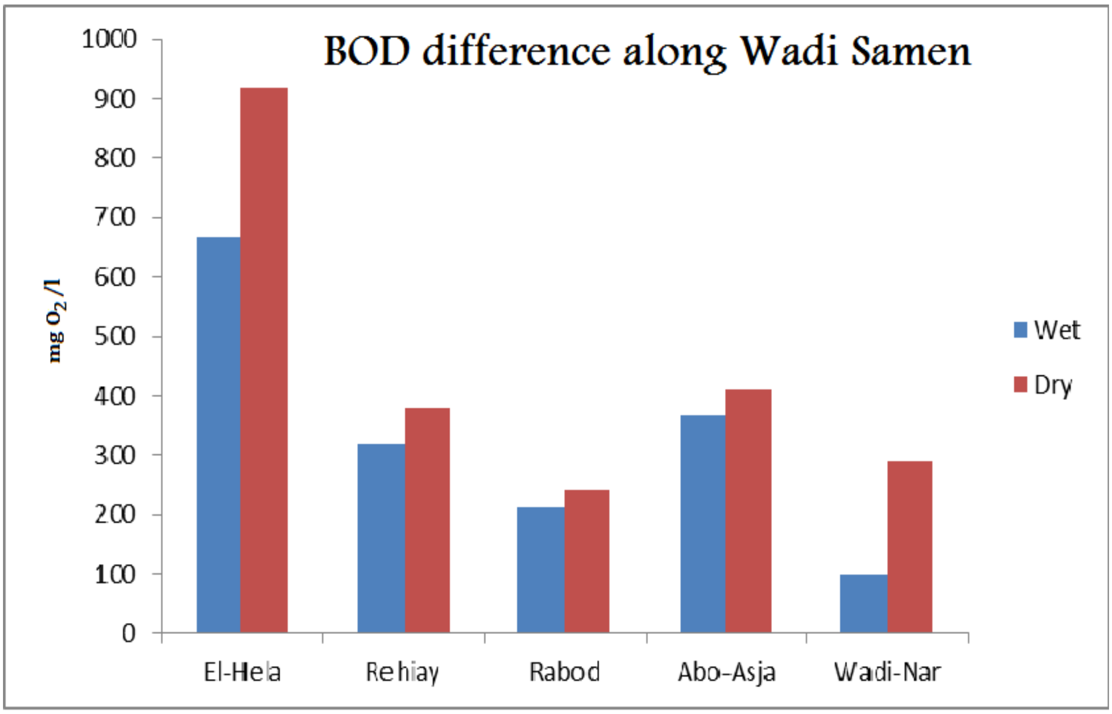


Figure 3.2: The BOD_5 difference trend of wastewater along Wadi-Samen

The Chemical Oxygen Demand (COD) content it's also indicates on the water pollution, which it's originates from many sources, the first source is industrial, domestic wastewater or agricultural and animal activities. COD values generally are higher than BOD values because COD = 2BOD (Bartram and Balance, 1996). Similarly to for the BOD_5 trend for both rounds, the trend of COD values along the Wadi-Samen acted the same manner for all samples (Figure 3.3). The lower COD concentration for Wadi-Al Nar in Hebron may be attributed to the stable water usage in all seasons of the year and decreases their water usage because of the lack of water resources in dry season including June, which was dry on June, 2015 or because it far from pipe outlet of drainage. Thus amount of COD less, because in previous areas may leakage in soil.

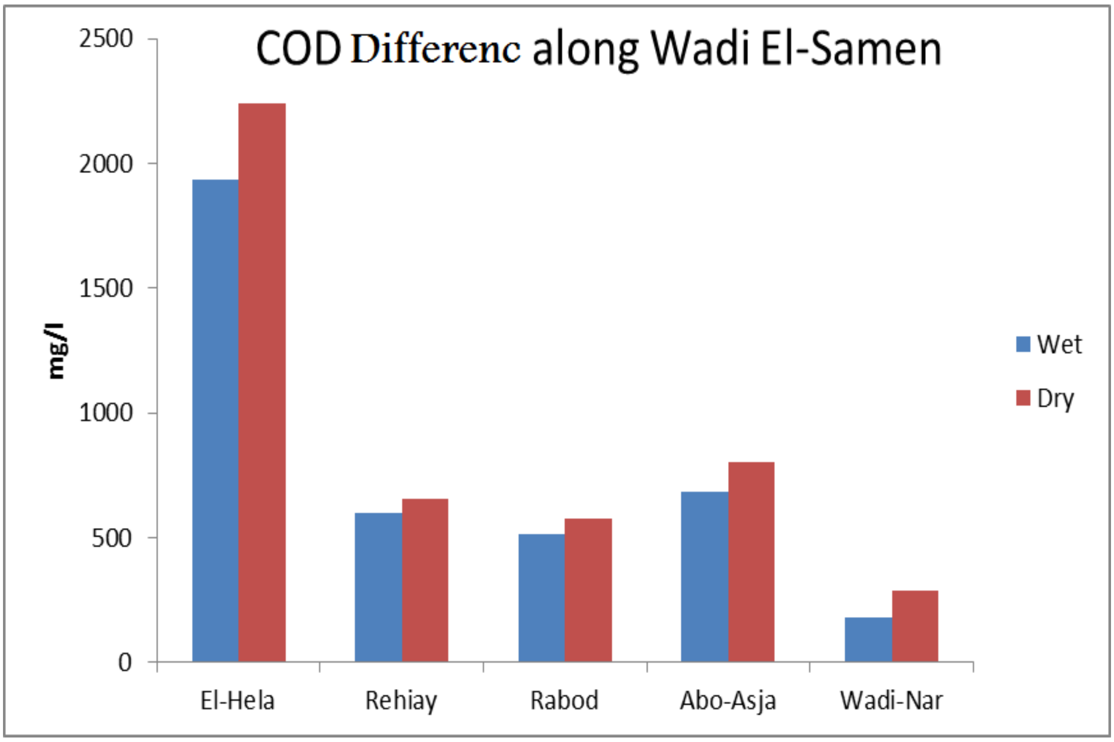


Figure 3.3: The COD difference trend along Wadi-Samen WW in both rounds

3.3.2 Physical parameters

pH is one of the important quality parameters for wastewater (Gelman, 2003). And it's appropriate for many purposes such as agriculture (Ahipathy and Puttaiah, 2006). Many components of the wastewater such as sodium content represented by detergent presence which could have on affect on pH. According (WHO, 2006) the range of pH for wastewater (6.5-9.5). All samples taken from different places along the Wadi do not exceed the standard value of WHO and showed normal results (Figure 3.4).

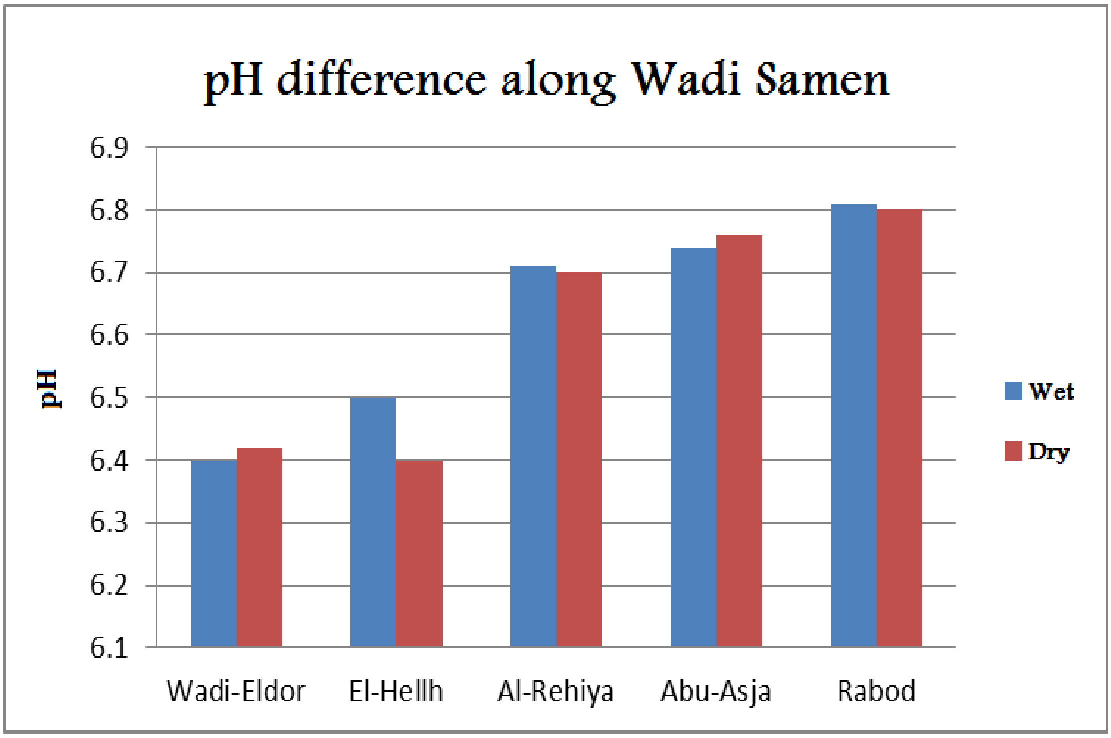


Figure 3.4: The pH difference of wastewater along Wadi-Samen wastewater

Due to the continuous discharging of the raw wastewater by Wadi-Eldor, El-Helh, Al-Rehiya, Abu-Asja and Rabod citizens along the Wadi, carrying potential basic load of pollutants, there is a slightly higher pH values of wastewater in (El-Helh and Wadi-Eldor WW) which might be caused by the presence of stone quarries and tanning on the stream's path (Figure 3.4).

The other physical parameter that affects wastewater quality is Electrical Conductivity (EC) (Figure 3.5), its shows indirectly the measurement of salinity (Harivandi and Beard, 1998). There is a strong relationship between the two parameters (Total Dissolved Solids (TDS) and EC) that affect each other, and the (EC) expresses a concentration of salts dissolved in wastewater TDS (Anzecc and Armcanz, 2000).

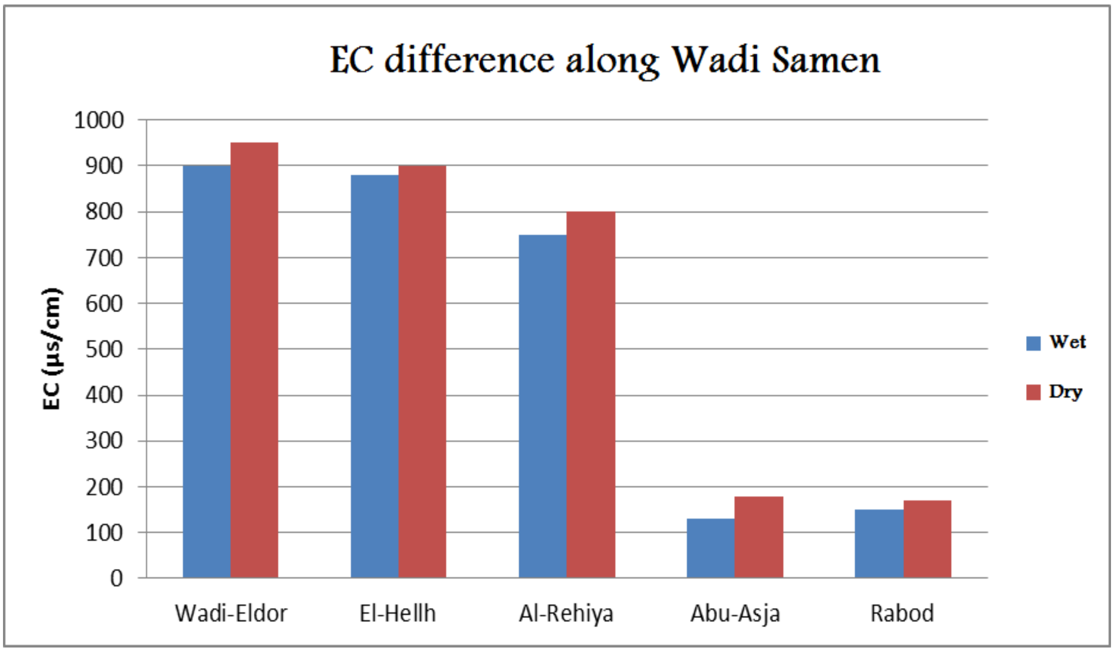


Figure 3.5: Illustrate a stable and straight trends in the EC values**.**

A wide range of EC was resulted for the two rounds (1200-2200 µs/cm) which is considered with medium strength. There are abnormal values of EC in El-Hellh and Wadi-Eldor samples in both rounds, where the rain water runoff may act the most influencing factor for such trend where clays and soluble salts are directed towards the Wadi from surrounding mountains and lands, these sediments with high ion exchange rates and salts content can increasing EC levels of uncovered wastewater in the wadi in wet season compared to the low EC level of the dry season (June).

Total dissolved solids (TDS), involve inorganic salts and small amounts of organic matter that are dissolved in water. The Total dissolved solids varies between samples according to several factors, one of them; is the solubility minerals originate from natural sources such as the geological region in the study area (WHO, 2006). The second factor and the more important is a seasonal effect, which is represented by change in temperature between the two seasons which lead to evaporating, and concentrating wastewater (Dreyer, 1982). According to results, the dry round (June

2015) represent more TDS value which equals (1600 mg/l) because of delayed rainy season in (2014-2015) winter. Which refers to limited spring's activity and their dilution effect. Further, the wet round (May) showed less TDS value represented, by (1300 mg/l) due to continuation of the springs flowing activities even after March, which in turn diluting the wastewater (Figure 3.6).

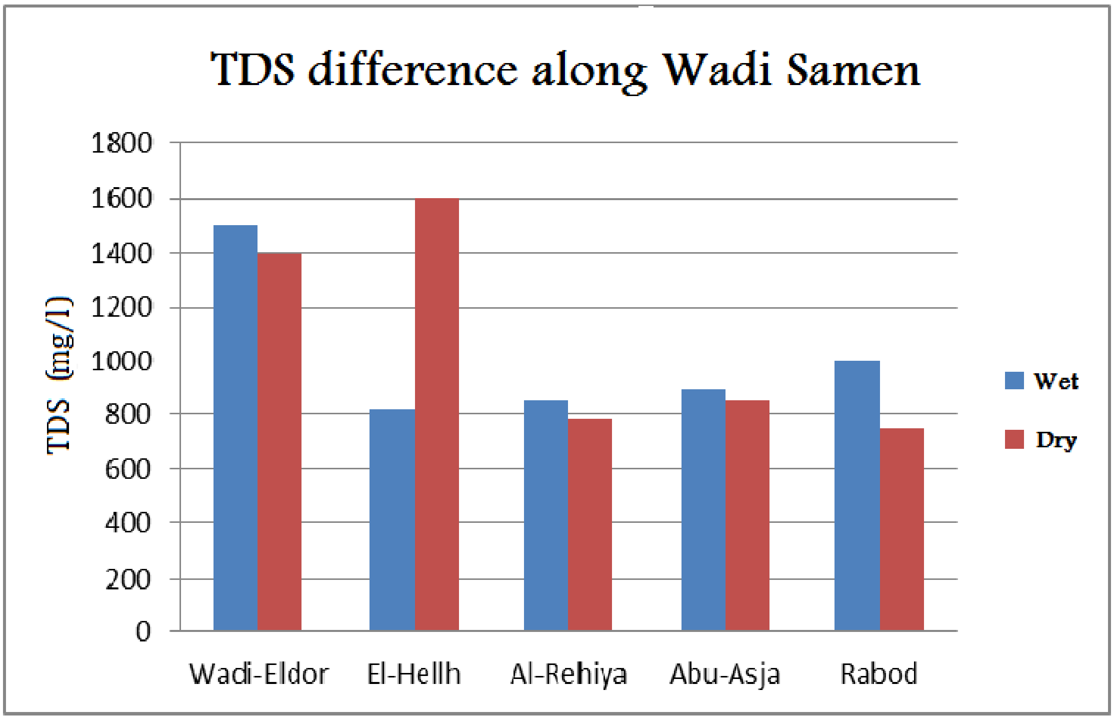


Figure 3.6: Wastewater trend for TDS along Wadi-Samen

According to (ESC, 1996), a significant dust, soil erosion and rain water runoff, as well as larger friction with rocks lead to high Total Suspended Solids content (TSS) in the wastewater. All of the sample results (except Wadi-Robot and Abu-Asja WW) exceed the typical TSS concentration which is (200 mg/l), in the wet round, because it's far from water stream. Rise in TSS in other places, due to the presence of quarrying and cutting stone in addition to the proximity of the end of the pipeline wastewater discharge which increase the concentration of TSS (Figure 3.7).

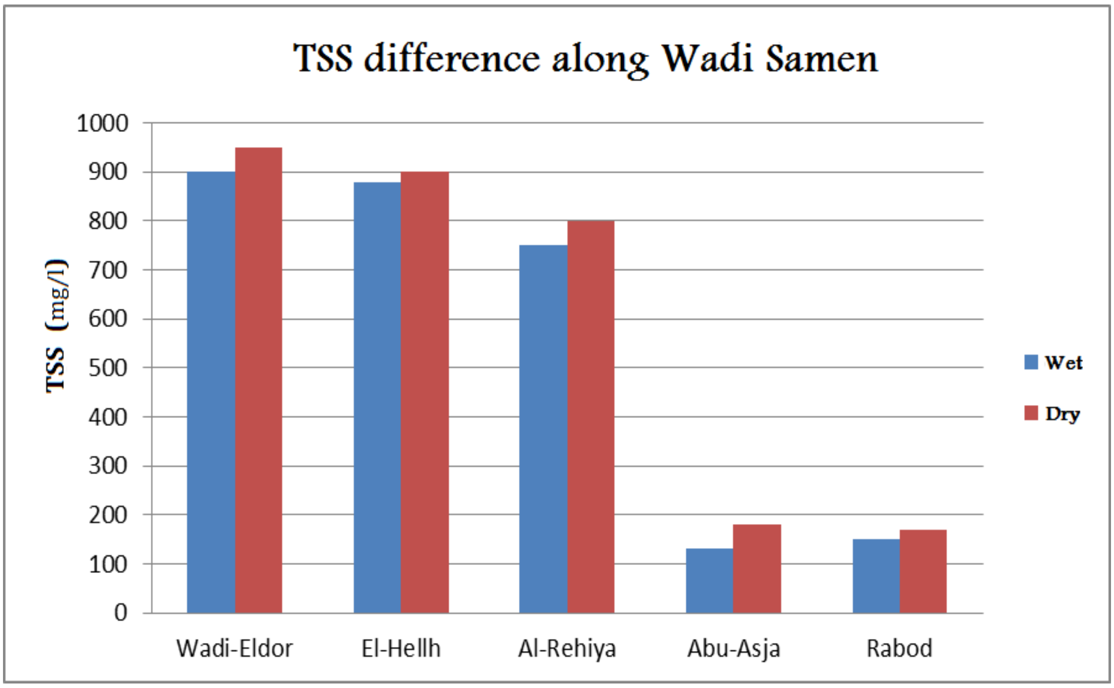


Figure 3.7: The wastewater trend for TSS along Wadi-Samen

3.4 Physical – Hydrochemical – Biological characteristic of springs

3.4.1 Physical properties

3.4.1.1 Total dissolved solids (TDS)

Total dissolved solids (TDS) include inorganic salts, principally, potassium, sodium, calcium, bicarbonates, chlorides, sulfates, magnesium, and some small amounts of organic matter that are dissolved in water. Generally, TDS is used as a secondary drinking water standard and as a environmental test because of its esthetic effect and there is no health hazard. Also the dissolved ions that result from TDS may cause water to be corrosive, of salty or brackish taste and decreased efficiency of hot water heaters. Furthermore, existence of dissolved ions in water in high level indicate that water contain ions that are above the primary drinking water standards, such as: arsenic, nitrate, copper, aluminium, lead, etc. (Qannam, 2003). A general classification of ground water according to the TDS (Table 3.1).

Table 3.1: General classification of groundwater according to the TDS (WHO, 2006).

Classification of Water	TDS (mg/l)
Fresh	<1000
Brackish	1000-10,000
Saline	10,000-100,000
Brine	>100,000

According to the samples which were analyzed it is clear that most the collected samples of springs and wells are of fresh water with TDS values of 300-900 mg/l. Values between 1000-1200 mg/l in the Al-Alaqa Alfoqa and Al-Biyara springs those are very close to the sewage conduit and agricultural land which means that the water is a brackish water type.

3.4.1.2 Electrical conductivity (EC)

The electrical conductivity (EC) of water estimates the total amount of solids dissolved in water based on the flow of electrical current through the sample. The electrical conductivity is a good indicator of the total salinity. EC is the reciprocal of resistivity (R): EC = 1/R and measured in millisiemens/cm (mS/cm) or (µS/cm). According to the results, which were conducted during the study, showed that the EC values ranges from 500-2000 µS/cm in the springs, while in the wells the values ranges from 500-1000 µS/cm. In Al-Rehiya and Al-Fawwar wells which are recorded the highest values that ranges between 500-1100 µS/cm in summer. Since the EC and TDS are related to the concentration of salts dissolved in water, they must be directly proportional. The relation between these two parameters for the analyzed samples in this study was plotted in (Figure 3.8), showed a linear relationship with a mathematical approximation of (EC can be converted to TDS using TDS mg/L = 0.64 X EC µS/cm). The relationship between (EC) and (TDS) in the spring water of the study area is strong and the value of correlation coefficient (R) is close to one by equations (TDS = 0.49 EC + 4.34 with $R^2 = 0.99$) (Rhoades, 1996; Qannam, 2003).

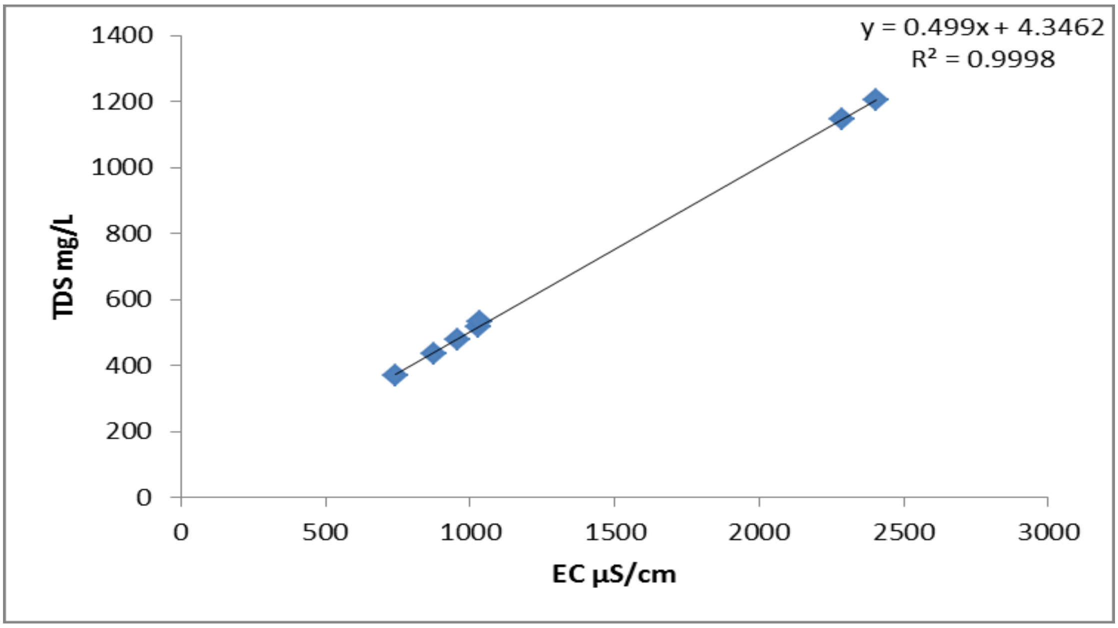


Figure 3.8: EC-TDS relationship of spring water samples in the study area for wet period.

According to the (Table 3.2) EC values for both periods which shows the relationship between electrical conductivity (EC) and water mineralization (TDS). The type of Ein Qurza, Ein Al-khirba, and Al-Fawwar spring water is a highly mineralized water, and the type of Ein Al-Alakh Al-Fokh and Al-Tahta, Ein El-Biara and Al-Rihiya spring water is excessively mineralized water.

Table 3.2: Relationship between electrical conductivity and water mineralization (TDS) (WHO, 2006)

Mineralization(TDS) mg/l	**EC µS/cm**
Very weakly mineralized water	<100
Weakly mineralized water	100-200
Slightly mineralized water	200-400
Moderately mineralized water	400-600
Highly mineralized water	600-1000
Excessively mineralized water	>1000

3.4.1.3 Temperature

Temperature is affects on characteristics of groundwater (physical and chemical), such as EC, pH and DO (Saether and Caritat, 1997; Skidmore at.el., 2003). The unit of temperature measurement is degree Celsius (^{0}C). All geochemical reactions depend on temperature (SCCG, 2006). during the study period, there was no abnormal temperature values recorded for the spring's water.

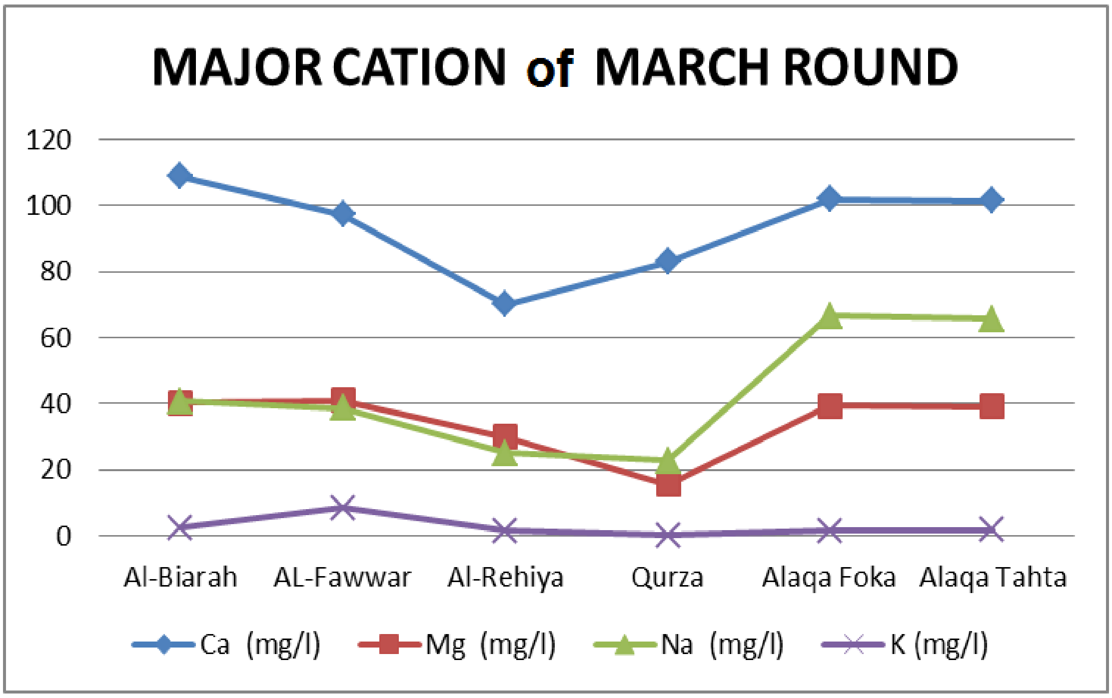
3.4.1.4 pH

The pH value is a master parameters in water. pH values of springs varied according to reactions occurring underground surface such as dissolved CO_2 gases derived from the atmosphere, and dissolving HCO^-_3 derived from carbonate rocks (Ghanem, 1999). According to (WHO guidelines, 2006), all of measured pH values for samples show acceptable values (7.39-7.8) and did not exceed the standards limits (6.5-8.5).

3.5 Hydro-Chemical properties

3.5.1 Cations

Calcium (Ca^{+2}) and magnesium (Mg^{+2}) are both abundant in soil and rocks. (Ca^{+2}) has a mean of 98.67 mg/l in the study area. A big range of (Ca^{+2}) is recorded in Alaqa-Al Foqa springs in both seasons, for Al-Fawwar well, Ein Alaqa-Foqa, Ein Alaqa-Tahta and Ein El-Biarah which had the concentration above 100 mg/l were as shown in (Figure 3.9). The concentration of calcium it becomes high in springs, this may refers to the long contact with carbonate rocks and because the weathering process of limestone, and dolomite. The water hardness it is caused by high levels of calcium and magnesium. The magnesium ion (Mg^{+2}) concentration of spring water samples is within the allowable level. The concentration of magnesium in the samples varies between (42-15.3 mg/l) in Al-Fawwar well, Ein Alaqa-Foqa, Ein Alaqa-Tahta and Ein El-Biarah, Ein-Kurza, Ein-El Kherbeh and El-Rehiya well in wet period and (77-5.9 mg/l) the same springs in wet period. The respectively reason for the increase in magnesium in Ein Alaqa-Foqa comes from dissolution of dolomite limestone. The most factors that contribute to presence of sodium (Na^+) in water, erosion of salt deposits and sodium bearing rock minerals, irrigation and precipitation leaching through soils high in sodium and groundwater pollution by sewage effluent (WHO, 2006). The high doses of the fertilizers and pesticide that contain (Na^+) and is used in intensive agriculture around the Al-Alaqa Elfoqa spring and Al-Biarah spring, play the most important role for such increase of (Na^+) concentration in the two rounds periods, and overcoming the rest factors.



Figures 3.9: The cations concentrations of water samples of the study area in wet period.

On the contrary, the springs that are located far from human activities, recorded the lowest values of (Na^+) such as Al-Fawwar, Al-Rihiya and Qurza springs. Around the Alaqa Foqa and Alaqa Tahta spring, high doses of the fertilizers that contain (Na^+) and is used in intensive agriculture which play the most important role for such increase of (Na^+) concentration in the two periods. However, none of the values exceeded the WHO limits for (Na^+) content (200 mg/l). Based on the samples results for study area and WHO standard, the potassium (K^+) ratio in all springs is not high and none of the values exceeded the WHO limits for (K^+) content (12 mg/l) (Table 3.3).

Table 3.3: The average cations (mg/l) in two period of Wadi-Samen spring.

Parameter	Wet season		Dry season		Average of two periods (mg/l)	PWA Standard 2001 (mg/l)	WHO Standard 2007 (mg/l)	Exceeding limits
	Range (mg/l)	Average (mg/l)	Range (mg/l)	Average (mg/l)				
Ca^{+2}	80-140	97.80	25-226	99.08	96.94	70	75	Exceed
Mg^{+2}	15-42	33.27	6-77	34.36	33.81	50	125	Not exceed
Na^{+}	21-66	39.17	17-150	50.81	45	200	200	Not exceed
K^{+}	0.1-8.90	3.01	0.1-8.78	4.20	3.60	10	12	Not exceed

3.5.2 Anions

Bicarbonate (HCO^-_3) is acceptable by the value of 500 mg/l in groundwater (Todd, 1980), concentration of bicarbonate in groundwater, depends on solubility extent of the carbonate rocks that dissolving the soil CO_2, and weathering process of silicate minerals, making it the strongest factor for water alkalinity. According to the result of study the concentration of the bicarbonate of the both season is less than 500 mg/l (Figure 3.10). The variations of (HCO^-_3) values between the two rounds, can be explained by the recharging impact on diluting the parameter concentration, and leading its values tend to balance as in the wet round (March 2015), and the opposite happened in the dry round (June 2015), where all of tested samples does not exceed the WHO limits (200 mg/l), therefore it's acceptable for drinking purposes.

Chloride (Cl^-) is considered to be a good indicator for groundwater contamination by sewage (Pacheco et.al., 2001). Chloride in spring water is acceptable when less than 250 mg/l (WHO, 1996). Concentration of chloride for both seasons is less than 250 mg/l, the concentrations of chloride in springs of study area is acceptable for drinking purpose (Figure 3.11 and Table 3.4).

Nitrate compound (NO^-_3), which is considered as a strong evidence for wastewater pollution source (WHO, 2006). Depending on the results of the study, all springs was found within the permissible limit of nitrate according to the World Health Organization, which is 50 mg/l.

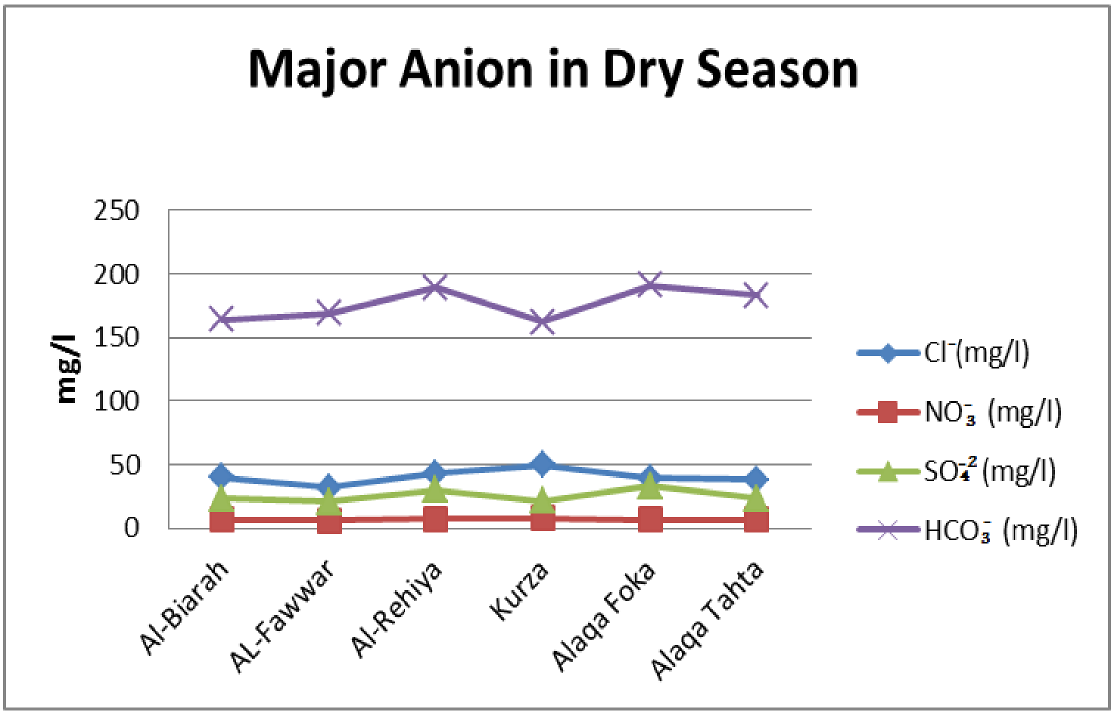


Figure 3.10: Major anions concentrations of spring's water of Wadi-Samen.

According (WHO, 2006), sulfate (SO^{-2}_4) exists in groundwater but must not exceed the 250 mg/l. The results showed no exceeded values permissible limit of sulfate and no significant variations between the two rounds which ranged between (12 mg/l and 24 mg/l).

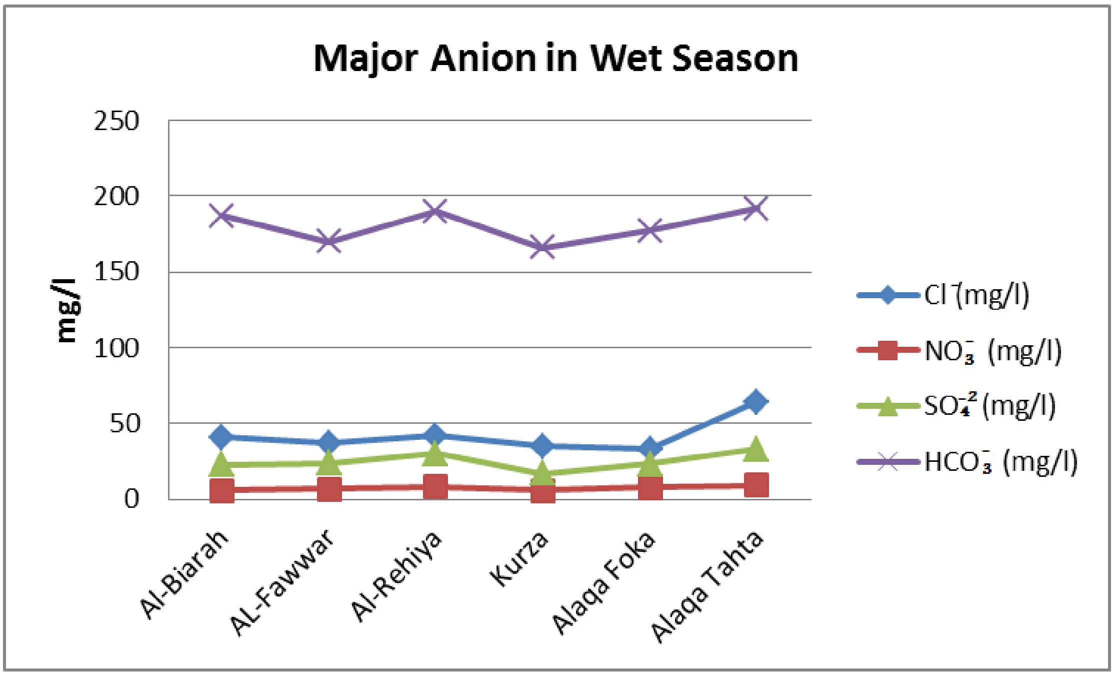


Figure 3.11: Major anions concentrations of spring's water of Wadi-Samen catchment in the wet round.

Table 3.4: The average anions (mg/l) in two period of Wadi-Samen springs.

Parameter	Wet season		Dry season		Average of two periods (mg/l)	PWA Standard 2001 (mg/l)	WHO Standard 2007 (mg/l)	Exceeding limits
	Range (mg/l)	Average (mg/l)	Range (mg/l)	Average (mg/l)				
Cl^-	32-50	39.51	33-64	45.5	42.50	250	250	Not exceed
HCO^-_3	149-191	169.66	154-192	174.16	171.91	250	200	Not exceed
SO^{-2}_4	20-30	22.0	13-33	22.16	22.08	200	250	Not exceed
NO^-_3	6.0-8.0	7.0	5-9	7.32	7.16	50	50	Not exceed

3.5.3 Microbiological analysis

In the study area the untreated sewage is originating from Hebron city, some villages, occupation colonies and other wastewater producers, such as cut ston and vacuum tankers who dispose their wastewater in the Wadi. Disposal of untreated municipal wastewater in this area is considered one of the most critical environmental problems. Municipal wastewater contains the human effluent, therefore water contaminated with these effluent may contain of infectious microorganisms and, consequently, may be hazardous to human health if used as drinking-water. Generally microbiological analysis is very important procedure because it helps us to detect fecal contamination. Fecal streptococci, total coliforms and fecal coliforms are used as indicators of possible sewage contamination because they are commonly found in human and animal feces. The main indicator of suitability of water for domestic/or other uses is coliform group (Ghanem 1999). Also different micro-organisms can be found in groundwater and surface water. The organisms that make water unpleasant for domestic purposes are Bacteria, Viruses, Fungus and Algae. Analyses for fecal coliform (FC) and total coliform (TC) is shown in (Table 3.5).

Table 3.5: Total (TC) and Fecal Coliforms (FC) in (CFU/100 ml) in Springs of Wadi-Samen catchment on March and Jun rounds.

Name of the spring	Dry season		Wet season	
	T.C CFU/100 ml	F.C CFU/100 ml	T.C CFU/100 ml	F.C CFU/100 ml
Al-Alaqah Al-Foqah	66000	50000	12500	170
Al-Alaqah Al-Tahta	48000	32000	27000	410
kurza	33000	Nil	430	Nil
Al-Baiarah	21000	710	1020	280
Al-Fawwar	136000	178000	9600	180
Al-Rihiya	21000	120	14200	39
Al-kherbeh	70	Nil	170	9

3.5.3.1 Total and fecal coliform bacteria

The bacteria which are present in sewage material is fecal coliform bacteria. The presence of fecal coliform in water indicates that a fecal source is animal manure, animal feedlot run-off, septic tank or cesspool leakage. Also the presence of fecal coliform in water indicates that the water may be contaminated with organisms that can cause disease. According to the tests the water samples showed a significant variation for the two parameters between the two rounds. In wet round gets dilution for water, therefore the wet round (March, 2015) samples showed lower contamination levels (Table 3.5). On the other hand, in dry round do not gets dilution for water so samples showed high contamination levels for the dry round (June, 2015). FC limits to zero, all analyzed samples revealed sewage contamination source particularly in Al-Alaqah Al-Foqah, Al-Alaqah Al-Tahta, Al-Baiara, Al-Fawwar and Al-Rehiya, (Table 3.5 and Appendix 6).

The presence of total and fecal coliform in drinking water must be zero in 100 ml (WHO, 1996) and the Palestinian (PWA, 2001). The results of this study showed that only the water of the network was free of coliform bacteria thus it's safe for drinking. Depending on the results of the study showed all the springs and wells in study area are contaminated with coliform bacteria, therefore they are not suitable for drinking unless being treated. Boiling or chlorination of the water are possible treatment techniques.

3.6 Trace elements

Heavy elements (Trace elements) represent a common type of chemical pollution in water. Heavy elements have stiff resistance for degradation in nature, thus are classified as a persistent (Arnason and Fletcher, 2003). Heavy metals harm humans through direct ingestion of contaminated water or through accumulation in the tissues of other organisms that are eaten by humans. Each element has certain effects on public health which are depending on its dose, bio-availability, and chemical composition. Heavy metals and trace elements in groundwater come from natural sources such as dissolution of minerals that contain traces in the aquifer and soil, and anthropogenic sources such as industrial sewage, heavy industries wastes and fertilizers etc (Tood, 2007). Nevertheless, these traces naturally exist in low concentrations in study area. Eighteen of heavy metals had analyzed in both seasons, Fe^{+2}, Cd^{+2}, Pb^{+2}, Zn^{+2}, Mn^{+2}, Be, Ba, Cr, Al, V, Co, Cu, Ni, Sr, Mo, Ag, Li, Ga. According to the (WHO, 2007) guidelines for heavy metals concentrations limits for drinking water are shown in (Table 3.6), it can be noticed that there are no exceeding value for all the measured elements in study area springs which indicate that there is no significant heavy metal-source contamination influencing the groundwater of Wadi-Samen catchment such as industrial wastes involving in Wadi-Samen.

Table 3.6: Comparison between the observed values of trace elements with WHO 2007 guidelines**.**

Parameter	Average Conc. (ppb)	WHO(2007) Guidelines (ppb)	Exceeding Limits	Parameter	Average Conc. (ppb)	WHO(2007) Guidelines (ppb)	Exceeding Limits
Fe	**8.30**	**500**	Not exceeded	**Pb**	**0.14**	**10**	Not exceeded
Co	**11.03**	**50**	Not exceeded	**Be**	**0.62**	**4**	Not exceeded
Ni	**4.33**	**20**	Not exceeded	**Mo**	**26.04**	**70**	Not exceeded
Cu	**22.66**	**1000**	Not exceeded	**V**	**11.88**	**NG**	
Zn	**4.99**	**3000**	Not exceeded	**Sr**	**5.09**	**NG**	
Cd	**3.47**	**3**	exceeded	**Ba**	**4.98**	**1000**	Not exceeded
Mn	**2.44**	**100**	Not exceeded	**Li**	**3.02**	**2**	exceeded
Al	**54.07**	**200**	Not exceeded	**Cr**	**10.89**	**50**	Not exceeded
Ag	**0.00**	**0. 2**	Not exceeded	**Ga**	**62.66**	**NG**	

NG = Not mentioned in the WHO Guideline.

Despite the absence of any exceeded value for measured heavy metals which are eighteen different elements Fe^{+2}, Cd^{+2}, Pb^{+2}, Zn^{+2}. Mn^{+2}, Ba, Mo^{+2}, Be, Ag, Cr, Al, V, Co, Cu, Ni, Sr, Li, Ga. According to results there are some abnormal elements recorded a various values from other elements shown in (Figure 3.12 and Figure 3.13). One of these traces is Lithium (Li) in Alaqa El-Foqah and Alaqa El-Tahta springs where two times of Li concentrations existed compared with other springs. Lithium exists in high concentrations in some areas, this is due to its natural occurrence, it is found in plants, animals, food products and beverages. Another reason for such increase of Li may be the presence of sewage wastewater nearby the springs and industrial activity which contain lithium (Sujatha et al,. 2001; Ahmad and Ghanem, 2015).

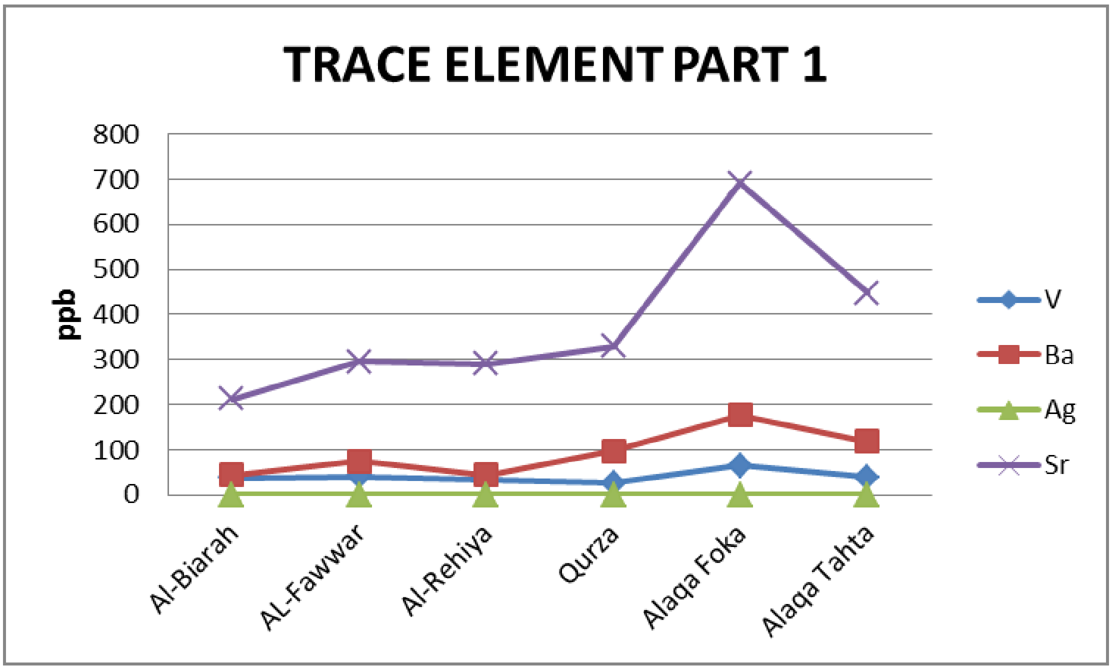


Figure 3.12: Trace elements (Sr, Ba, V and Ag) concentrations in springs water of Wadi-Samen catchment.

Springs contaminated by heavy elements like strontium is among the springs of Wadi-Samen catchment. Strontium (Sr) the analysis which recorded relatively higher concentration in Al-Alaqa Tahta compared with other springs. This is due to the heavy use of fertilizers and sewage-related irrigation (Figure 3.12) (Byerrum et al. 1974).

Although cadmium presents naturally in water from the erosion of cadmium deposits found in rocks and soils, cadmium is widely used in industrial applications, including the manufacture of batteries. It is also found in industrial wastes, sewage sludge, mining wastes, fossil fuel combustion products and tanning factories, those can influence Cd levels of surrounding groundwater by infiltration process in the case of Al-Fawwar spring, Al-Alaqah Al-Foqah, Al-Alaqah Al-Tahta, Qurza, Al-Baiarah, Al-Rehiya and Al-kherbeh spring water (Figure 3.14). The same trend of Cd happened to Vanadium (V) levels in the spring which prove man’s activity negative effects represented by urban sewage sludge, and certain fertilizers,in the region (Friberg et al., 1986).

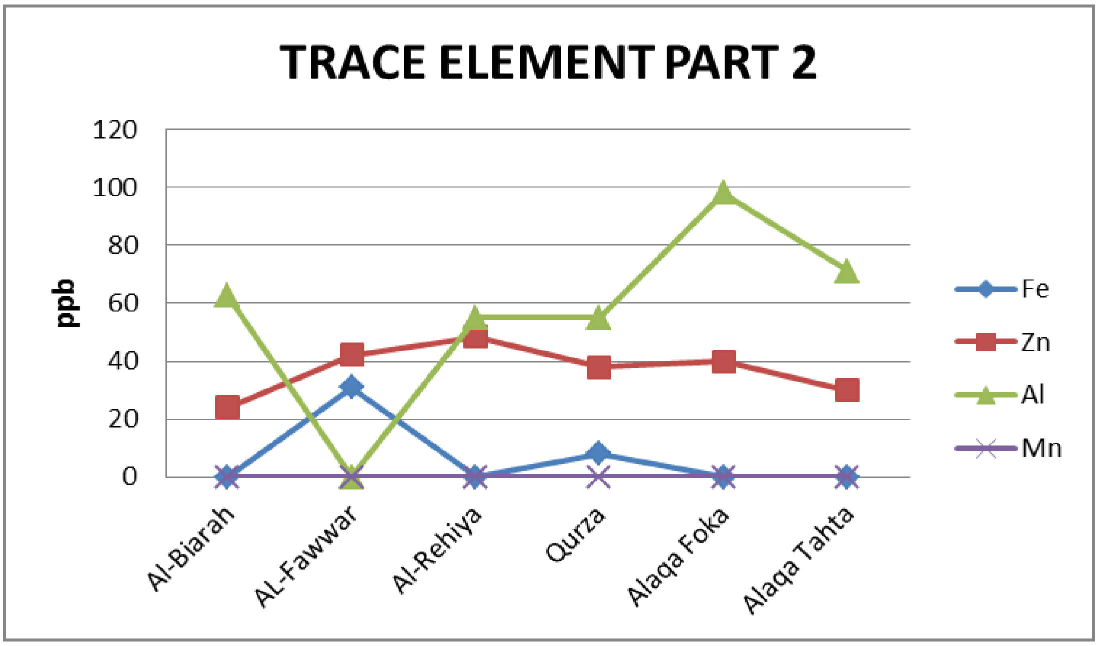


Figure 3.13: Trace elements (Fe, Zn, Al and Mn) concentrations in springs of Wadi-Samen catchment.

According to results, Alaqa El-Foqah spring containing a quantity of Aluminum (Al^{+3}) which has relatively higher levels than the other springs (Figure 3.13). On the other hand, Al-Fawwar spring and Qurza spring containing a quantity of iron (Fe^{+2}) which is relatively higher levels than the other springs, the concentration of aluminum and iron ions in the spring were high, due to originated by natural sources which are the rocks and clays (Appendix 10).

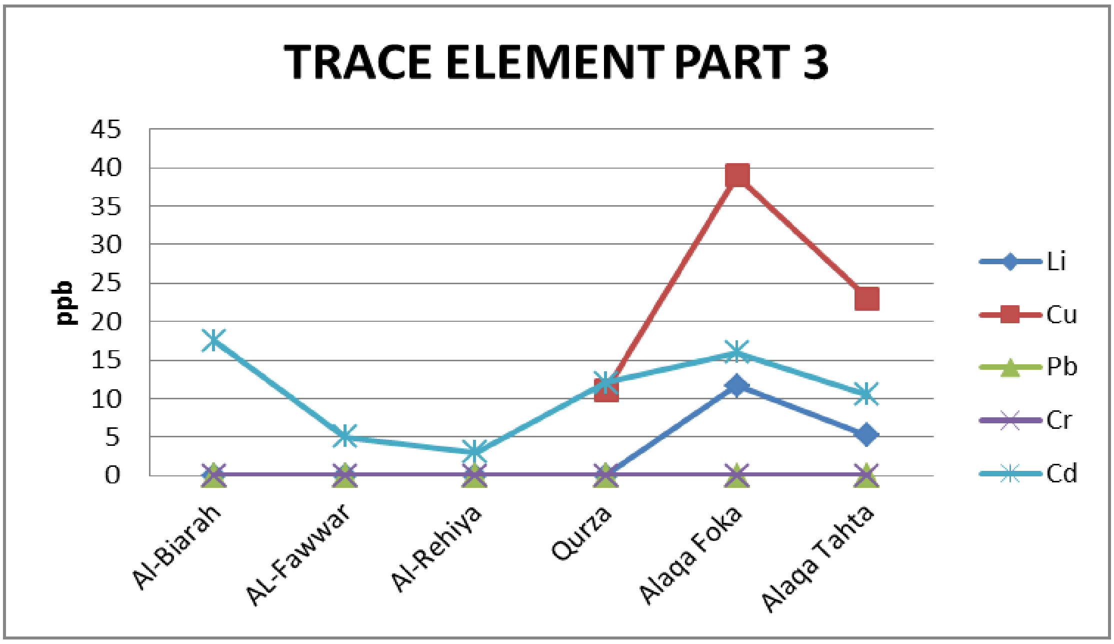


Figure 3.14: Trace elements (Li, Cu, Pb, Cr, Cd) concentrations in springs of Wadi-Samen catchment.

3.7 Water origin and classification:

Nature of rocks and movement of groundwater can change groundwater chemistry (Hem, 1985). The quality of groundwater depends on the purpose of use; it will be used for drinking water or industrial and irrigation. In order to set criteria for quality of water, measurements of chemical, physical and biological properties must be done under standards methods (Winter et al. 1998, Ghanem. 2014).

3.7.1 Springs water classification

3.7.2 Piper diagram

Piper diagram, is used as an effective graphical representation of chemistry in water samples in hydro-geological studies and is used as trilinear diagram that permits the classification of water samples into seven water types by based on the four main anions (bicarbonate, sulfate, chloride and nitrate) and the four main cations (calcium, magnesium, and sodium + potassium) (Langguth, 1966). In this study, a windows software called Aquachem program was used for plotting this diagram. According to piper diagram shows all samples are falling in earth alkaline water with prevailing bicarbonate in the two rounds (Figure 3.15).

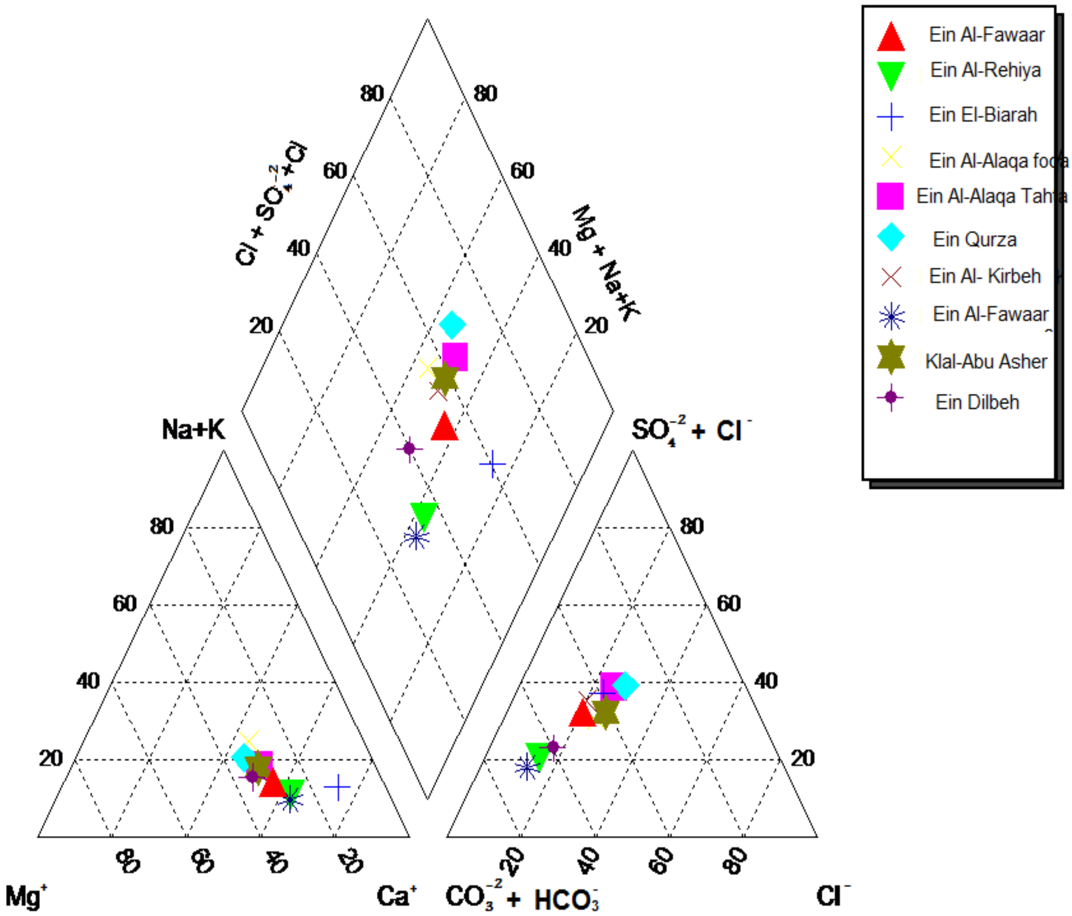


Figure 3.15: Piper diagram plot for springs of Wadi-Samen catchment for March and June rounds combined.

3.8 Water types

Spring water samples are plotted using piper trilinear diagram, show that 75% of all samples are falling in the domain of Ca–Mg–HCO^-_3, 25% of the samples show water type of Ca-HCO^-_3 and Ca-Cl-HCO^-_3, nature which indicates interaction with limestone rocks. Based on water type classification.

3.8.1 Spring water suitability for different purposes

Water quality is determined by assessing three classes of attributes: biological, chemical, and physical. The required water quality is determined by purpose of used (domestic, urban, agricultural or industrial) (WHO, 2007). Therefore, it is necessary to evaluate groundwater suitability for these purposes and especially for human drinking. To assess of groundwater suitability for all purposes especially for human uses. Groundwater which is considered suitable for human uses depends on several parameters (major and minor elements, inorganic, organic chemicals and biological constituents). Palestine standard (PWA, 2001) and World Health Organization standard (WHO, 2007) which were used to evaluating the suitability of groundwater for human activity in the study area.

In two periods (dry and wet) for analyzed water samples by (ppb) unit are compared with (WHO, 2007) standards. As a result the spring water in study area of some springs is unsuitable for human drinking purposes where in the case of suitable ones element, another element is not suitable such as Cd and Li.

The quality of plants, resistance to environmental conditions, ability to retain water, the properties of the soil structure, the irrigation method used and other factors, are important for productivity of agricultural crops (Todd, 1980). The excess of salts content is one of the major concerns with water used for irrigation. A high salt concentration present in irrigation water could negatively affect the growth of plant by changing the osmotic conditions in the root zone which would decrease or limit the water uptake (a physical effect). Some toxic constituents such as boron might influence the metabolic reactions (a chemical effect). Salt may also affect the soil by changing the soil structure and aeration, which would indirectly affect the growth of plants (Tood, 1980).

3.8.2 EC of springs

According EC (µS /cm) values for both rounds springs water in Todd classification table (Table 3.7), the results showed that all springs are suitable to irrigate all kinds of Fruit, Vegetable and Field crops because they presented in the first row of classification which is (Low Salt Tolerance crops).

Table 3.7: Classification of (Todd, 2007) for the tolerance of different types of crops by using conductivity values

Crop division	Low salt tolerance crops EC (µS/cm)	Medium salt tolerance crops EC (µS/cm)	High salt tolerance crops. EC (µS/cm)
Fruit crops	**0-3000** Limon, Strawberry, Peach spricot, Almond, Plum Orange, Apple, Pear	**3000-4000** Cantaloupe, Olive, Figs, Pomegranate	**4000-10,000** Date palm
Vegetable crops	**3000-4000** Green beans, Celery, Radish	**4000-10,000** Cucumber, Peas, Onion carrot, Potatoes, Sweet corn, Lettuce, Cauliflower, Bell pepper, Cabbage, Broccoli, Tomato	**10,000-120,000** Spinach, Garden beets
Field crops	**4000-6000** Field beans	**6000-10,000** Sunflower, Corn (field) ,Rice, Wheat	**10,000-16,000** Cotton, Sugar beet.

3.8.3 Salinity

Wilcox diagram which describes the relationship between SAR and conductivity. Wilcox diagram is divided into four salinity hazard columns in vertical (C1-C4) and four sodium hazard sections horizontally (S1-S4) (Figure 3.16). The results of the Wilcox analyzing put all the samples in medium salinity (C2) and low sodium (S1) in the two rounds, this zone indicate it’s suitability for agriculture (Wilcox, 1955).

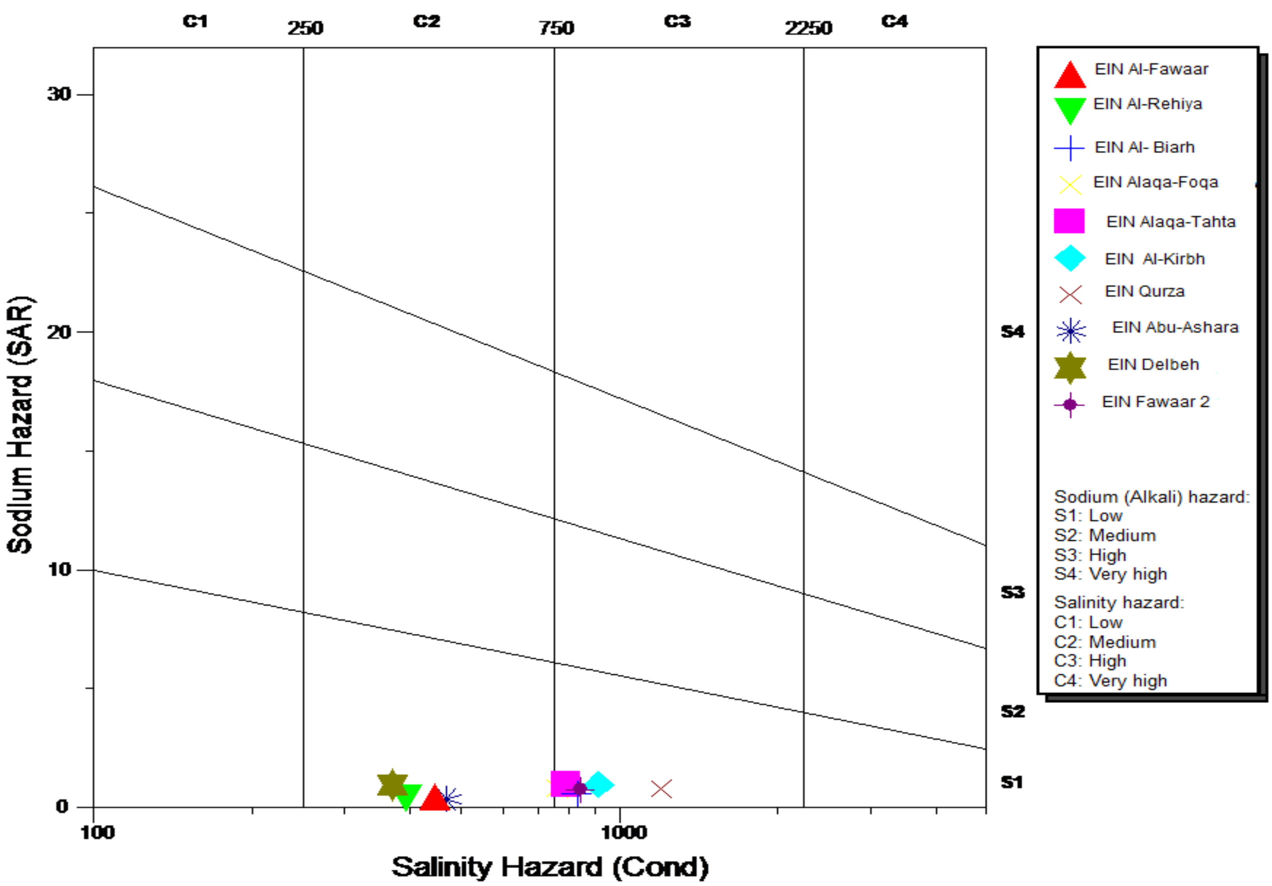


Figure 3.16: Wilcox classification of the water samples.

3.8.4 SAR

Sodium adsorption ratio (SAR) is one of the most popular indicators to show the suitability of water quality for irrigation which based on the water content of Na^{+}, Ca^{+2} and Mg^{+2} by applying a special equation (Table 3.8).

$$S.A.R = \frac{Na^{+}}{\sqrt{\frac{1}{2}(Ca^{2+} + Mg^{2+})}}$$

Table 3.8: The average concentrations of Na^{+}, Ca^{+2}, Mg^{+2} and SAR values for the projected springs

Spring name	Na^{+} (mg/l)	Ca^{+2} (mg/l)	Mg^{+2} (mg/l)	SAR
Al-Alaqah Al-Foqah	89.30	101.90	77.82	9.42
Al-Alaqah Al-Tahta	65.72	90.81	35.81	8.26
Qurza	17.98	25.22	5.99	4.55
Al-Baiarah	35.37	93.46	34.51	4.42
Al-Fawwar	41.06	102.00	41.18	4.48
Al-Rihiya	24.36	68.36	29.92	3.48
Al-kherbeh	21.93	84.99	15.32	3.09

According to the previous equation, a calculated SAR value for each spring sample was plotted in a certain table that classify it's suitability for irrigation. This classification is related to United States Department of Agriculture (USDA, 1954) which classify the SAR into four ranges (Table 3.9).

Table 3.9: Classification of water for irrigation suitability based on SAR (USDA, 1954).

SAR value	Irrigation suitability
<10	Excellent
10-18	Good
18-26	Fair
>26	Poor

After applying the SAR equation for all spring's samples, the analysis of the results showed that all water springs in both rounds situated in the zone of excellent class for irrigation suitability, which had SAR values below ten and that means low salinity effects on the studied area.

Chapter Four

Wastewater effects on socio-economic aspects

4.1 Introduction

This chapter discusses an analysis of socio-economic effects of wastewater in the study area, to reach this purpose the research based on a field survey by which a questionnaire with a random sample of the study area residents was designed and distributed.

4.2 Questionnaire main components

Questionnaire items have been classified according to five main components, affected by wastewater in the study area, which could be listed as follows:

- Effects of wastewater on livestock and agricultural production (economic)
- Effects of wastewater on natural and aesthetic wealth (environmental).
- Effects of wastewater on socio aspects- economic.
- Effects of wastewater on health aspects (health care).
- Effects of wastewater on used nearby groundwater.

4.3 Results and discussions

This part of the chapter shows an analysis of the questionnaire results, divided into four sections: general, health, socio-economic and the environmental sections.

4.3.1 The general section

- **Geographical distribution**

Questionnaires were divided equally among two agglomeration, which could guarantee homogeneous covered area (Table 4.1).

Table 4.1: Geographical distribution of respondents

Community	No. of Questionnaires	Percentage (%)
Al-Rehiya	25	50.0
Abu-Asja	25	50.0
Total	50	100.0

- **Age structure**

Regarding the distribution of the participants across age categories, the results varied between the two communities. In Rehiya, the sample captured respondents from all age groups, and in the same thing in Abu El-Asja all sample captured respondents from all age groups (Figure 4.1).

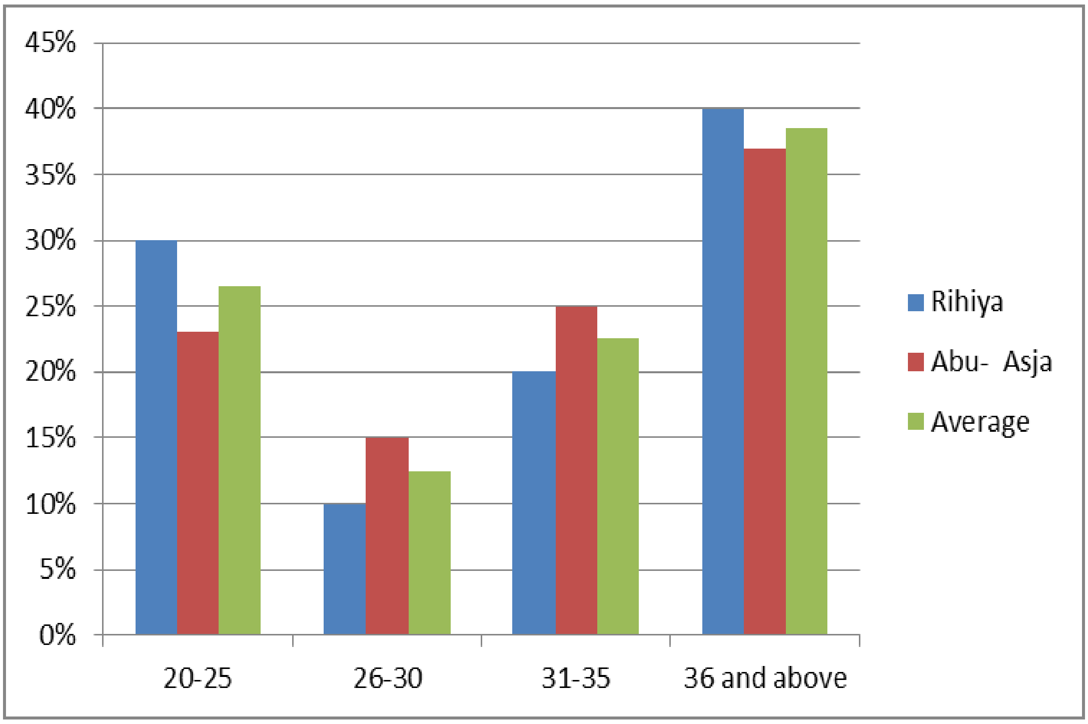


Figure 4.1: Distribution of age categories

- **Gender composition**

Palestinian women, have an important role in the management of their household water resources, only 40% of those surveyed were females (Figure 4.2).

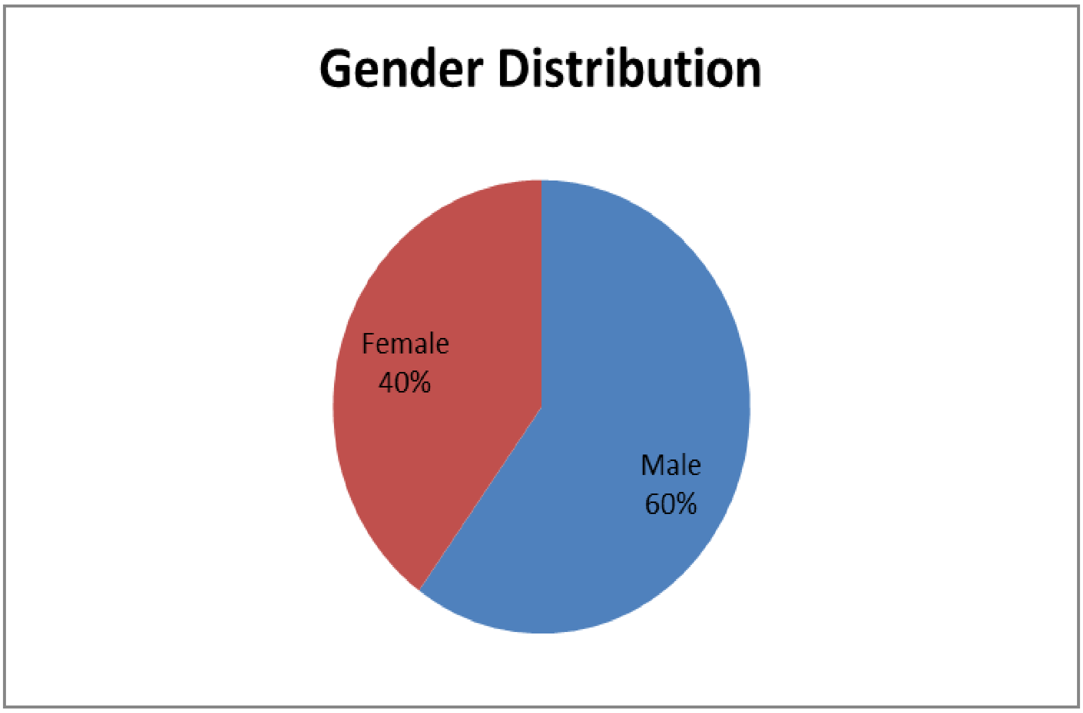


Figure 4.2: Gender distribution of respondents

- **Academic achievements**

Educational levels were classified to three levels; primary, secondary and university - college levels. Based on the survey results have shown that 35% of Al-Reheia village sample get a university-college degrees, compared to 55% from Abu-Asja sample, whereas 45% of Al-Reheia sample had a secondary school education because its residents do not allow females to go to universities, according to their beliefs and customs (Figure 4.3).

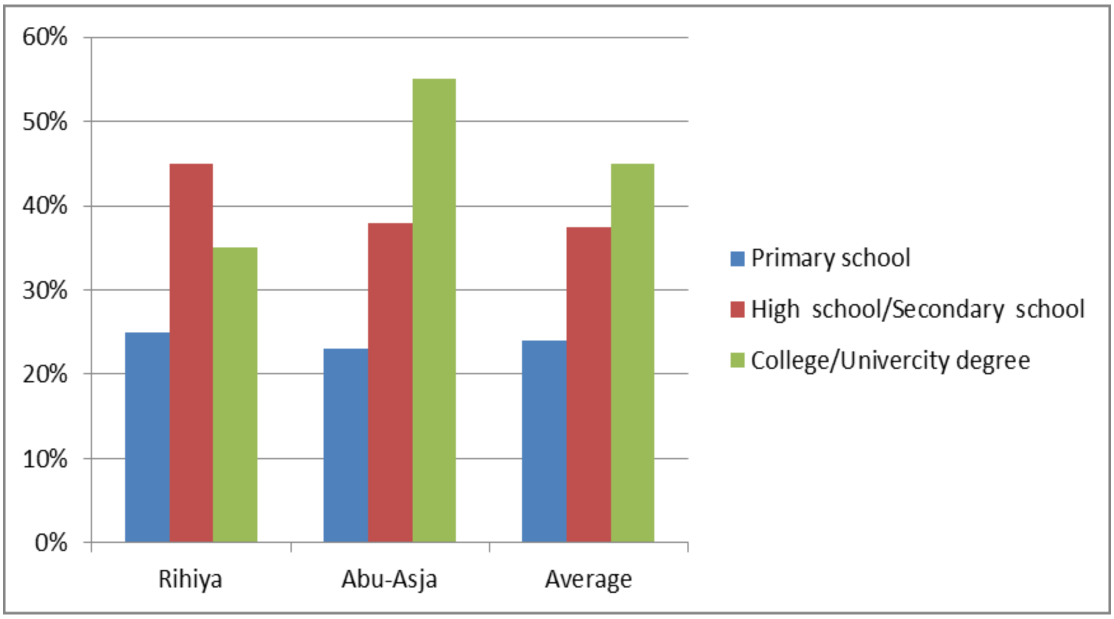


Figure 4.3: Academic achievements of respondents

- **Type of profession**

According to data analysis, they show that the population (about 60%) do not have permanent job. Comparatively, 40 percent of the overall sample are employed in governmental or private sectors (Table 4.2 and Figure 4.4).

Table 4.2: Occupation of the respondents

Community	Profession				Total
	Public sector	Private sector	Skilled work	Others	
Al-Rehiya	22.0%	14%	38%	26%	100%
Abu-Asja	28.0%	6%	34%	32%	100%
Average	25.0%	10%	36%	29%	100%

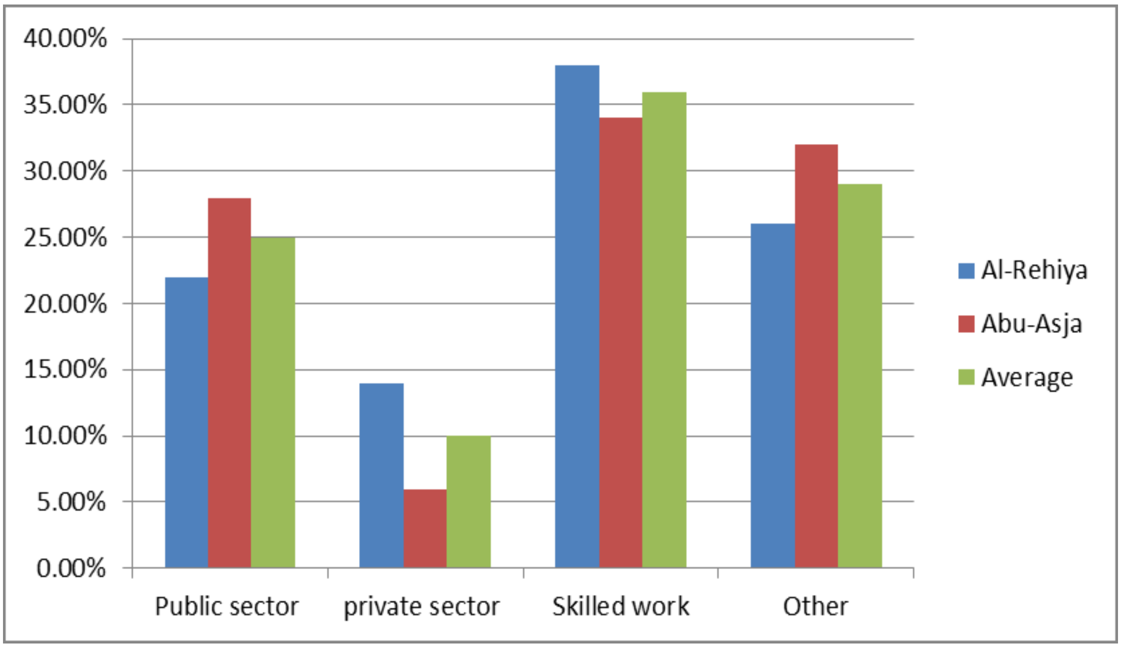


Figure 4.4: Profession of respondents

4.3.2 Health section

Disposal of raw wastewater of Hebron district in Wadi-Samen has negative impacts on both the socio-economic conditions and on human health. Respondents of both communities believe that raw wastewater has negative influences on public health. More than half of respondents from Al-Rihiya reported having been infected by a waterborne/sanitation disease, while 33% reported the same in Abu-Asja. After conducting interviews with local residents which showed the following results. Skin diseases were widespread, especially between children. These included skin rash and poisoning resulting from mosquitoes, asthma and amoeba disease and spreading malodorous smell (Figure 4.5).

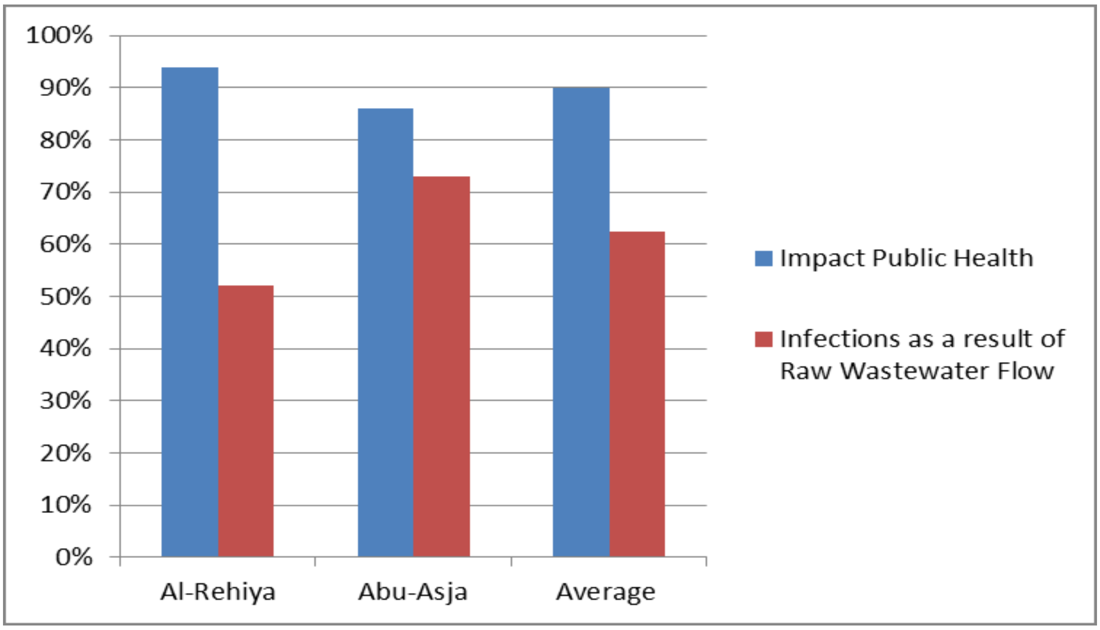


Figure 4.5: Public health impact of Wadi-Samen flow and infections proportions of raw wastewater flow

4.3.3 Socio-Economic section

The largest city in West Bank is Hebron city, according to a study by the applied research institute (Arij, 2009), a total area estimated by 74,1x10^6 m^2, including 30 x10^6 m^2 covered by housing units. According to the Palestinian Central Bureau of Statistics (PCBS, 2011), the village of Al-Rehiya estimate about 6 x10^6 m^2, including 2,5 x10^6 m^2 operated by houses, Al Rehiya is a rural community located a distance of 6 km southeast of Hebron.

- **Effects of wastewater flow on sizes of cultivated area.**

Among the risks posed by areas with uncovered wastewater streams in Wadi-Samen:

- The main reasons that affect the farmers not to cultivate their lands is flow of wastewater in the basin of Wadi. Also once they realize that they originate from affected areas by wastewater the people refuse to purchase crops.
- Damaged soil, dehydrated trees, increasing soil salinity and intoxication.
- One of the women in the survey area stated that she did not open house windows because of spread malodorous smells.
- Widespread mosquitoes, causing a further financial burden on households for medical attention and skin diseases. Interviewees asserted they needed a separate budget line item to fight mosquitos or mitigate resultant maladies.
- The wastewater flow is a alienate factor residents, investors and visitors.

- **Agricultural and livestock production**

  The main reasons that made the farmers not to cultivate their land and allow urban expansion on agricultural land was flow of untreated wastewater in the Wadi-Samin basin. Also dissuaded local people from purchasing grown vegetables in the soil which were contaminated by raw sewage.

  The extent of the Wadi's flow impact of agricultural production rates and livestock on the study area was clarified (Table 4.3). The results varied between the two communities, with a clear negative effects on lands of Abu-Aasja because of the village location near the Wadi's flow.

Table 4.3: Extent of impact of Wadi-Samen flow on agricultural and livestock activities**.**

Community	Extent of impact of agricultural production rates and livestock in the study area			Total
	Decrease by a 0-50% rate	Decrease by a 50-95% rate	Abandoned land	
Rihiya	31.0%	36.0%	33.0%	100.0%
Abu-Aasja	43.7%	40.8%	15.5%	100.0%
Average	38.8%	36.7%	24.5%	100.0%

- **Impact on the social dimension of the region**

The main threat that posed to the individuals, especially children is the wastewater flow. Also the wastewater flow reflects negative impact on social relations between local residents. In addition wastewater stream considers repellent factor for residents, investors and visitors. Some participants confirmed that they faced serious problems because certain families had refused to marry their daughters to residents living in the affected community because of hazards generated by the wastewater stream. The survey result show that most of people lived near of Wadi flow that are effected of this water (Figure 4.6).

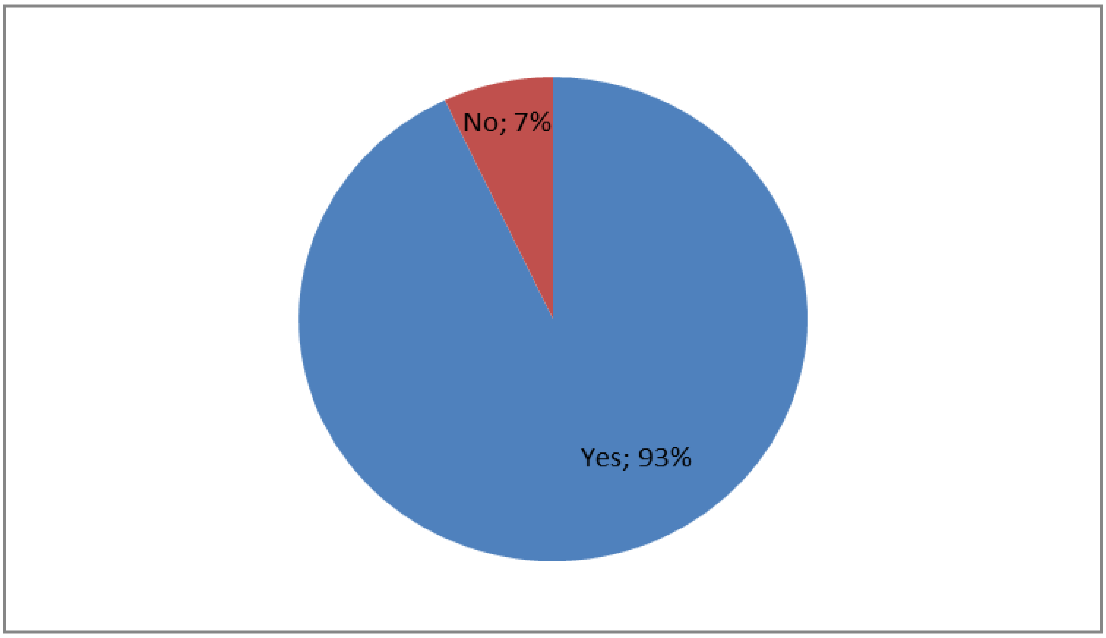


Figure 4.6: Impact of Wadi-samen flow on residence

- **Impact on the use of water resources**

Most of the participants use the springs in study area for agricultural purposes, either for irrigation or for livestock. Most of the respondents do not use spring water for household purposes due to its bad quality except AL-Rehiya village because it is the only well in the area that is used for drinking purposes, despite its proximity to wastewater stream (Figures 4.7).

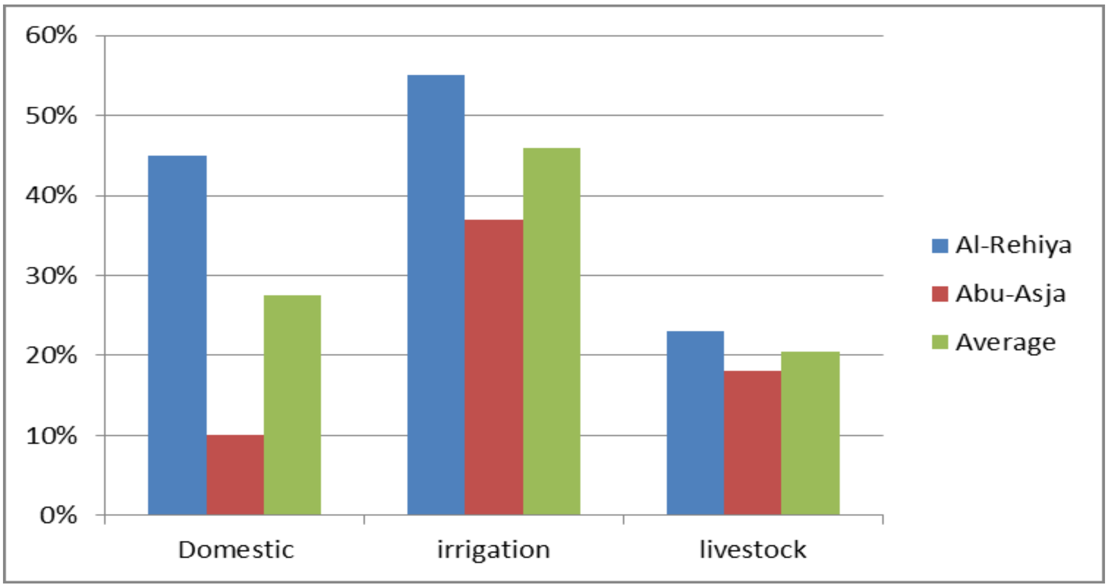


Figure 4.7: Purpose of spring water uses

4.3.4 The environmental section

Most of participants believe that the raw wastewater has direct or indirect negative impacts on the environment. According to (Table 4.4) there are people who believe that there is no effect for wastewater on aesthetic conditions, because they live far away from wastewater flow.

Table 4.4: Impact of Wadi-Samen flow on environment.

Community	Impact on the aesthetic conditions of the study area		Total
	Yes	No	
Rihiya	95%	5%	100%
Abu- Asja	90%	10%	100%
Average	92.5%	7.5%	100%

Regarding to wildlife, especially animals and plants, most of respondents also believe that wastewater has negative impact on both the wild mammals, birds and insects. Many of the respondents noticed the decrease in wild animals that used to be common in the area (Table 4.5).

Table 4.5: Impact of Wadi flow on wildlife.

Community	Impact on wildlife
Rihiya	80%
Abu- Asja	77%
Average	78.5%

Chapter Five

Conclusions and Recommendations

5.1 Conclusions

All provinces of the West Bank suffers water scarcity as do the Wadi-Samen basin. Israeli control of the headwater and frequent interruptions of water for long periods forced the people to utilize water of unprotected springs and wells. Wadi-Samen which is considered as a conduit for wastewater flow from Kiryat Arba colony and Hebron municipality, these uncontrolled disposal of raw sewage has potential negative impacts on the human health, local socioeconomic situation and landscape. However, Khirbet-Qilks is less susceptible to the adverse effects of the discharged raw wastewater due to its farther distance from the Wadi, while El-Helah, Rehiya, Abu-Asja and Rabod people are more suffering from these significant impacts.

One of the most negative effects of flow of wastewater thorough Wadi's is distortion of the aesthetic view of the local environment, which was a recreation area where people were used to spend their time on banks of Wadi enjoying beauty of nature before discharging a huge amounts of raw wastewater into Wadi and increasing wastewater proportion against spring's water within the flow. The wastewater quality along Wadi affects on the springs especially in the dry season pollution caused by wastewater may increased in the spring water because of lack of rain.

Generally, the assessment of water quality for a springs and wells through the analysis of physical parameters such as (EC, pH, Temp. and TDS) and chemical parameters such as major anions (Cl^-, HCO^-_3, NO^-_3 and SO^{-2}_4), major cations (Ca^{+2}, Na^+, Mg^{+2} and K^+) and heavy metals (Fe^{+2}, Pb^{+2}, Zn^{+2}, Cd^{+2}, Mn^{+2}, Ba, Mo^{+2}, Be, Cr, Ag, V, Al, Cu, Co, Ni, Li, Sr, Ga). pH average ranging between (7.8) for dry period and (7.08) for the wet period which means springs water generally were going toward of high alkalinity. This can be explained by the serious contribution of wastewater that drainage by Kiriat Arba colony and Hebron citizens who may increase in alkaline pollutants, thus, increase the pH.

In addition, there a strong correlation between EC and TDS changing together through the Wadi-Samen wastewater (TDS = 0.49 EC + 4.34 with R^2 = 0.99). According to springs' water analyzing, TDS levels for the sampled springs of Wadi-Samen catchment are considered as fresh water and suitable for irrigation activities.

Moreover, the measurement of major cations showed that the concentration of Ca^{+2} is higher than the other major cations which reflects the structure formation of groundwater aquifer, which are dolomite and limestone. On the other hand, HCO^{-}_3 concentration is higher than other major anions in both seasons, this explains the presence of high amounts of carbonate compound in the soil, especially in dry season. According to Total Hardness (TH) all springs in the study area are classified as very hard to hard water due to the presence of high amount of dissolved calcium salts.

The NO^{-}_3 for all spring water in study area ranges about 10 mg/l; according to samples analysis the concentration of nitrate in dry period is higher than wet period due to agricultural activities fertilizers and sewage effect.

Wastewater discharging along time and closeness in distance of the springs' locations to the wastewater flow is proportional to the microbial contamination content of TC and FC, all samples in study area have microbial contaminant except Qurza and Al-Kirbh springs.
Existence FC and TC in large quantities in these springs which make water springs unsuitable for drinking purposes according to (WHO, 2007) and (PWA, 2001) standards, but it is suitable for agriculture usage.
In Wadi-Samen springs, it is noticeable that there are no exceeding values for all the measured elements which indicate that there is no significant heavy metal-source contamination influencing groundwater of Wadi-Samen catchment such as industrial wastes or excessive using of fertilizers and insecticides of agricultural activities that containing heavy metals, except cadmium and lithium elements which found in higher than permitted quantity due to agricultural activity and sewage surrounding the springs. 75% of all samples are existing in the domain of Ca–Mg–HCO^{-}_3, which frequently recharging water in limestone and dolomite aquifers. 25% of the measured samples showed the water type Ca–HCO^{-}_3 and Ca–Cl–HCO^{-}_3.

On the other hand, by using EC test, Wilcox and SAR equation for all springs showed a good and suitable water quality for agricultural activities such as irrigation.

According to people's evaluation and field interviews, the spread of waterborne diseases and the diseases transmitted by mosquitoes such as rashes in Alrihiya, Abu-Asja and Rabod. As a result, there has been little desire for residents of the same area to buy the agricultural and animal products as dairy products or crops, and have begun finding out another alternative source. All of this lead to a significant economic losses.

In the end, this research is the first in this region. And there are not many previous studies on study area.

5.2 Recommendations

It found that it's important to take the following points into consideration for planning and management programs to improve water quality of springs and some steps that could reduce risk of hazardous raw wastewater:

- Construction of sewer system and wastewater treatment plant in Hebron governorate.
- Development of legislation and laws from PA to protect aquifers.
- Industrial pollution researches is needed.

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Appendices

Appendix 1: Physical parameters of some Wadi-Samen springs in the wet round (March, 2015).

Station Name	Date	pH	TDS (mg/l)	EC (µS/cm)	Temperature (^{0}C)
Al-Fawwar	21/03/2015	6.87	1145	2285	25
Al-Rehiay	21/03/2015	6.85	520	1005	22.5
Al-Biarh	21/03/2015	6.99	478	956	23
Al-Alaqa El-Foqa	21/03/2015	6.82	1203	2405	21.8
Al-Alaqa El-Tahta	21/03/2015	6.96	518	1036	24.4
Al-Kirbe	21/03/2015	6.73	371	741	23.2
Qurza	21/03/2015	7.08	437	873	21.9

Appendix 2: Physical parameters of some Wadi-Samen springs in the dry round (June, 2015).

Station Name	Date	pH	TDS (mg/l)	EC (µS/cm)	Temperature (^{0}C)
Al-Fawwar	11/6/2015	6.99	432	866	22
Al-Rehiay	11/6/2015	6.85	532	1029	21.6
Al-Biarh	11/6/2015	6.85	1105	2213	23.7
Al-Alaqa El-Foqa	11/6/2015	6.83	720	1432	22.9
Al-Alaqa El-Tahta	11/6/2015	6.92	985	1995	21
Al-Kirbe	11/6/2015	7.02	401	798	22
Qurza		6.88	481	948	

Appendix 3: Chemical parameters (major Cations and major Anions (mg/l)) of some Wadi-Samen springs in the wet round (March, 2015)

Station Name	Cl^-	NO^-_3	SO^{-2}_4	HCO^-_3	Mg^{+2}	Ca^{+2}	Na^+	K^+
Al-Fawwar	36.9	7.3	24.1	169	40.98	101.9	38.74	8.54
Al-Rehiay	40.5	7.3	29.1	183	40.1	68.	24.36	1.49
Al-Biarh	40.9	6.1	22.5	187	40.37	108	40.69	2.38
Al-Alaqa El-Foqa	32.5	7.5	23.4	177	40.2	97.31	66.62	1.66
Al-Alaqa El-Tahta	64.1	8.7	33.2	192	39.08	101.95	65.84	1.7
Al-Kirbe	63.2	5.9	12.9	154	41.93	95.43	39.4	8.99
Qurza	35	5.7	16.7	166	15.59	83.01	22.69	0.13

Appendix 4 : Chemical parameters (major Cations and major Anions (mg/l)) of some Wadi-Samen springs in the dry round (June, 2015)

Station Name	Cl^-	NO^-_3	SO^{-2}_4	HCO^-_3	Mg^{+2}	Ca^{+2}	Na^+	K^+
Al-Fawwar	31.8	6.1	20.9	169	41.18	102.00	41.06	8.78
Al-Rehiay	42.8	7.3	29.8	189	29.92	67.36	24.36	1.49
Al-Biarh	33.9	6.4	22.9	164	34.51	93.46	35.37	1.96
Al-Alaqa El-Foqa	39.1	6.8	22.4	191	77.82	225.90	149.30	5.86
Al-Alaqa El-Tahta	37.9	7.1	23.4	183	35.81	90.81	65.72	1.55
Al-Kirbe	44.3	7.6	19.5	149	5.99	25.22	17.98	1.35
Qurza	50.2	7.9	21.7	162	15.32	84.93	21.93	0.11

Appendix 5 : The geographical coordinates (meters) of the measured springs

Station Name	X	Y	Height
Al-Fawwar	7506431	4432824	720
Al-Rehiay	7510655	4431859	708
Al-Biarh	7505789	4432825	692
Al-Alaqa El-Foqa	7502071	4423049	688
Al-Alaqa El-Tahta	7502410	4421750	657
Al-Kirbe	7508429	4439810	712
Qurza	7503775	4419633	640

Appendix 6 : The microbial content in some springs of Wadi-Samen catchment (CFU/100 ml) in the wet round (March, 2015)

Spring Name	F.C	T.C
Al-Fawwar	136000	178000
Al-Rehiay	79	14000
Al-Biarh	710	1020
Al-Alaqa El-Foqa	50000	66000
Al-Alaqa El-Tahta	32000	48000
Al-Kirbe	0	70
Qurza	0	33000

Appendix 7 : The microbial content in some springs of Wadi-Samen catchment (CFU/100 ml) in the dry round (June)

Spring Name	F. C	T.C
Al-Fawwar	18	9600
Al-Rehiay	39	14200
Al-Biarh	280	21000
Al-Alaqa El-Foqa	170	12500
Al-Alaqa El-Tahta	410	27000
Al-Kirbe	9	175
Qurza	0	340

Appendix 8 : Different parameters of Wadi-Samen wastewater along the Wadi in the wet round (March, 2015)

Stations names	pH	TDS (mg/l)	EC (µS/cm)	TSS (mg/l)	BOD_5 (mg/l)	COD (mg/l)
Wadi-Eldor	6.45	1488	2977	872	859	1600
El-Hellh	6.4	1620	3230	888	918	1933
Al-Rehiya	6.55	729	1462	536	379	688
Abu-Asja	6.76	874	1749	180	366	683
Rabod	6.8	757	1515	256	213	516

Appendix 9 : Different parameters of Wadi-Samen wastewater along the Wadi in the dry round (June, 2015)

Stations names	pH	TDS (mg/l)	EC (µS/cm)	TSS (mg/l)	BOD_5 (mg/l)	COD (mg/l)
Wadi-Eldor	6.66	980	1973	640	698	1376
El-Hellh	6.62	854	1699	324	366	715
Al-Rehiya	6.71	820	1588	219	318	655
Abu-Asja	6.74	890	1769	138	410	805
Rabod	6.81	1001	1989	247	241	477

Appendix 10 : Trace elements concentrations (ppb) in springs of Wadi-Samen catchment in the dry season (Part 1)

Spring name	Barium	Vanadium	Iron	Cobalt	Cadmium	Chromium	Beryllium	Lithium
Al-Fawwar	74.24	39.23	31.29	0.20	0.01	0.13	ND	ND
Al-Rehiay	42.34	34.28	ND	0.1	ND	0.12	ND	ND
Al-Biarh	44.12	36.84	ND	0.30	0.01	0.20	ND	ND
Al-Alaqa El-Foqa	176.10	64.49	ND	0.27	ND	0.50	ND	11.71
Al-Alaqa El-Tahta	118.00	38.67	ND	0.22	0.01	0.48	0.02	5.17
Al-Kirbe	23.54	13.03	ND	0.11	0.11	0.28	0.20	ND
Qurza	96.80	25.69	7.87	0.37	ND	0.11	0.05	ND

Appendix 10 : Trace elements concentrations (ppb) in springs of Wadi-Samen catchment in the dry season (Part 2)

Spring name	Aluminum	Strontium	Manganese	Nickel	Copper	Zinc	Silver
Al-Fawwar	ND	294.5	ND	ND	ND	41.87	0.01
Al-Rehiay	55.08	289.80	1.20	ND	ND	48.42	ND
Al-Biarh	62.54	211.60	ND	1.73	ND	23.80	ND
Al-Alaqa El-Foqa	97.65	690.60	0.42	1.76	39.04	40.22	ND
Al-Alaqa El-Tahta	70.99	447.40	0.21	1.77	22.61	30.33	0.01
Al-Kirbe	ND	183.60	0.41	1.73	11.42	89.71	0.10
Qurza	54.67	329.40	ND	1.02	ND	37.43	ND

(ND): not detected

Appendix 11 : Copy of the distributed questionnaires on Al-Fawwar, Al-Rehiay , Abu-Asja and Qurza citizens in Arabic language.

Institute of Environmental and Water Studies

BIRZEIT UNIVERSITY
Birzeit, Palestine

الأستبانة

تهدف هذه الدراسة إلى تحديد أهم المشاكل التي تسببها المياه العادمة غير المعالجة و التي تتدفق في حوض وادي السمن في منطقة الخليل ولهذه الاستبانة أهمية كبيرة في دراستي التي أجريها على تلك المنطقة ولا سيما الأهمية الاقتصادية والاجتماعية، وفي هذه الاستبانة سنراعي السرية التامة في حماية المعلومات ولن تستخدم إلا في مجال البحث ولن تعرض للنشر أو التوزيع.

1- مكان سكنك الحالي :

( ) الريحية ( ) وادي أبو العسجا ( ) الفوار

2- نوع الجنس :

( ) ذكر ( ) أنثى

3- الفئة العمرية (عمرك) :

( ) 20-25 ( ) 26-30 ( ) 31-35 ( ) 36- فما فوق

4- المستوى التعليمي لديك :

( ) ابتدائي ( ) ثانوي ( ) جامعي

5- ما هي مهنتك ؟

(   ) موظف في قطاع حكومي   (   ) موظف في قطاع خاص

(   ) زراعة   (   ) مهنة حرة

(   ) غير ذلك

6- هل تعتقد أن المياه العادمة في وادي السمن قد أثرت بشكل مباشر أو غير مباشر على الصحة العامة للسكان ؟

(   ) نعم   (   ) لا

7- هل تعتقد أن المياه العادمة المتدفقة في وادي السمن قد أثرت بشكل مباشر أو غير مباشر على الوضع الاقتصادي للمنطقة ؟

(   ) نعم   (   ) لا

8- هل عانيت أو أي من أسرتك من أي أمراض مزمنة أو أي مرض يذكر نتيجة المياه العادمة الجارية في وادي السمن ؟

(   ) نعم   (   ) لا

9- إذا كانت إجابتك نعم عن السؤال السابق، أذكر الاجراءات التي قمت بها من حيث زياراتك للعيادة الطبية وأذكر عدد المرضى أو الأمراض التي أصبت بها ونحوه:

....

....

....

....

10- **هل تملك أراضي زراعية محاذية لمجرى المياه العادمة في منطقة وادي السمن؟**

(   ) نعم   (   ) لا

11- **إذا كانت إجابتك على السؤال السابق بنعم، فكم عدد الدونمات التي تمتلكها.**

....

....

12- **هل تمت زراعة هذه الاراضي في القديم :**

(   ) نعم   (   ) لا

13- **إذا كانت إجابتك على السؤال السابق بنعم، فما نوع الأشجار التي كانت مزروعة.**

....

....

14- **هل يتم زراعة الأراضي المحاذية لمجرى المياه العادمة حاليا؟**

(   ) نعم   (   ) لا

15- **هل أدى تصريف المياه العادمة ووصولها إلى الأراضي الزراعية إلى التأثير على ناتجها الزراعي؟**

(   ) نعم   (   ) لا

16- **هل قمت بهجرة أرضك الزراعية نتيجة الآثار السلبية الناجمة عن المياه العادمة في وادي السمن؟**

(   ) نعم   (   ) لا

17- هل لاحظت أي تأثير يذكر من المياه العادمة على التربة ونتيجة لذلك أصبحت غير صالحة للزراعة ؟

(   ) نعم (   ) لا

18- هل تسكن الآن أو سبق لك و أن سكنت سابقا بجوار مجرى المياه العادمة في وادي السمن ؟

(   ) نعم (   ) لا

19- اذا كانت اجابتك نعم عن السؤال السابق، هل لمست أي تأثرت مباشر أو غير مباشر سلبية من المياه العادمة في وادي السمن كالروائح الكريهة مثلا أو البعوض .

(   ) نعم (   ) لا

20- هل فكرت في تغيير مكان سكنك نتيجة الآثار السلبية للمياه العادمة في الوادي؟

(   ) نعم (   ) لا

21- هل أثر تدفق المياه العادمة المكشوفة في وادي السمن سلبيا على جمال الطبيعة ؟

(   ) نعم (   ) لا

22- هل الآثار البيئية الملوثة التي تركتها المياه العادمة في وادي السمن أثرت على الحياة الحيوانية من حيث الانتاجية في المنطقة ؟

(   ) نعم (   ) لا

23- هل أثرت المياه العادمة في وادي السمن على الحياة البرية في المناطق المحيطة بها ؟

(   ) نعم (   ) لا

24- اذا كانت إجابتك بنعم عن السؤال السابق، حدد بشكل مختصر أنواع الحيوانات أو النباتات البرية المتأثرة بشكل مباشر أو غير مباشر بالآثار السلبية للمياه العادمة على تلك الكائنات.

....

....

25- هل يوجد ينابيع قريبة من مكان سكنك؟

(   ) نعم   (   ) لا

26- اذا كانت إجابتك بنعم عن السؤال السابق، ما هو نوع الاستخدام لمياه هذه الينابيع:

(   ) لأغراض منزلية   (   ) لري المحاصيل   (   ) لري الاشجار المثمرة

(   ) لسقاية الحيوانات

27- اذا كانت اجابتك ب لا، ما هو السبب في ذلك :

(   ) بسبب تردي جودة المياه   (   ) لأسباب اخرى تريد ذكرها

....

28- هل سبق لك و أن استخدمت أو أحد آخر استخدم مياه المجاري لري المحاصيل الزراعية لديه؟

(   ) نعم   (   ) لا

29- باعتقادك إلى أي مدى أثرت المياه العادمة في وادي السمن سلبيا على إنتاجية الأراضي الزراعية والثروات الحيوانية في المناطق المجاورة للوادي:

(   ) تناقصت بنسبة 0-50 %   (   ) تناقصت بنسبة 50-95 %   (   ) تمت هجرة هذه الاراضي

30- آراء أخرى تريد أن تقترحا.

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شكراً لتعاونكم معنا