An-Najah National University
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Wastewater Characteristics and the Impact of its Use in Irrigation on Soil: The Case of Faria Catchment

Prepared By

Mohammad Subhi Mohammad Abu Baker

Supervised By

Dr. Mohammad N. Almasri

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Mohammad Subhi Mohammad Abu Baker

This Thesis was defended successfully on 5 / 6 /2007 and approved by:

Committee Members	Signature
1. Dr. Mohammad N. Almasri	....
2. Dr. Amal Hudhud	....
3. Dr. Marwan Haddad	....
4. Dr. Anan Jayyousi	....
5. Dr. Nidal Za'tar	....

In the name of God

... Dedicated to
my parents and fiancé

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List of Abbreviations

As	Arsenic
BOD_5	Biochemical oxidation demand
Ca	Calcium
Cd	Cadmium
Cl^-	Chloride
cm	Centimeter
Co	Cobalt
Cr	Chromium
Ct	Total carbon
Cu	Copper
DEM	Digital elevation model
GIS	Geographical information system
gm	Gram
GPS	Geographical positioning system
HCO_3^-	Bicarbonate
K	Potassium
kg	Kilogram
km	Kilometer
LCL	Lower control limit
Mg	Magnesium
mm	Millimeter
Mn	Manganese
Mo	Molybdenum
Na	Sodium
Ni	Nickel
Nt	Total nitrogen
Pb	Lead
ppm	Part per million
T	Typical concentration
Tp	Total phosphate
UCL	Upper control limit
WESI	Water and environment studies institute – An-Najah National University
WHO	World health organization
Zn	Zinc

WASTEWATER CHARACTERISTICS AND THE IMPACT OF ITS USE IN IRRIGATION ON SOIL: THE CASE OF FARIA CATCHMENT

By

Mohammad Subhi Mohammad Abu Baker

Supervisor
Dr. Mohammad N. Almasri

Abstract

The use of untreated wastewater in irrigation is a common practice in several countries such as Palestine. Since decades, Palestinians in many locations used raw wastewater for irrigation due to several reasons that include: (i) shortage of freshwater resources that can cover there domestic and agricultural needs, (ii) the Israeli control of the available freshwater resources, (iii) the wastewater is of costless value and (iv) the absence of enforceable regulations that restrict the use of wastewater in irrigation. Faria Catchment, Palestine is a representative example of the use of untreated wastewater in agriculture.

The goal of this research is to investigate and analyze the quality-related parameters of the wastewater used in irrigation in Faria Catchment. These parameters include pH, EC, Cl^-, NO_3-N, TP, Mg^{+2}, Ca^{+2}, hardness, HCO_3^-, Zn^{+2}, K^+, Cu^{+2}, BOD_5, Na^+, SAR and turbidity. A second objective of this research is to compare these parameters with the international standards for using wastewater in irrigation. Thereafter, wastewater impacts on selected soil parameters such as pH, texture, accumulation of heavy metals in soil profiles, total carbon and total nitrogen were investigated.

Results show that wastewater quality varies spatially and temporally. However, the values of these parameters are extremely above the permissible limits for using wastewater in irrigation. The doses of industrial wastewater result in extreme values in certain parameters such as SAR, EC and Cl^-. The use of wastewater in irrigation shows clear effects on the top soil texture, total carbon and total nitrogen amounts and the accumulation of heavy metals in soil profile especially arsenic, cadmium and lead.

CHAPTER ONE: Introduction

1.1 Background

The Middle East region is suffering from a chronic shortage in water resources and alarming rate of population increase. West Bank, as part of this region, has also limited water resources. These resources include groundwater and harvested rainwater. Water resources in the West Bank are under the Israeli control. This situation has restricted the availability and accessibility of water resources to the Palestinians. Palestinians ought to develop their water resources to compensate the shortage in water supply and save the available fresh water for domestic use. One of the most potential and promising alternative solutions is to reuse the treated wastewater for irrigation in agriculture (Haruvy, 1997).

Raw wastewater is being used since decades for irrigation in several sites in the West Bank such as Wadi Az-Zemar in Tulkarm area, Faria Catchment in the eastern part of Nablus City (Field visits, 2006), Wadi Al-Qelt and Wadi An-Nar between Jerusalem and Bethlehem (ARIJ, 1996). Among these sites, Faria Catchment stands as a representative example for the use of raw wastewater in irrigation.

The use of untreated wastewater in irrigation is an established practice in Faria Catchment. The eastern portion of the City of Nablus, Balata, and Askar refugee camps and the eastern industrial zone of Nablus City discharge their untreated wastewater to this Catchment (Field visits, 2006). The wastewater is raw and it originates from domestic and industrial sources. However, the surface flow from springs and rainwater in the Faria Catchment mixes with untreated wastewater. This is in some way or another dilutes the wastewater especially in areas distanced from the Catchment inlet.

Farmers in Faria Catchment use wastewater in irrigation because it is a costless resource and due to the inexistence of enforceable regulations to restrict the use of untreated wastewater (Al-a'ama. and Nakhla, 1995). The annual quantity of wastewater that flows from Nablus City towards Faria Catchment is around 2.2 million cubic meters (mcm) from domestic sources (PWA, 2003) and 0.2 mcm from industrial sources (Nablus Municipality, 2006).

Wastewater effluent contains several chemical and biological elements that adversely affect human health. The use of raw and diluted wastewater in agriculture had caused several cases of Ameba and helminthic disease in Faria Catchment (Salahat, Albathan village council, personal communication 2005). The flowing untreated wastewater in Faria Catchment contaminates surface water and potentially groundwater since the depth to water table in several wells is less than 5 m (PWA, 2003). The soil also is adversely impacted by using wastewater in irrigation. Such impacts include the deterioration of the soil structure. Raw wastewater contains heavy metals that will ultimately accumulate in soil profile and potentially percolate towards groundwater resources if it is used in irrigation. Some of these heavy metals are hazardous to plants and human health such as lead and arsenic.

As such, it is necessary to investigate and analyze wastewater quality to determine element concentrations in order to better identify the associated impacts on water resources and soil properties (Stuart and Milne, 2001). In addition, by analyzing wastewater quality it is possible to determine the suitable treatment processes that can be considered for the future proposed treatment plant in the eastern part of the City of Nablus.

GIS was used extensively in this research in: (i) the determination of wastewater and soil sampling locations, (ii) the designation of the locations that are irrigated with raw and diluted wastewater, (iii) the delineation of the zones of groundwater vulnerability to contamination, and (iv) the description of the study area.

This thesis concentrates on investigating the effluent chemical characteristics at the main outlet in the eastern portion of Nablus City. In addition, it studies the effects of using water of different qualities in irrigation on the soil properties, accumulation of heavy metals in soil profile and the vulnerability of the underlying groundwater resources to contamination in Faria Catchment.

1.2 Research Objectives

The main objectives of this research are:

1. To study the chemical characteristics of wastewater being discharged into Faria Catchment from Nablus City; and
2. To evaluate the impact of using wastewater in irrigation on soil chemical characteristics at different soil depths and different locations.

1.3 Research Question

The goal of this research is to study and if possible, to answer the following question conveniently:

Do the current practices of using untreated wastewater in irrigation have a noticeable impact on soil pH, texture, total nitrogen, total carbon and the occurrence of heavy metals at considerable depths?

1.4 Research Motivation

Wastewater is an important non-conventional water resource for the Palestinians. Therefore, it is important to determine its quality parameters, to investigate its effects on soil properties, to figure out the vulnerability of groundwater to contamination especially in irrigated areas with wastewater, and to enrich the database that can be used for any future design of a wastewater treatment plant. It is essential to provide new data regarding wastewater characteristics and soil properties in Faria Catchment since the available data in this regard is quite old and may not exist for certain parameters. In addition, It is fairly unknown, quantitatively, the impact of the use of wastewater (raw and diluted) in irrigation on the soil chemical properties. The outcome of this research is of great importance to decision makers and to the best of my knowledge; this is the first time such a research to be carried out in the study area.

1.5 Who will Benefit

The main expected beneficiaries from this research are:

- <u>Nablus Municipality:</u> to help in the design of the proposed wastewater treatment plant for the eastern portion of Nablus City;
- <u>Ministry of Agriculture</u>: to determine the impacts of the use of raw wastewater in irrigation on soil;

- Palestinian Water Authority: to find out the potential use of wastewater and its suitability as a non conventional water resource;
- Farmers: they will be aware regarding the potential impacts of using untreated wastewater; and
- Academic and research sector: since this work deemed to be the first to be carried out in the West Bank, it will stimulate the interest to carry out similar work at different locations.

1.7 Thesis Outline

This thesis is comprised of seven chapters. Chapter two presents research methodology. Chapter three provides a general background. Chapter four gives a general description about the study area. Research results and analysis are provided in chapters five and six. Research conclusions and recommendations are summarized in chapter seven.

CHAPTER TWO: Research Methodology

Figure (1) depicts the flowchart of the research methodology that consists of the following components:

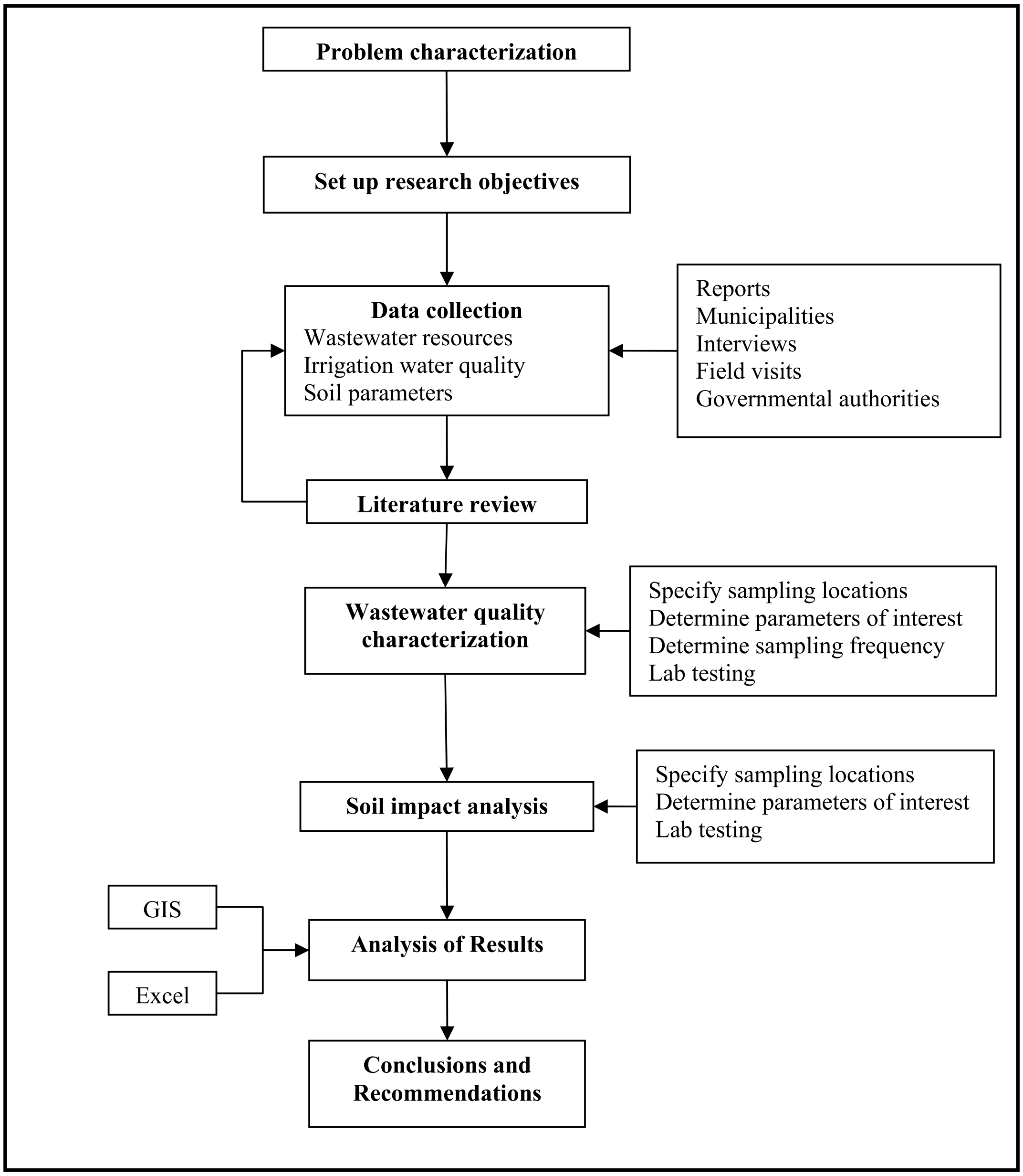

Figure (1): Flowchart of Research Methodolog

2.1 Problem Characterization

The characteristics of the wastewater used in irrigation in Faria Catchment are unknown. Also the impacts on soil properties as pH, soil texture, heavy metal accumulation and total carbon and total nitrogen in soil were not studied deeply. As such, related problems are well identified and characterized for the study area.

2.2 Research Objectives

Determination of wastewater characteristics and the impact of its use on soil properties in Faria Catchment.

2.3 Data Collection

In order to build up a solid knowledge regarding the current situation in Faria Catchment, all the required data related to wastewater sources, irrigation water quality and soil parameters in Faria Catchment were collected from several sources that include previous reports, municipalities, interviews, field visits and governmental authorities.

2.4 Literature Review

This step involves the reviewing of past research standard results and other published data related to the use of wastewater in irrigation. This is in one way helps in checking latest experiences in this regard and elaborates on the methodologies adopted in such situations.

2.5 Sampling

The collected samples of raw and diluted wastewater and the freshwater from the specified accessible locations were tested at WESI labs for the following parameters pH, EC, Cl^-, NO_3^-,TP, HCO_3^-, Mg^{+2}, Ca^{+2}, Hardness, Na^+, SAR, Cu^+,Fe^{+3}, BOD_5 and Turbidity.

Soil samples were collected from selected locations and cover areas irrigated with fresh water, diluted wastewater and raw wastewater.

These soil samples were analyzed at Ruhr University labs, Germany. Soil analysis was carried out to identify the impacts of different water qualities used in irrigation on soil texture, pH value, accumulation of heavy metals, total carbon and total nitrogen in soil profiles.

2.6 Analysis of Results

The lab results for wastewater and soil were analyzed using Excel and GIS.

2.7 Conclusions and Recommendations

Depending on the outcome of the analysis, conclusions and recommendations were made.

CHAPTER THREE: General Background

3.1 Introduction

The scarcity of water resources in arid and semi-arid regions enforces the decision makers and planers to look for new conventional and non conventional water resources. This is essential to compensate the existing shortage in water supply and to promote further development.

Wastewater is a non conventional water resource that can be used after treatment in agricultural irrigation and specific industrial activities. Wastewater reuse in agriculture conserves the freshwater resources for domestic purposes. In addition, it has a high nutrient content that is good for crops, which reduces the needed quantities of fertilizers (FAO, 1992).

This chapter discusses several main issues related to wastewater such as the general characteristics of wastewater, along with the main constituents of wastewater and the heavy metals found in wastewater. The last section in this chapter summarizes the effects of using wastewater for irrigation on soil characteristics.

3.2 General Characteristics of Wastewater

Municipal wastewater is comprised of water (99.9%) together with small concentration of suspended and dissolved organic and inorganic solids, viruses, bacteria, protozoa and helminthes (FAO, 1992). The main constituents of wastewater are summarized in Table (1).

Table (1): Main Constituents Found in Wastewater (FAO, 1992)

Item	Constituent
1	Total solids that divided to dissolved and suspended solid
2	Nitrogen
3	Phosphorus
4	Chloride
5	Grease
6	BOD_5
7	Pathogens that includes: bacteria. Viruses, worms and protozoa
8	Trace and heavy metals

The presence and concentrations values of the items in Table (1) differ from location to location. These differences are due to many reasons that include: the sources of wastewater and water consumption where as the concentrations of constituents decrease with the increase in consumption.

The most common inorganic elements found in wastewater that result in harmfulness effects on soil, plants, animals, and human health are heavy metals. When wastewater contaminated with heavy metals is being used for irrigation, these metals will accumulate in soil profile (FAO, 1992). Table (2) summarizes the standard concentrations of heavy metals in treated wastewater suitable for irrigation. The typical concentration of heavy metals in soil and plants are presented in Table 3.

Table (2): Suitable Heavy Metal Concentrations for Irrigation (Pettygrove and Asano, 1984)

Element	Water quality for irrigation (mg/l) Long term	Short term
As	0.1	10
Cd	0.01	0.05
Cr	0.1	20
Cu	0.2	5
Pb	5	20
Mo	0.01	0.05
Ni	0.2	2
Zn	2	10

Table (3): Concentrations of Heavy Metals in Soil and Plants (Pettygrove and Asano, 1984)

Element	Soil concentration Range ppm	Typical	Typical concentration in plant tissue Range (ppm)	Impact on plant growth
As	0.1 – 40	6	0.1 – 5	Not required
Cd	0.01 – 7	0.06	0.2 – 0.8	Not required: toxic
Cr	5 – 3,000	100	0.2 – 1	Not required: low toxicity
Co	1 – 40	8	0.05 – 0.15	Required by legume at <0.2 ppm
Cu	2 – 100	20	2 – 15	Required at 2 – 4 ppm, toxic at >20ppm
Pb	2 – 200	10	0.1 – 10	Not required: low toxicity
Mn	100 – 400	850	15 – 100	Required: toxicity depend on Fe/Mn ration
Mo	0.2 – 5	2	1 – 100	Required at <0.1 ppm: low toxicity
Ni	10 – 1,000	40	1 – 10	Not required: toxic at >50 ppm
Zn	10 – 300	50	15 – 200	Required: toxic at >200 ppm

3.3 Existence of Heavy Metals in Wastewater

Heavy metals are the group of metals that have density greater than 4 g/cm^3. Under this group, the following elements are included: arsenic, cadmium, chromium, copper, lead, mercury, zinc, nickel, molybdenum, and manganese (FAO, 1992). Generally, heavy metals appear in wastewater and storm water collection systems from many sources that can be categorized into the following (Sorme and LagerKvist, 2002):

1. Household: this includes feces, urine, amalgam, detergents, pipes and tapes, drinking water, and paints;
2. Drainage water: it is the water that leaks into the sewage system from surrounding soil;
3. Business: this includes car washes, dentists and large enterprises;
4. Pipe sediments;
5. Atmospheric deposition: metal transmitted from other areas;
6. Traffic: which includes brake linings, tires, asphalt, gasoline and oil;
7. Building materials; and
8. Chemicals.

Most heavy metals are essential to plant growth at low concentrations. Nevertheless, these heavy metals become toxic and harmful at high concentrations. Toxicity generally results in impaired growth, reduce yields and cause plant death (FAO, 1992).

Table (4) summarizes the recommended concentrations of heavy metals in irrigation water. The physical and mechanical properties of soil such as stability, soil structure and permeability are very sensitive to the type of ion elements present in irrigation water (FAO, 1992).

In the following, a brief description of selected heavy metals is provided.

Table (4): Recommended Maximum Concentrations of Heavy Metals in Irrigation Water (Ayers and Westcot, 1994).

Element	**Recommended maximum concentration (mg/l)**	**Remarks**
Arsenic	5	Can cause non productivity in acid soils (pH<5.5), More alkaline soils pH>7 will precipitate the ion and eliminate any toxicity
Cadmium	0.01	Toxic to beans, beets and turnips at concentrations as low as 0.1 mg/l in nutrient solutions. Conservative limits recommended due to it is potential for accumulation in plants and soils to concentrations that may be harmful to humans
Cobalt	0.05	Toxic to tomato plants at 0.1 mg/l in nutrient solution. Tends to be inactivated by neutral and alkaline soils
Chromium	0.1	Not generally recognized as an essential growth element. Conservative limits recommended due to lack of knowledge on its toxicity to plants
Copper	0.2	Toxic to a number of plants at 0.1 to 1 mg/l in nutrient solutions
Manganese	0.2	Toxic to a number of crops at a few tenths to a few mg/l, but usually only in acid soils
Molybdenum	0.01	Not toxic to plants at normal concentrations in soils and water. Can be toxic to livestock if forage is grown in soils with high concentrations of available molybdenum
Nickel	0.2	Toxic to a number of plants at 0.5 mg/l to 1 mg/l; reduced toxicity at neutral or alkaline pH
Lead	5	Can inhibit plant cell growth at very high concentrations

3.3.1 Arsenic

Arsenic can be found in nature as free metal or in compounds forms. Arsenic atomic weight is 74.97. Arsenic is toxic and accumulates in plants and animals bodies. Arsenic is toxic to human at a dose over 100 mg. It is described as carcinogenic (Dojlido and Best, 1993).

Arsenic in wastewater comes from industrial resources that include ceramics, paints, poisons, medicines semiconductors, washing products, and agricultural activities that include insecticides, and weed killer (Dojlido and Best, 1993).

3.3.2 Copper

Copper is found in nature as a free metal and in compounds. Copper atomic weight is 63.55. Copper is essential in small amounts for plants but become toxic at large doses because copper at a concentration greater than 100 µg/l in soil solution restricts the growth of aquatic plants. Only mercury is more toxic than copper for plants (Dojlido and Best, 1993).

Copper in wastewater comes from industrial sources such as alloys manufacturing and heat exchangers and from households such as pipes and tips. Sorme and LagerKvist, (2002) were carried out a research in Stockholm to investigate the sources of copper in urban wastewater and they found that 59% of the copper measured in wastewater were generated in households.

3.3.3 Lead

Lead can be found in nature as native or in compounds forms, lead atomic weight is 207.2. Lead does not appear to be an essential element to support life of any organism. If lead enters the human body it will accumulate in bones tissue. Lead is less toxic to plant than mercury and copper (Dojlido and Best, 1993).

Lead in wastewater comes from recycled batteries, storage tank linings and corrosive liquid tanks paints, antibacterial and wood preservatives, in addition to petrol (Dojlido and Best, 1993). Lead may come from atmospheric resources (Sorme and LagerKvist, 2002).

3.3.4 Zinc

Zinc is found in nature in native and in compound forms. Zinc atomic weight is 65.38. Zinc is essential in small concentrations because it is found in red blood cells and there are about 20 enzymes that contain zinc. Zinc is harmful to plants and toxic to fish at high concentrations (Dojlido and Best, 1993).

Sorme and LagerKvist (2002) found that the main sources of zinc in wastewater are galvanized material and car washing. Dojlido and Best (1993) found that industries, earth crust, rain water, paint, drugs, fungicides, and cosmetics are the main sources of zinc in wastewater.

3.3.5 Cobalt

Cobalt found in nature as a compound mainly with sulfur, arsenic, and copper, but it is not found in native form. Cobalt atomic weight is 58.93. Cobalt is essential to living organisms because it is present in vitamin B_{12}

(cobaltomine). Shortage of cobalt in the herbage results in weakness, anemia and eventually death for grazing animals. On the other hand, cobalt at high doses is toxic especially for fish at a range of 30 to 100 mg/l. (Dojlido and Best, 1993).

Cobalt in wastewater comes from ceramics and paint industries, and agricultural activities that include additives to fertilizers (Dojlido and Best, 1993).

3.3.6 Cadmium

Cadmium is not found in nature in native form but almost as (CdS) compound. Cadmium atomic weight is 112.4. Cadmium in wastewater comes from industrial sources such as galvanizing. Households sources include disposal batteries, traffic sources such as tires and oil and from farming sources because cadmium is used to treat poultry infected with parasitic worms (Dojlido and Best, 1993).

Cadmium is very toxic and its harmfulness come from its ability to accumulate in human body if it enters throw contaminated water or food chain (Dojlido and Best, 1993).

3.3.7 Nickel

Nickel is generally found in nature as compounds. Nickel atomic weight is 58.71 and the average concentration of nickel in earth crust is 75 mg/kg. Nickel is an essential trace metal, but at high concentrations it is toxic to human and can be carcinogenic. For plants it is less toxic than mercury, copper, cadmium, and silver, but more toxic than lead and zinc (Dojlido and Best, 1993).

The main sources of nickel in wastewater are industrial sources that include, plating corrosion resistance, crude oils and petroleum products, households such as disposed batteries, crude oils, leaching from rocks (Dojlido, Best, 1993). And atmospheric resources (Sorme and LagerKvist, 2002)

3.3.8 Molybdenum

Molybdenum is a rare element that is not found in nature in native form but always as compounds. Molybdenum atomic weight is 95.94. Molybdenum is necessary for plant growing but it is toxic to grazing animals.

Molybdenum in wastewater comes mainly from hardened steels industry, burning of fossil fuel, manufacturing of glass and agricultural activities that include fertilizers (Dojlido and Best, 1993).

3.4 Effects of Wastewater Used for Irrigation on Soil Characteristics

Soil is a porous media that contains solids, liquids, and gases created at the land surface by weathering processes, derived from biological, geological, and hydrological phenomena (Sposito, 1989). Wang et al. (2003) define soil as the medium that supports plant growth and modulates nutrients and pollutants in the environment.

The main functions of soil are the ability to hold, accept and release water to plants and release nutrients and chemicals and media for root growth (Sposito, 1989).

Soil has physical and chemical characteristics such as porosity, permeability, water holding capacity, trace metal concentrations, pH, total carbon and total nitrogen. These characteristics may be affected by the quality of water used for irrigation.

Mapanda et al. (2004) carried out a study related to using raw wastewater for irrigation in Zimbabwe. They found that the application of wastewater increased soil pH by 0.5–3 units after comparing the wastewater irrigated sites to the non-irrigated ones. They noticed that some heavy metals, notably Cu, Zn and Cd, have begun to exceed their maximum permitted limits.

Sharma et al. (2005) studied the effect of using treated and untreated wastewater for irrigation on soil and vegetable contamination by heavy metals in India. The study concludes that irrigation by treated or untreated wastewater has increased the heavy metal concentrations of Zn and Mn in soil and plants of receiving area. Cadmium concentration in irrigation water was found to be above the permissible limit as set by world health organization (WHO) for irrigation of agricultural land at Dinapur and Lohta sites. Heavy metal concentrations in plants show significant spatial and temporal variations. Cd, Pb, and Ni were above the Indian permissible limits.

Huerta et al. (2002) found in a study carried out in Mexico that the wastewater is contaminating the soils with elements considered as toxic, not only by themselves, but in conjunction with others. The elemental concentrations are always higher in the wastewater irrigated soils than in those irrigated with groundwater.

Viviani and Iovino (2004) carried out a laboratory experiment to investigate the effect of using wastewater in irrigation on the hydraulic conductivity of loam and clay soils. The loam soil hydraulic conductivity was reduced to about 80% of the initial value after infiltration of 175 mm of municipal wastewater with total dissolved solids in the range of 57 to 68 mg/l. Reductions in hydraulic conductivity were more remarkable in the clay soil.

Wang et al. (2003) found that the use of reclaimed wastewater in irrigation reduce the porosity of soil and reduce nutrient holding capacity.

Gracia and Prats (2005) noticed that high and sustained amounts of heavy metals applied on soil will exceed the soil retention and adsorption capacity, which results in the movement of pollutants down through the soil profile.

Feigin et al. (1991) found that irrigation with wastewater increases soil salinity, increases nutrient contents, increases pathogens in soil, and increases trace metal concentrations in soil. They found also that suspended solids clog the soil pores.

Dojlido and Best (1993) noticed that high levels of sodium in irrigation water affects on soil structure, infiltration, and permeability rates.

3.5 Microbial Health risk of wastewater

In developing countries, raw sewage is rarely treated before being applied in irrigation and this direct reuse without any restrictions poses potential health hazards and adverse environmental impacts (PESCOD, 1988).

Wastewater poses a serous risk of water born diseases such as holera, typhoid, dysentery, plague and helminthes. In 19^{th} century large scale application of untreated wastewater for irrigation caused epidemics of water born disease. However, raw wastewater continues to be used in some regions for irrigation, despite the clear health hazards associated with it (UNEP 2002).

Municipal wastewater contains all groups of pathogens that include viruses, bacteria, protozoa, fungi and helminthes (Alqam, 1998). The possible levels of pathogens in wastewater are summarized in Table (5).

Table (5): Possible levels of pathogens in raw wastewater.

Type of pathogen		Possible concentration per liter in municipal wastewater
Viruses	Entroviruses	5000
Bacteria	Pathogenic E. coli	NA
	Salmonella spp.	7000
	Shigella spp.	7000
	Vibrio cholerae	1000
Protozoa	Entamoeba histolytica	4500
Helminthes	Ascaris Lumbricoides	600
	Hookworms	32
	Schistosoma mansoni	1
	Taenia saginata	10
	Trichuris trichiura	120

(FAO, 1992)

Pathogens increase the health concerns in agricultural use of wastewater. Shuval et al, (1986) carried out a research in Germany, Denmark and India regarding the use of raw wastewater in agriculture and they found that☹i) where raw wastewater used in the irrigation of vegetables that are eaten uncooked, helminthic disease caused by ascaris and Trichuris spp. Are endemic in the population, (ii) sewage farm workers exposed to raw wastewater in areas of hookworms and ascaris infections are endemic significantly compared with other agriculture workers, (iii) Cholera can be transmitted through the same channels as shown in the previous points; (iv)

Cattle grazing on fields freshly irrigated with raw wastewater can be heavily infected with cysticerosis disease.

Srikanth and Naik, (2004) carried out a research related to reusing of raw wastewater for vegetable cultivation in Asmara city, Eriteria. Results showed that vegetables were heavily contaminated with fecal coli forms, gardia cysts shagella and salmonella. Also they noticed that vegetables grown on the raw sewage cause diardiasis amebiase and diarrhea in the farming community.

3.6 Regulations and Standards in Palestine

Since 1994, Palestinian authority have set and improved several regulations related to water quality, domestic wastewater, and industrial wastewater in industrial areas. These regulations include: (i) protection measures for human health, natural resources and environment and (ii) enforceable systems to support the mentioned protection measures.

The Palestinian standard institution sets specifications related to water and wastewater that include: (i) drinking water quality; (ii) concentration levels of wastewater parameters; and (iii) reuse of treated wastewater for irrigation. These specifications concentrate on salinity, chemical and biological parameters (Ministry of industry, 2002).

The Palestinian ministry of environment affairs had developed the Palestinian environment strategy in 1999 (Al-habash, 2003). This strategy had set three measures: (i) setting industrial wastewater and domestic wastewater standards for reuse; (ii) pretreatment requirements and standards for discharging industrial wastewater into sewer system; and (iii) setting up and monitoring enforceable systems that supports the mentioned measures.

CHAPTER FOUR: Description of the Study Area

4.1 General

Faria Catchment is located in the northeastern portion of the West Bank. Its western part bisects Nablus City while its eastern boundary is adjacent to the Jordan River as shown in Figure (2). Faria Catchment extends over Nablus, Tubas and Jericho governorates with a total area of 320 km^2, which accounts for 6% of the of West Bank area. Faria Catchment is almost contained within the Eastern Aquifer Basin. The main sources of water in Faria Catchment are rainfall, springs and groundwater. The main use of water is for domestic and agricultural purposes. Faria Catchment accounts for 20% of the West Bank water resources and it provides more than 26% of total West Bank food basket (Birzeit University- Callvin Collage Partnership, 2003). Wadi Faria (surface runoff) does not dry completely in the summer because of the springs and wastewater effluent form the Eastern part of Nablus City (Abu Ghosh, 2006, personal communication). Within the catchment, the runoff decreases from west to east as the slope becomes relatively gentile eastwards down the main stream where rainfall rates reduce also.

This chapter discuses mainly the following subjects: water and environmental problems in Faria Catchment, climate, soil types, land use, water resources and wastewater resources and quantities in Faria Chatchment.

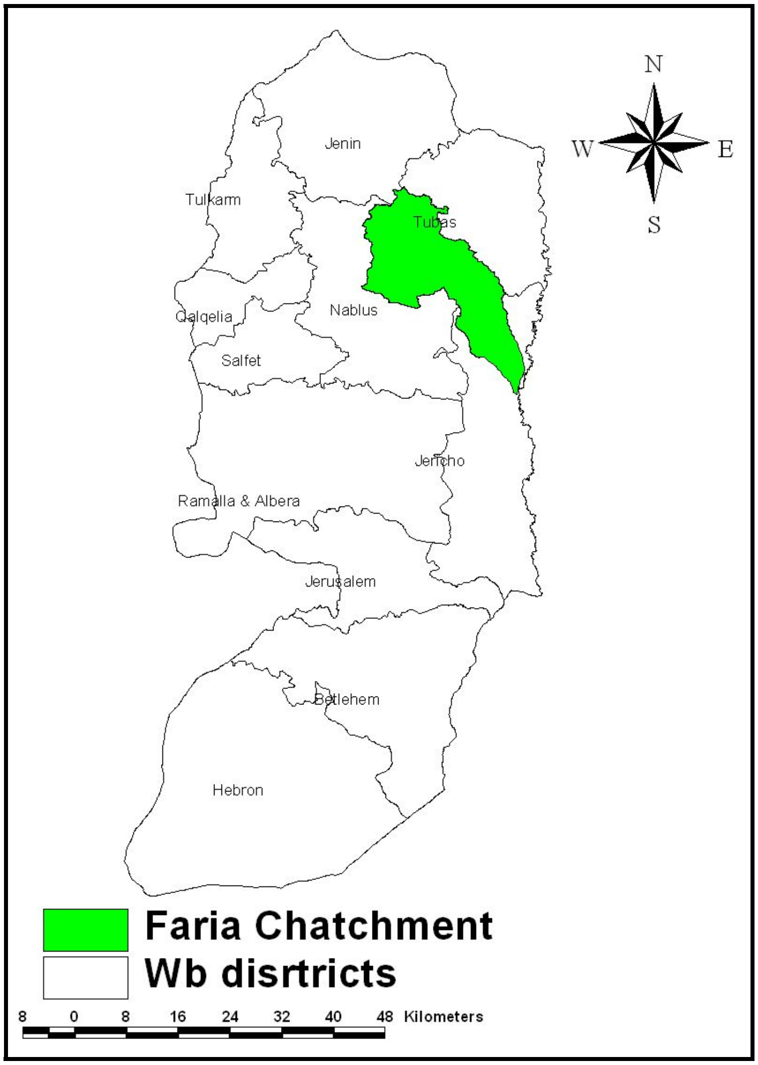

Figure (2): Location of Faria Catchment in the West Bank.

4.2 Key Water and Environmental Problems in Faria Catchment

From the knowledge I gained through the initial preliminary investigations that I carried out, it can be inferred that Faria Catchment is under severe problematic conditions that need to be addressed in order to set up proper strategies and management policies.

The major problems can be summarized as follows:

1. More than 40% of the people in the Catchment lacks water supply for drinking purposes (Almasri et al., 2005);

2. The estimated annual water gap between water needs and obtainable water supply is about 20 million cubic meters. This gap is increasing with time;

3. The use of untreated wastewater in irrigation is an on going practice (Birzeit University- Callvin Collage Partnership, 2003);

4. Lack of storage reservoirs to capture the rain floods during the rainy season in order to be used later or to be artificially recharged;

5. Unbalanced utilization of groundwater causes increasing salinity especially in the south eastern part of the Catchment in the proximity of Jordan River (Almasri et al., 2005);

6. Water losses through evaporation and infiltration from the agricultural canals are high and thus large quantities of water are not fully utilized;

7. Water pollution is an ongoing problem. For instances, surface water originating from the springs mixes with wastewater coming from Nablus City and Faria refugee camp;

8. There is no wastewater treatment plant in the Catchment;

9. Cesspools are major threats to pollute the shallow groundwater;

10. Unmanaged solid waste dumping in some areas adds additional complexity to the pollution problems (Birzeit University- Callvin Collage Partnership, 2003).

4.3 Climate

Faria Catchment is dominated by a Mediterranean semi-arid climate with mild rainy winters and moderately hot summers. The winter rainy season is from October to April and the dry season is from May to September. In Faria Catchment, rainfall decreases from approximately 600 mm in the north western portion, to about 150 mm in the south eastern portion as shown in Figure (3). The maximum potential rate of evapotranspiration is 1,500 mm/year. Actual evapotranspiration is estimated to be 345 mm/year (MOT, 1998).

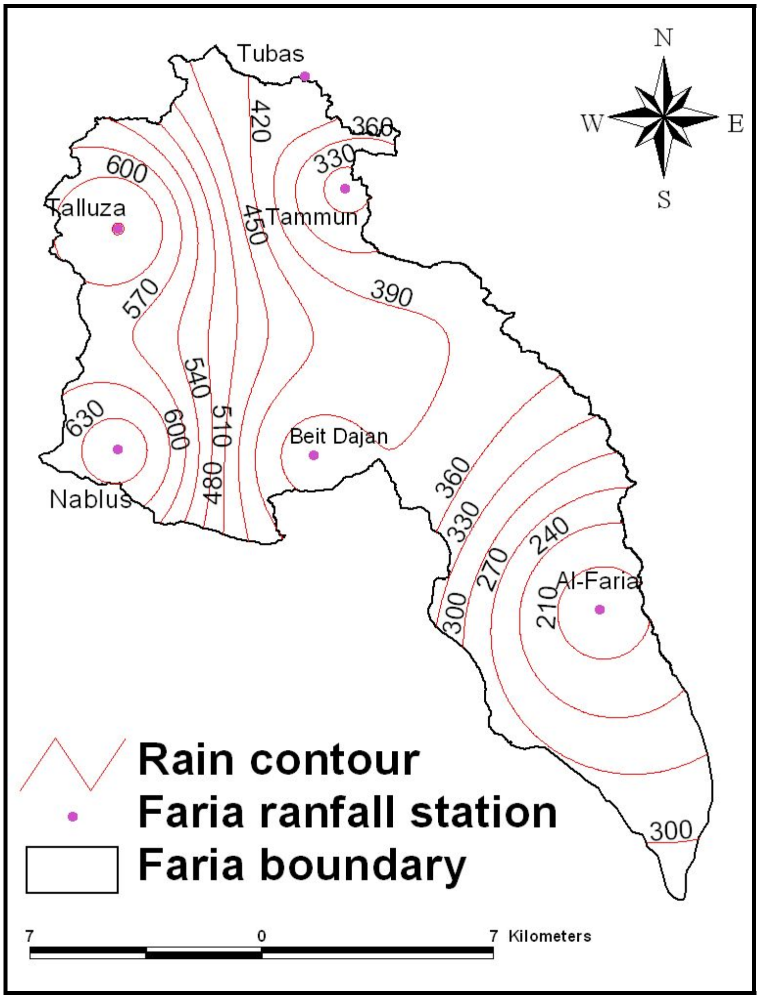

Figure (3): Rainfall Stations and Contours for Faria Catchment.

4.4 Soil types

Figure (4) depicts the major types of soils present in Faria Catchment. There are two main soil types that cover most of the Catchment. These two types are Terra Rosa and Colluvial-Alluvial soils, together covering more than 60% of the total area as summarized in Table (6).

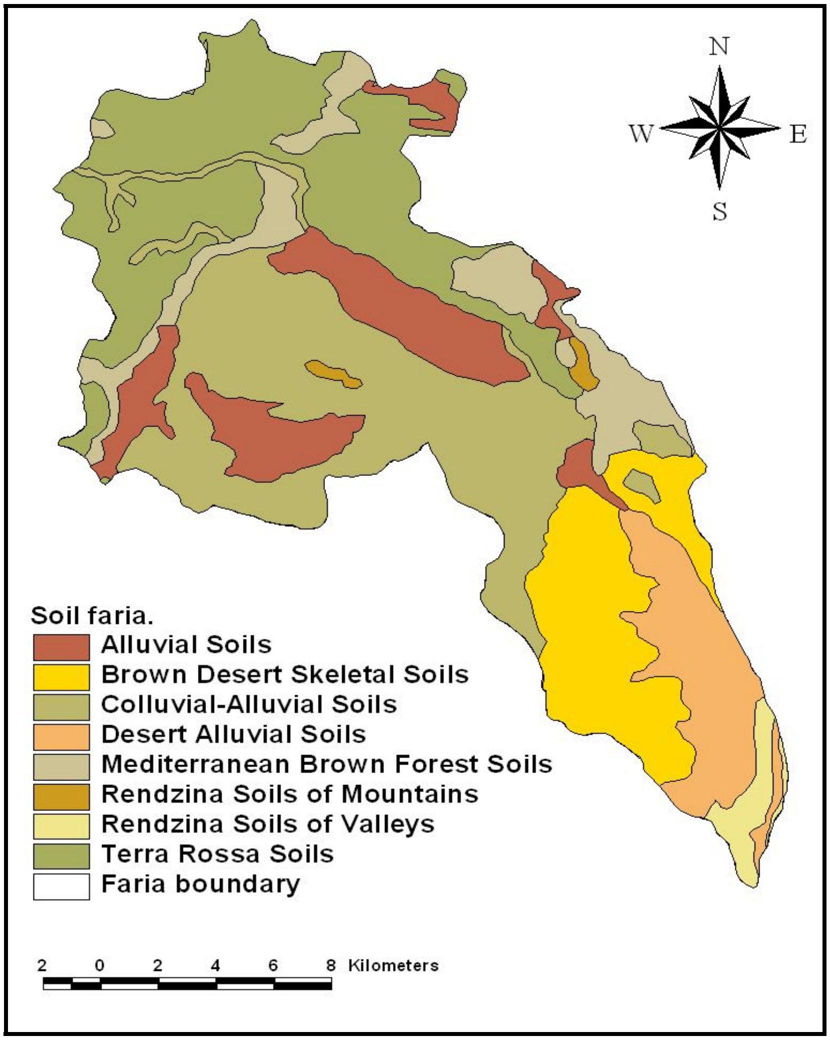

Figure (4): The Distribution of Soil in Faria Catchment.

Table (6): Soil Types and Corresponding Area.

Soil type	Area (km^2)	%
Alluvial	38.4	12
Brown Desert Skeletal	43.8	14
Colluvial-Alluvial	109.5	34
Desert Alluvial	17.6	6
Mediterranean Brown Forests	20.5	6
Rendzina of Mountains	1.3	0.4
Rendzina of Valleys	4.4	1
Terra Rossa	84.5	26.6
Total	**320**	**100**

4.5 Land Use

There are 20 Palestinian villages, hamlets with a total built up area of about 9.5 km2, and 11 Israeli settlements with a total built up area of 5.1 km^2. The remaining land use is primarily for agricultural activities such as vegetable plantation and trees, forests, natural grass, and bare rocks. Figure (5) shows the distribution of land use classes in Faria Catchment while Table (7) summarizes the area of each land use type.

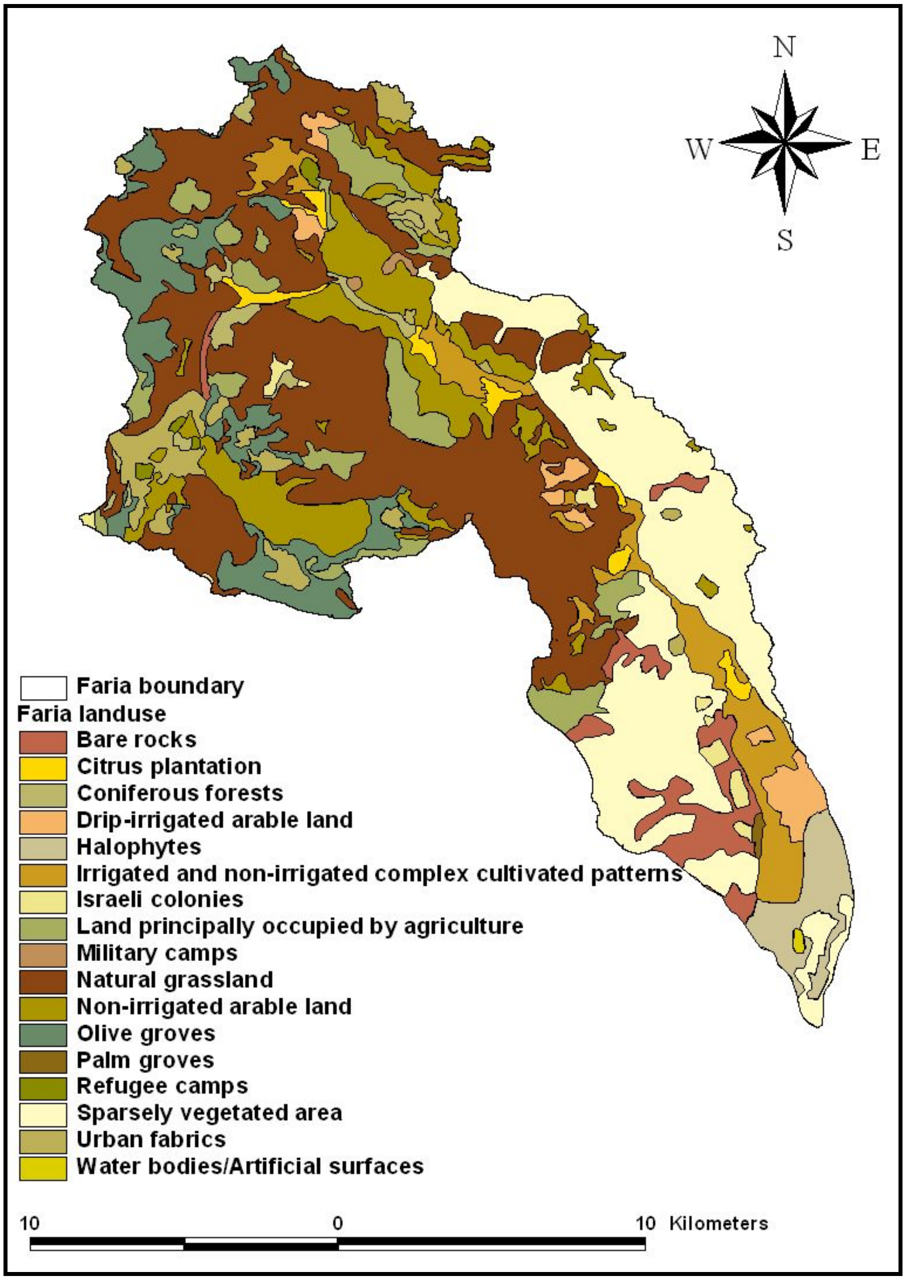

Figure (5): Land Use Map of Faria Catchment.

Table (7): Summary of Land Use in Faria Catchment (Shadeed, 2006).

Land use Cover	**Area (Dunum)**	**Area (%)**
Artificial Surfaces		
Refuge camps	972	0.3
Urban fabrics	13,300	4.1
Israeli colonies	3,107	1.0
Military camps	668	0.2
Sub Total	**18,047**	**5.6**
Agricultural Areas		
Non-irrigated arable land	37,289	11.6
Drip-irrigated arable land	6,978	2.2
Olive groves	26,506	8.3
Palm groves	394	0.1
Citrus plantations	4,650	1.5
Irrigated and non-irrigated complex cultivated pattern	19,172	6.0
Land principally occupied by agriculture	20,458	6.4
Sub Total	**115,447**	**36.1**
Forests and Semi Natural Vegetation		
Coniferous forests	4,716	1.5
Natural grassland	96,374	30.1
Bare rock	12,523	3.9
Sparsely vegetated area	63,886	20.0
Halophytes	8,757	2.7
Sub Total	**186,256**	**58.2**
Water Bodies/ Artificial Surfaces	250	**0.1**
Total	**320,000**	**100%**

4.6 Water Resources

There are 70 wells in Faria Catchment of which 62 are agricultural wells, 3 are domestic and 5 are Israeli wells. All these wells are located in Ras Al-Faria, Al-Aqrabanieh, Al-Nasaria, Froush Beit Dajan and Jiftlik along the flexure of Faria (EQA, 2004).The distribution of these wells is depicted in Figure (6). Within the Faria Catchment, there are 13 fresh water springs that are divided into four groups. These groups are Faria, Badan, Miska and Nablus. Mean annual discharge for these springs are shown in Figure (7) (Almasri et al., 2005).

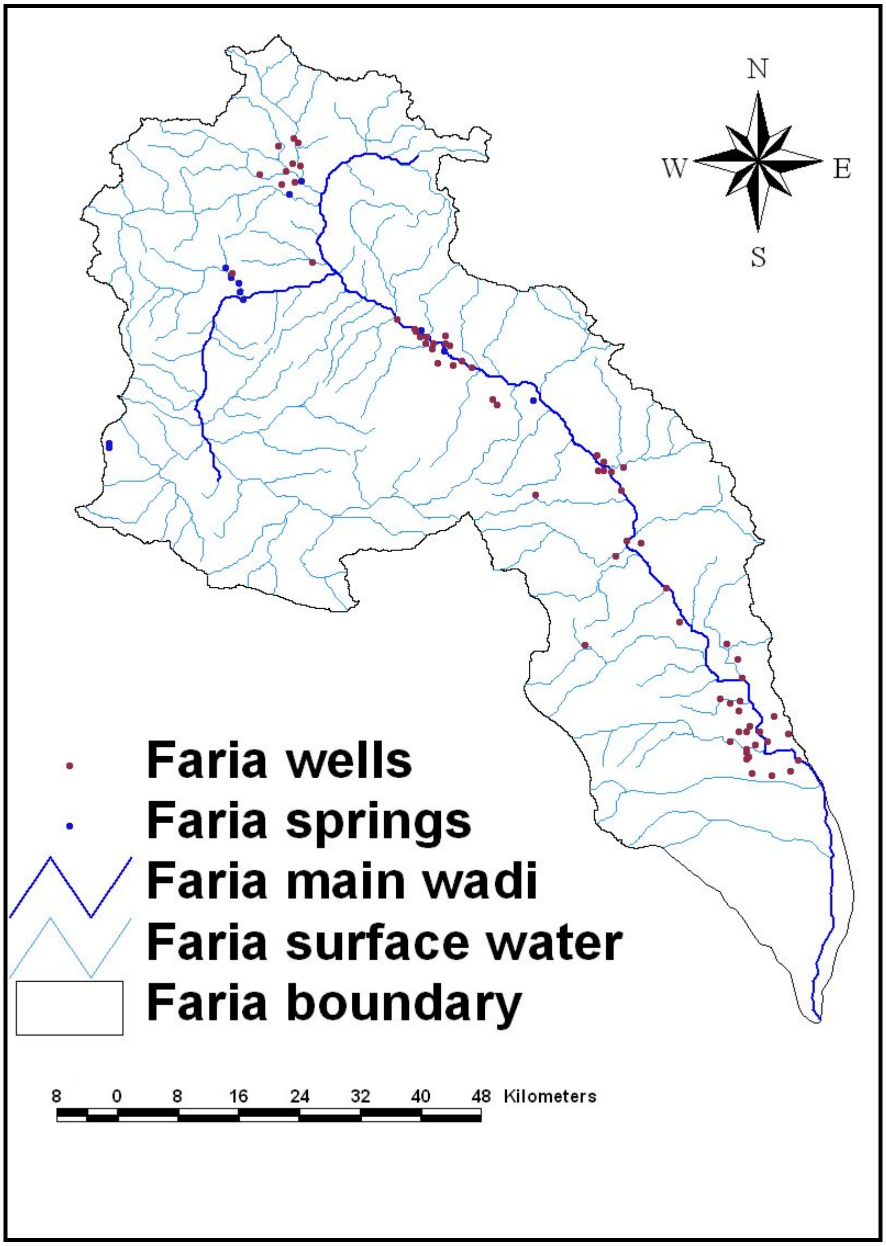

Figure (6): Springs, Wells and Surface Water Network of Faria Catchment.

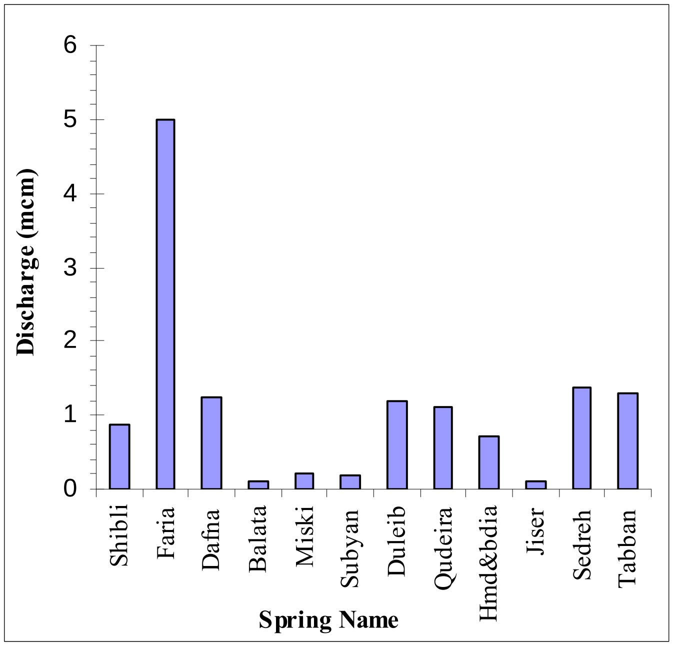

Figure (7): Annual Spring Yield in Faria Catchment.

4.7 Wastewater Sources

The main sources of wastewater that flows into Faria Catchment are the following:

1. Domestic wastewater from Al-Faria, Balata and Askar refugee Camps, Almasaken alsha'abya, Aldahia, Rujeeb and doctor housing area;

2. Domestic wastewater from the area draining the eastern portion of Nablus City;

3. Industrial wastewater from the Eastern Industrial Zone of Nablus City;

4. Discharging of the evacuation tanks from surrounding villages; and

5. Leachate from solid waste dumpsites.

4.8 The Eastern Industrial Zone of Nablus City

In the eastern part of Nablus City, there are 115 industrial facilities. Most of these facilities are located in the Industrial Zone. Due to the decline in the economic situation, a total of 25 industrial facilities were closed (Nablus Municipality, 2006).

The main types of industries in the industrial zone are classified into eight types that include stone cutting, quarries and concrete, tiles and concrete blocks, plastic, paper and forage, metal and furniture, chemical industries, food industry and the slaughterhouse. Figure (8) depicts the types of industries and the number of facilities for each type in the eastern industrial zone of Nablus City.

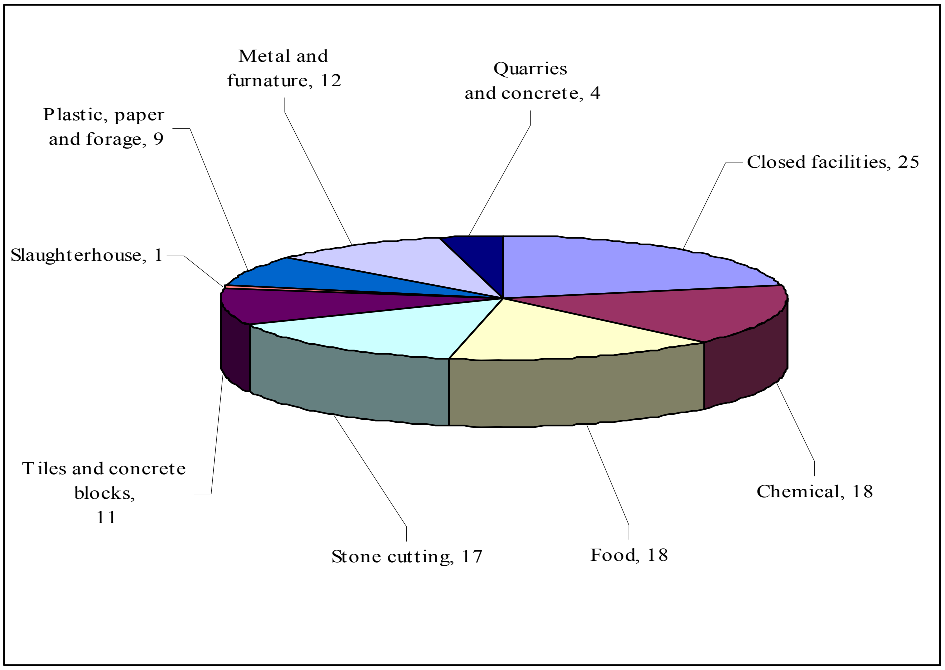

Figure (8): Type of Industries and Number of Each Type in the Eastern Industrial Zone of Nablus City

Most of these facilities produce wastewater that is similar to domestic wastewater while other industries produce wastewater of specific quality that necessitates special attention and pretreatment (Nablus Municipality, 2006). Only cutting stone factories have on-site treatment that includes settling basins used for settling and reusing as cooling water. Figure (9) shows the annual generated wastewater quantities from industrial facilities in the eastern industrial zone (Adapted from Wadi Zeimar and Nablus East Industrial Survey, 2006).

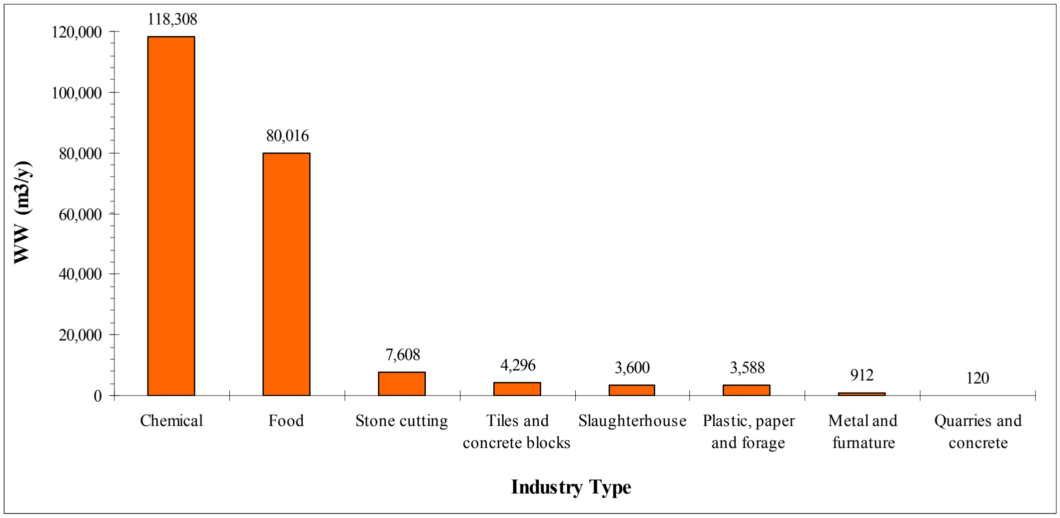

Figure (9): Annual Generated Wastewater Quantities from the Industrial Facilities in the Industrial Zone.

The generated quantities of wastewater from the eastern industrial zone is collected by the main network of domestic wastewater and discharged to Faria Catchment (the wadi). Figure (10) shows the main methods for collecting wastewater and the number of facilities served with each method.

Industrial wastewater is characterized by great variability in both flow rate and composition. This is because the facilities are small to medium in size and do not work 24 hours a day. Table (8) summarizes the type of industries, total wastewater generated and the composition of the generated wastewater.

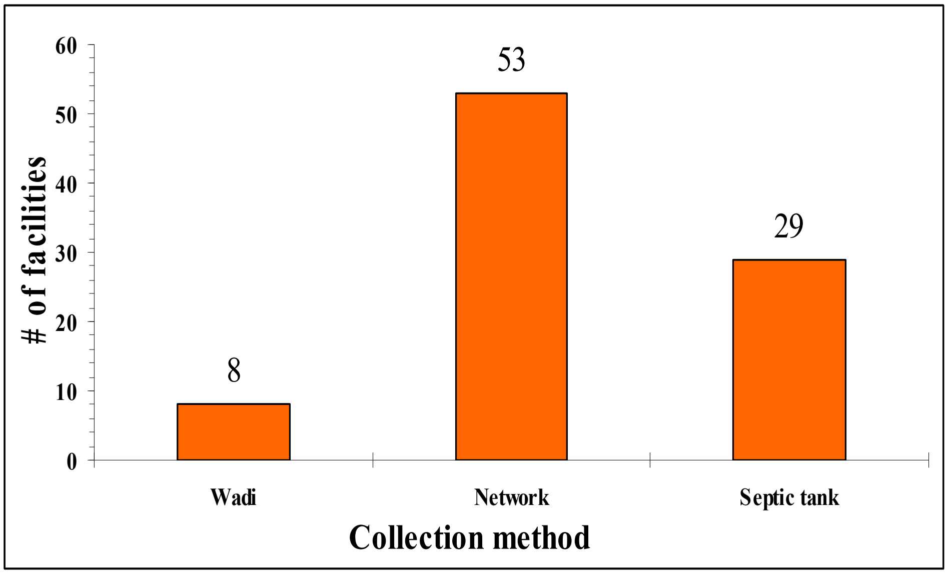

Figure (10): Wastewater Collection Method in the Eastern Industrial Zone of Nablus City.

Table (8): Type of Industries, Wastewater Generation and Composition in the East Industrial Zone of Nablus City (Adapted from Wadi Zeimar and Nablus East Industrial Survey, 2006).

Item	Industry type	Total	Water consumption m^3/month	Wastewater generation m^3/month	Raw wastewater	Wastewater collection method	On-site treatment
1	Stone cutting	17	905	634	Grains, dust and small stones	Cesspit/septic tank	Primary sedimentation
2	Quarries and concrete		180	Few quantities for domestic uses	Cement and sand	Wadi	No
3	Tiles and concrete block						
3.1	Tiles	7	355	248	Cement and sand	Cesspit/septic tank	Primary sedimentation
3.2	Concrete Block	4	940	Few quantities for domestic uses	Domestic	network	No
4	Plastic, paper and forage						
4.1	Plastic and nylon	4	12	12	Domestic wastewater	Network	No
4.2	Paper and printing	2	375	187	Ink, white acid and benzene	Network	No
4.3	Forage industry	1	82	82	Domestic	Network	No
4.4	Shoes and rubber	1	3	3	Domestic	Network	No
4.5	Diapers	1	15	15	Domestic	Network	No

Item	Industry type	Total	Water consumption m^3/month	Wastewater generation m^3/month	Raw wastewater	Wastewater collection method	On-site treatment
5	Metal and furniture	12	86	76	Domestic	Network	No
6	Chemical Ind.						
6.1	Textile	2	9,300	9,300	Soap, sodium bisulfate anhydrous, enzyme, vinegar and NaOCl	Network	No
6.2	Tannery	1	430	430	Arsenic and salt	Network	No
6.3	Carton	1	200			Network	No
6.4	Cosmetics	3	69	69	Glycerin mono striate, white paraffin oil, setric acid, sad alcohol titanium dioxide and tri ethanol amine	Network	No
6.5	Paints	1	105	11	Domestic wastewater	Network	No
6.6	Soap	2	20	20	Domestic	Network	No
6.7	Chemical detergents	5	265	29	Benzene, sulphonic acid, sodium laury, ether sulfate, sodium hypochlorite, di-ethanol amid, sodium chloride and domestic wastewater	Cesspit/septic tank	No
6.8	Insecticide and veterinary medicines	3	67	Unknown	Antibiotics, pesticides, soda, acid, phenol and additives.	Network	No

Item	Industry type	Total	Water consumption m^3/month	Wastewater generation m^3/month	Raw wastewater	Wastewater collection method	On-site treatment
7	Food industry						
7.1	Tahina industry	7	1,295	1,295	High chloride load, salt	Wadi and network	No
7.2	Dairy products	1	3,000	3,000	High chloride, phosphoric acid, organic materials, whey protein and lactose sugar	Network	No
7.3		4	390	55	Domestic	Network	No
7.4	Sweets, flour	1	400	280	Domestic	Network	No
7.5	and soft drinks Pickles	1	2,020	2,020	Sulfuric acid, soda	Network	No
7.6	Vegetable	3					
7.7	ghee and vegetable oils Olive oil mills Luncheon meat	1	25	18	Domestic and organic materials	Network	No
8	Slaughter house	1	300	300	High BOD, blood and organic materials	Wadi Sajoor	No
9	Closed factories	25	-	-	-	-	-

4.9 Generated Wastewater Quantities in Faria Catchment

The generated wastewater quantities in Faria Catchment are highly variable. The main sources of effluents in Faria Catchment are the eastern part of Nablus City, Balata, Askar and Faria Camps. The estimated annual quantities of wastewater that flow into Faria Catchment is around 2.2 mcm from domestic sources (adapted from PCBS, 2003 and PWA, 2000) and 0.2 mcm from industrial sources (Adapted from Wadi Zeimar and Nablus East Industrial Survey, 2006).

4.10 Wastewater Collection Systems in Faria Catchment

Wastewater collection network systems exist in Nablus City and Faria Camp with rare expansions in specific villages. Such collection systems are generally old and suffer from leakage and deterioration (UNEP, 2003).

Nablus sewerage system is a combined system for the collection of wastewater and storm water and covers approximately 70% of the City (UNEP, 2003). The sewerage system of Nablus City is divided into two major parts, eastern and western. In the eastern side, the sewerage pipeline discharges into Wadi Al-Sajoor where sewage flows through Wadi Al–Badan and into the Jordan valley. Farmers use the untreated wastewater for irrigating vegetables, citrus and olives while the percolated amounts may leach down to pollute the underlying aquifer system. In the western side, the sewerage pipelines of Nablus City along with the wastewater from the neighboring villages discharge into Wadi Zeimar.

The areas that are uncovered by sewage collection network systems use cesspits as a mean of sewage collection. Cesspits are the most common form of sewage collection in villages (PCBS, 2000). Vacuum tanks are used to evacuate wastewater from cesspits and subsequently they empty their content either in wadis, on agricultural lands, or in open fields. Most of the cesspits are built without concrete linings in order to facilitate sewage infiltration and thereby to minimize emptying costs.

4.11 Wastewater-Based Irrigated Areas in Faria Catchment

A map of the wastewater irrigated areas in Faria Catchment was developed for the following reasons: (i) to specify the locations that are being irrigated with wastewater, (ii) to develop a groundwater vulnerability map to contamination (shown in section 4.12), and (iii) to study the impacts of wastewater on soil properties (see chapter six). The process of creating the map of the areas that are being irrigated with wastewater in Faria Catchment did undergo many steps as summarized below:

1. From previous land use maps for Faria Catchment, the Catchment was divided according to irrigation frequency. The land use map of Faria Catchment according to irrigation frequency is depicted in Figure (11);

2. Field visits were carried out to Faria Catchment to investigate the locations that are being irrigated with wastewater. These areas were delineated using GPS;

3. The collected data were converted to a GIS shapefile. The total irrigated area with wastewater is around 1,700 dunums as depicted in Figure (12). However, it should be noticed that after Faria project location there are 16,000 dunums that are being irrigated with diluted

wastewater. These additional areas were not shown in Figure (12) since accessibility to the area was restricted by the Israeli army.

From the field visits it was noticed that farmers use raw wastewater in Azomt fields. These fields are very close to the main outlet of the sewage system of Nablus City. In addition, farmers use raw wastewater in the fields that are adjacent to the main outlet of the sewage system of Faria Camp. Diluted wastewater is being used in the fields after Al-malaqi Bridge. In general, the distance between the wadi and the fields that are being irrigated with pure and diluted wastewater is less than 150 m. Farmers in general get the water from the wadi to their fields by gravity as shown in Figure (13).

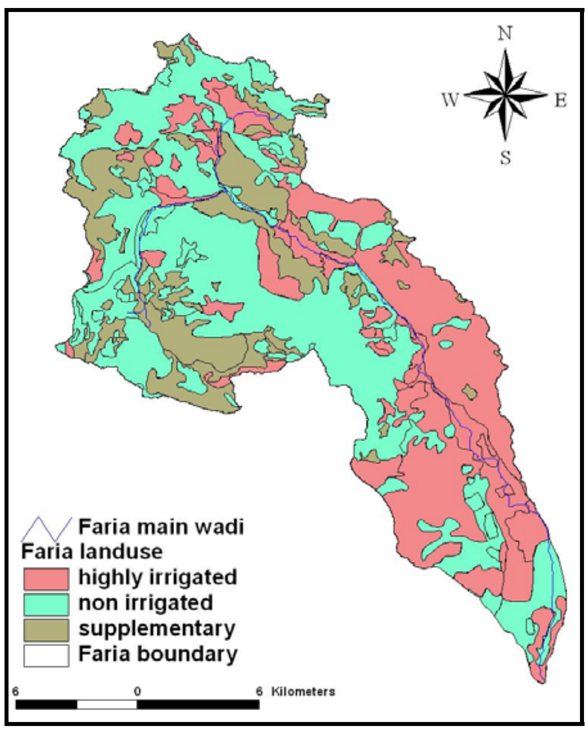

Figure (11): Land Use of Faria Catchment According to Irrigation Frequency.

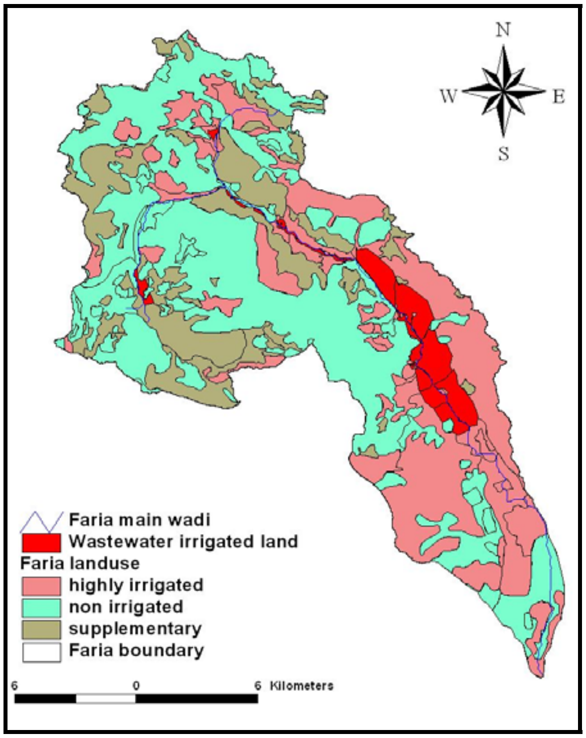

Figure (12): Fields irrigated with Raw Wastewater in Faria Catchment.

Figure (13): Using Diluted Wastewater for Irrigation after Al-malaqi Bridge.

4.12 Groundwater Vulnerability Map of Faria Catchment

As mentioned earlier, in several locations in Faria Catchment, farmers use raw and diluted wastewater for irrigation without any treatment or ruse restrictions. The wastewater that flows from the eastern part of Nablus City and Faria Camp may infiltrate and pollute the groundwater resources. To protect the groundwater resources, it is essential to investigate the locations that are being irrigated with wastewater and to associate these locations with vulnerable areas.

As such, a vulnerability map of groundwater to contamination was developed for Faria Catchment to find out areas of high risk of polluting the aquifer. There are several methods that can be used to assess the vulnerability of groundwater to contamination and one of these methods is the DRASTIC method (Qamhieh, 2006).

The DRASTIC method is a parameter weighting and rating method. A weight is assigned to each parameter in order to reflect the relationship between the parameters. Rating parameters for each interval are multiplied accordingly with the weight factor and the summation yields the final score that reflects the degree of vulnerability to contamination. The parameters of this method and the corresponding weights are summarized in Table (9).

Table (9) : DRASTIC Parameters

Parameter	Weight
D: Depth to water table	5
R: Net recharge	4
A: Aquifer media	3
S: Soil media	2
T: Topography	1
I: Impact of vadose zone media	5
C: Aquifer hydraulic conductivity	3

The equation used to compute the DRASTIC index (DI) is:

$$DI = 5 \times D + 4 \times R + 3 \times A + 2 \times S + 1 \times T + 5 \times I + 3 \times C$$

where D, R, A, S, T, I and C are the ratings summarized in Table (9). The DRASTIC index represents the relative groundwater vulnerability to contamination. Table (10) summarizes the quantitative risk categories.

Table (10): DRASTIC Index

DRASTIC qualitative category	Low	Moderate	High	Very high
Drastic index	1-100	101-140	141-200	>200

By using the capabilities of GIS program all the DRASTIC parameters were computed and evaluated to create the vulnerability map for Faria Catchment. The vulnerability map of Faria Catchment is shown in Figure (14).

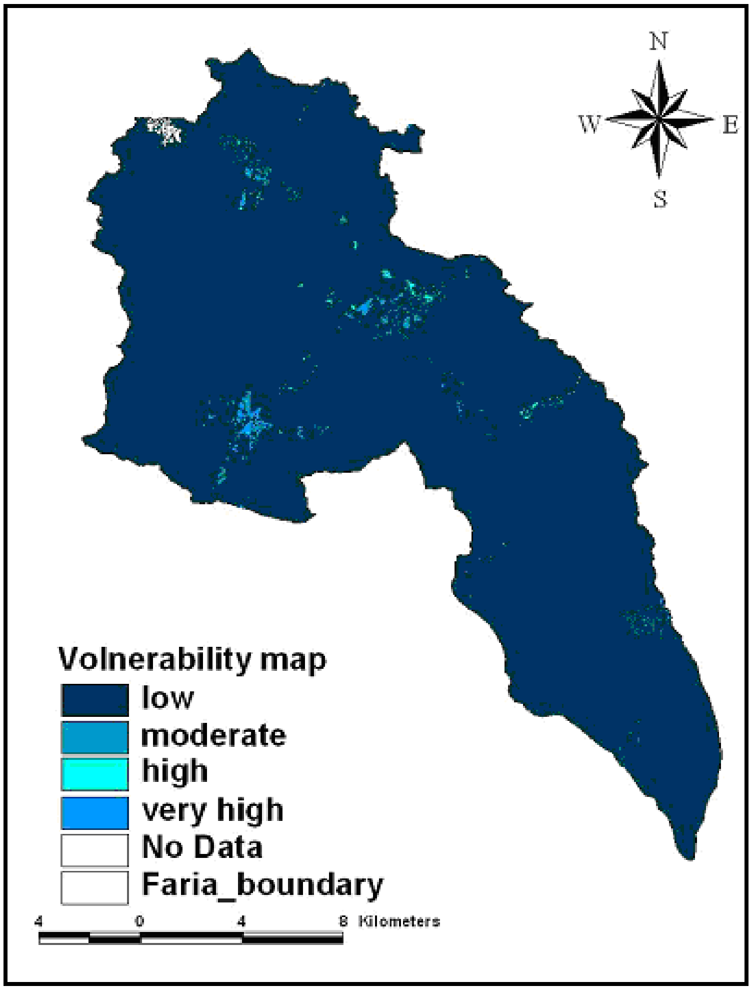

Figure (14): The Vulnerability Map for Faria Catchment

From the vulnerability map of Faria Catchment, it is apparent that the majority of the area has a low vulnerability to groundwater contamination. However, the locations that have a high vulnerability are close to the main wadi where the wells and springs are concentrated.

By over laying the layer of fields irrigated with wastewater that is shown in Figure (12) and the groundwater vulnerability layer that is shown in Figure (14), it is obvious that some locations that have high vulnerability index are irrigated with wastewater. This increases the likelihood of groundwater pollution. Figure (15) shows the locations that are irrigated with wastewater and have vulnerability to groundwater contamination.

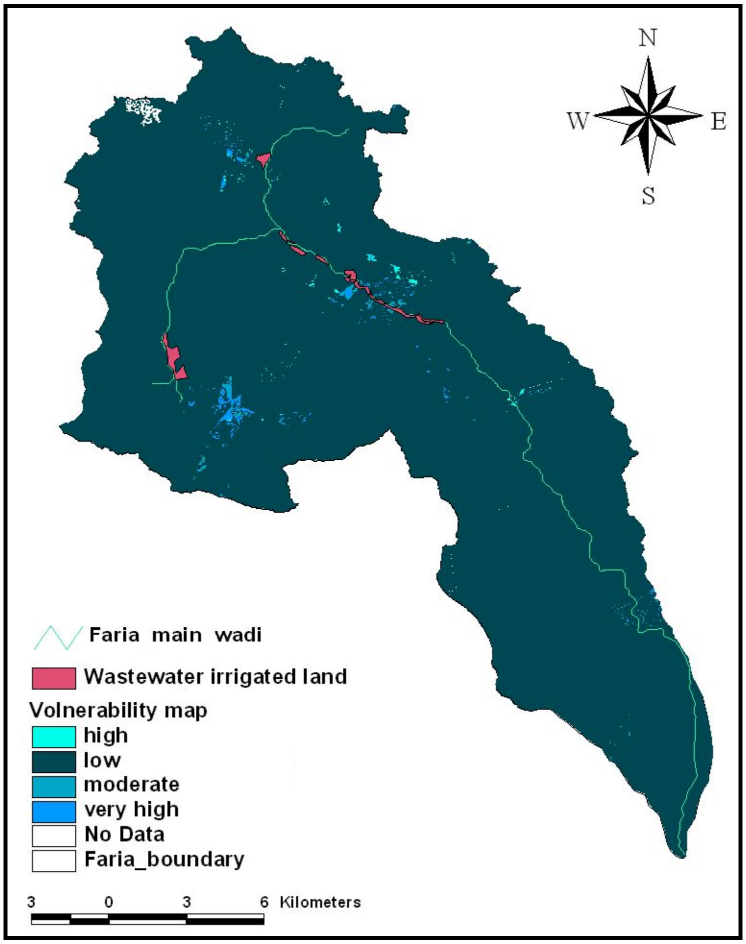

Figure (15): The Locations Irrigated with Wastewater and have a High Vulnerability Index

CHAPTER FIVE: Characterization of Wastewater Quality in Faria Catchment

5.1 Introduction

The composition of wastewater is quite variable spatially and temporally due to the storm water in winter, human and industrial activities, specific seasonal activities and climate changes.

This phase of research was carried out to investigate the characteristics of raw and diluted wastewater used for irrigation in Faria Catchment since all available data are old and insufficient.

The sampling process was carried out at four locations in Faria Catchment with the intension to cover the spatial and temporal variations in the tested parameters. These locations and the criteria used to choose them are shown in section 5.2.

The main parameters which were tested include pH, EC, Cl^-, hardness, Mg^{+2}, Ca^{+2}, TP, NO_3-N, Na^+, Cu^{+2}, Zn^{+2}, Fe^{+3}, K^+, HCO_3^-, turbidity and BOD_5. Results are utilized in comparison with national and international standards in order to figure out the suitability for use in irrigation.

This chapter focuses on the following subjects: wastewater-sampling process, characteristics of sampling locations, the methods used in analysis and the presentation of data using GIS and Excel.

5.2 Wastewater Sampling

Field visits were carried out to determine wastewater sampling locations and four locations were chosen. Thereafter, the selected locations were mapped using a GPS to facilitate representation by GIS. These locations were chosen according to the following criteria:

1. Expected quality of wastewater (raw versus diluted);

6. Degree of dilution;

7. Geographical location;

8. Accessibility to sampling locations (political considerations); and

9. Proximity to irrigated areas.

Table (11 summarizes the wastewater sampling locations in Faria Catchment while Figure (16 depicts their spatial locations.

Table (11): Wastewater Sampling Locations in Faria Catchment

ID	Location Name	X	Y	Z
1	Main outlet – Nablus City	178,583	179,270	455
2	Tahuna	180,982	184,795	108
3	Al-Malaqi	183,469	185,451	50
4	The Faria project	190,150	181,497	-83

where X : the east-west direction

Y : the north-south

Z : the altitude above mean sea level

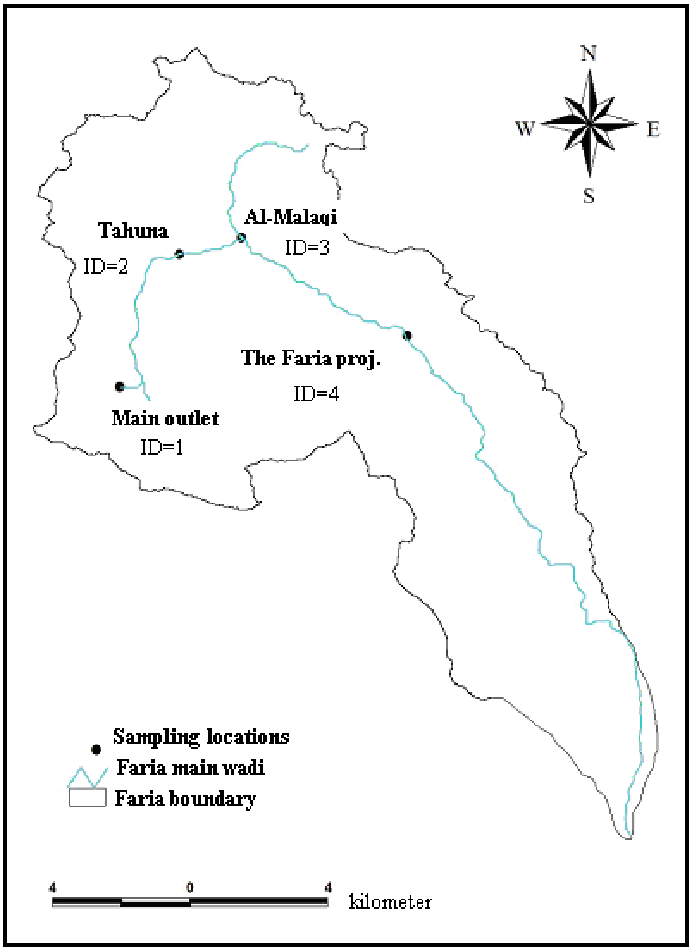

Figure (16): The Spatial Distribution of Wastewater Sampling Locations.

The frequency of wastewater sampling was twice a month for almost one year starting on 2/01/2006 up to 4/12/2006. Due to mobility and accessibility problems, this sampling frequency was implemented for the main outlet of the sewage system of the eastern part of Nablus City. The remainders of the locations shown in Figure (16 were sampled sporadically.

5.3 Characteristics of Sampling Locations

For the sampling location ID = 1 (main outlet of sewage system – Eastern Part of Nablus City), all the collected wastewater from the eastern part of

Nablus City that includes industrial and domestic wastewater leave the system at this point to Wadi Sajoor. However, farmers in the adjacent fields (Azmot field) use the raw wastewater for irrigation and animal grazing without any type of treatment.

For the sampling location ID = 2 (Tahuna), raw wastewater from Nablus City before this location mixes with freshwater from a group of springs. Farmers in the adjacent fields use only the freshwater mainly for the irrigation of citrus, olives and vegetables.

For the sampling location ID = 3 (Al-malaqi Bridge), Al-malaqi Bridge is the junction point that connects the water that comes from Al-Faria and the mixed wastewater that comes from Al-Bathan. After this point, all the surface water is polluted with effluents and flowing in concrete canals and the wadi. The farmers in the adjacent fields use water mainly for citrus, olives and vegetables.

For sampling location ID = 4 (The Faria project), it is the last point of the open channel and the beginning of the closed piped system. The rate of dilution in this location increases compared to the diluted wastewater in Al-Aqrabanieh due to the mixing with water from Ein Shebli spring. All types of vegetables are irrigated with this diluted wastewater for a total area of 16,000 dunums (Eng. Mohammad Alhanbali, Personal communication, 2006).

5.4 Analysis of Samples

A list of parameters was determined for sample analysis. This list is summarized in Table (12) and the parameters are briefly illustrated along with the method of measurement.

Table (12): The Selected Parameters for Sample Analysis

ID	Test	Unit	Equipment
1	pH	-	pH meter
2	Electrical Conductivity (EC)	μSemins	EC meter
3	NO_3-N	mg/l	Nitrate meter
4	Chloride (Cl^-)	mg/l	Titration
5	Total Phosphate (TP)	mg/l	spectrophotometer
6	Magnesium (Mg^{+2})	mg/l	Titration
7	Calcium (Ca^{+2})	mg/l	Titration
8	Hardness	mg/l	Titration
9	HCO_3^-	mg/l	Titration
10	Zink (Zn^{+2})	mg/l	Atomic absorption
11	Iron (Fe^{+3})	mg/l	Atomic absorption
12	Sodium (Na^+)	mg/l	Flame photometer
13	Potassium (K^+)	mg/l	Flame photometer
14	Biological Oxygen Demand (BOD_5)	mg/l	Incubator
15	Turbidity	NTU	Turbidity meter

5.4.1 pH value

pH is a measurement of acidity or basicity (FAO, 1992). This test helps to determine the values of pH of water that is used for irrigation. The normal range of pH for irrigation water is shown in Table (13). pH values were measured using a pH meter (Clesceri et al., 1998).

Table (13): Standard Parameters Values for Using Wastewater in Irrigation (FAO, 1992).

Parameter	Unit	Degree of restriction in use		
		None	Slight to moderate	Sever
Salinity(EC)	μSemins	< 700	700 – 3,000	> 3,000
SAR	Indicator	< 3	3 – 9	> 9
Chloride (Cl^-)	mg/l	< 142	142 – 355	> 355
Nitrogen (NO_3-N)	mg/l	< 5	5 – 30	> 30
Bicarbonate (HCO_3^-)	mg/l	< 92	92 – 519	> 519
Iron	mg/l	Maximum recommended concentration 5		
Zinc	mg/l	Maximum recommended concentration 2		
Copper	mg/l	Maximum recommended concentration 0.2		
pH	Normal range (6.5 – 8)			

5.4.2 Electrical Conductivity (EC)

Electrical conductivity is a measurement of salinity (FAO, 1992). EC is a measure of the total suspended and dissolved ions and solids. The standard values of EC of water used for irrigation are summarized in Table (13). The EC values were measured using an EC meter (Clesceri et al., 1998).

5.4.3 NO_3-N

Nitrate test is a measure of nitrate concentration as (nitrogen), to investigate if the value is within the acceptable range for using it in irrigation. Nitrogen is a vital nutrient for plant development since nitrogen is an essential component of proteins (Hagin and Tucker, 1982). However; nitrate becomes harmful to human beings (especially for infants) if it reaches the water resources when used for drinking. The standard values for concentration of nitrate in water used for irrigation is summarized in Table (13). Two methods were used to measure NO_3-N, a nitrate meter with EDTA and a spectrophotometer (Clesceri et al., 1998).

5.4.4 Chloride (Cl^-)

Chloride is one of the most important quality parameters of water used in irrigation due to its toxicity to plants and as a salinity indicator. The standard value of chloride concentration in water used for irrigation is shown in Table (13). Chloride is measured by titration with $AgNO_3$ (Clesceri et al., 1998).

5.4.5 Total Phosphate (TP)

Phosphate is a vital nutrient for plants. As such, it is important to measure its value to estimate the total quantities of phosphate that can farmers gain from using wastewater in irrigation. Total phosphate is measured by spectrophotometer (Clesceri et al., 1998).

5.4.6 Hardness (Calcium and Magnesium)

Hardness is a measurement used originally to investigate the suitability of water for washing with soap. In wastewater, hardness shows the concentration of Ca^{+2} and Mg^{+2} dissolved ions since these ions precipitate and affect the method off irrigation, also high hardness can reduce the toxic effects of heavy metals such as Cr (Dojildo and Best, 1993). The value of Hardness, Ca^{+2} and Mg^{+2} is measured by the titration with EDTA (Clesceri et al., 1998).

5.4.7 Bicarbonate (HCO_3^-)

Bicarbonate is measured in wastewater as an indicator of alkalinity. The standard values for concentration of bicarbonate in water used for irrigation is shown in Table (13). Bicarbonate is measured by the titration with H_2SO_4 (0.02 N) (Clesceri et al., 1998).

5.5 Results and Analysis

Two types of analysis were conducted. In the first, temporal variations at specific locations were considered, while in the second a comparison of parameters at different locations in Faria Catchment was assessed.

5.5.1 Temporal Variations of Wastewater Parameters

In this type of analysis, a total of 16 raw wastewater samples were taken from the main outlet of the sewage system of Nablus City to measure the parameters that are summarized in Table (12). Table (14) summarizes the analysis results of the selected parameters, while Table (15) gives the general statistical measures computed for the parameter results.

Table (14): Results of the Parameter Analysis for Wastewater at the Main Outlet of the Eastern Part of Nablus City.

	Date															
Parameter	**2/1/06**	**18/2/06**	**5/3/06**	**19/3/06**	**3/4/06**	**17/4/06**	**30/4/06**	**11/5/06**	**27/5/06**	**29/8/06**	**21/9/06**	**2/10/06**	**31/10/06**	**20/11/06**	**21/11/06**	**4/12/06**
pH	7.61	8.28	6.93	8.3	7.75	7.76	7.47	7.4	7.36	10.21	9.05	6.8	8.05	7.27	7.63	5.53
EC	4,640	1,970	3,080	2980	1,550	2,000	2,620	2,650	2,710	3,930	3,270	5,000	3,880	18,300	2,300	43,600
NO_3	NA	86	119	146	78	71	62	70	65	66	70	60	-	-	-	177
Cl^-	1,150	320	545	495	280	365	620	645	630	1,225	875	1,145	879	6,697	305	17,944
TP	11.26	10.74	12.95	10.63	3.50	11.32	-	-	-	2.16	3.10	19.4	13.74	13.84	12.47	8.95
Mg	12.15	12.2	19.4	26.7	19.4	19.4	26.70	12.00	24.30	12.15	38.88	4.90	9.72	72.90	12.15	170.10
Ca	152	100	108	96	76	104	100	120	120	60	76	132	112	280	100	520
Hardness	430	300	350	350	270	340	360	350	400	200	350	350	320	1000	300	2,000
HCO_3	781	854	781	830	427	622	-	-	-	219	597	1,073	927	1,464	817	1,098
Zn	0.15	0.16	0.24	0.024	0.0	0.0	-	-	-	0.0	0.0	0.0	0.31	0.05	0.07	0.16
Cu	0.0	0.0	0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fe	0.36	0.46	0.77	0.078	0.0	0.0	-	-	-	0.0	0.0	0.0	0.08	0.17	0.0	1.06
Na	920	190	308	292	144	198	-	-	-	780	820	920	580	737	450	1,505
K	120	32	48	47	30	28	-	-	-	50	49	50	55	85	52	103
Turbidity	-	40.8	48.8	50	30.2	48.9	50.2	51.4	50.6	42	-	-	-	-	-	-
BOD_5	102	162	427	502	280	630	816	790	830	940	740	840	540	740	493	772

Table (15): Statistical Analysis of the Measured Wastewater Parameters (see Table (14))

Parameter	Unit	Min.	Max.	Median	Mean	Standard Dev.	Skew
pH	indicator	5.5	10.2	7.62	7.71	1.02	0.477
EC	μSemins	1,550	43,600	3,030	6,530	10,634	3.284
NO_3	mg/l	60	177	70.44	89.06	37.89	1.603
Cl^-	mg/l	280	17,944	637	2,132	4,486	3.374
TP	mg/l	2.16	19.40	11.26	10.31	4.89	-0.311
Mg	mg/l	4.9	170.10	19.44	30.82	40.47	3.118
Ca	mg/l	60	520	104	141	112.4	2.986
Hardness	mg/l	200	2,000	350	479.38	441.3	3.187
HCO_3^-	mg/l	219	1,464	817	807	312.77	0.178
Zn	mg/l	0	0.31	0.05	0.09	0.1	0.973
Cu	mg/l	0	0	0	0	0	N.V
Fe	mg/l	0	1.06	0.08	0.23	0.34	1.613
Na	mg/l	144	1,505	580.0	603	394	0.838
K	mg/l	28	120	50	57.61	28.03	1.294
Turbidity	NTU	30.20	51.40	48.90	45.88	7.01	-1.666
BOD_5	mg/l	102	940	685	600.25	255	-0.716

pH

pH values were measured in 16 samples as depicted in Figure (17). The maximum value was found to be 10.2 and the minimum value was 5.5. Out of the 16 values, there were six readings that do not fall within the pH standard range for using water for irrigation of 6.5-8 (FAO, 1992). However; the overall average and median were 7.7 and 7.6; respectively and fall within the standard range. The variability of pH values indicates that the constituents of wastewater are not steady and changes from acid to base depends on the discharged wastewater from domestic and industrial sources. The main industries in the study area that increase the acidity are: chemical detergents, cosmetics, diary products, and paper and printing. On the other hand, textile, vegetable ghee and insecticide and veterinary medicines industries increase the basicity.

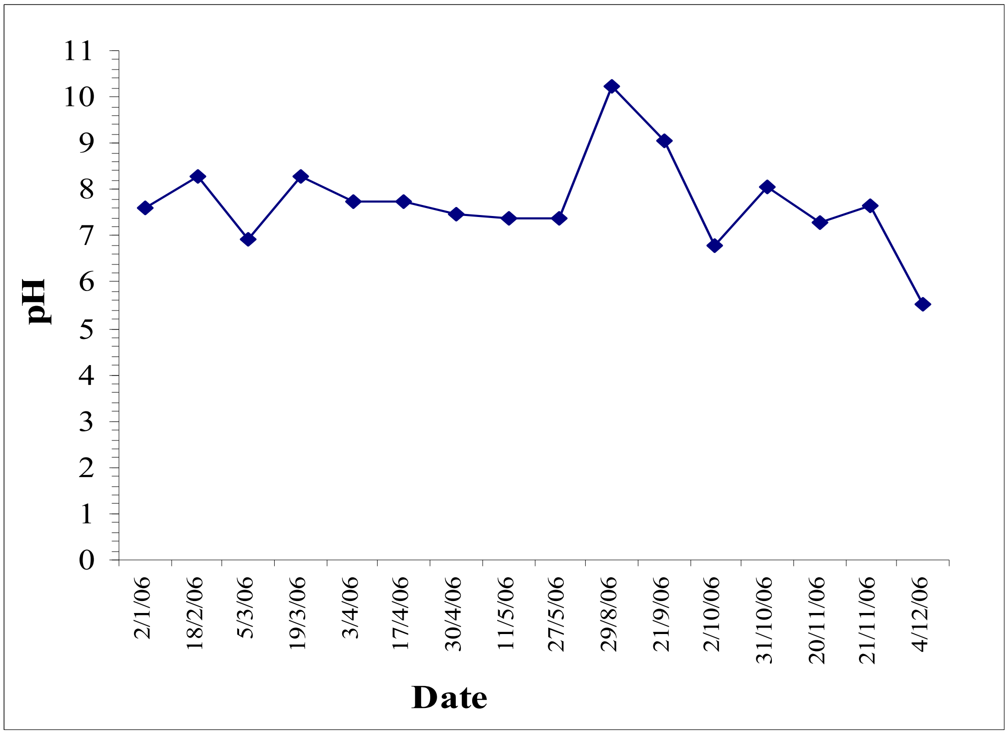

Figure (17): Temporal Variability of pH Values in wastewater from the Main Outlet of Nablus City.

Electrical Conductivity (EC)

As mentioned earlier, the value of the upper control limit (UCL) of EC is 3,000 µSemins. Above this limit it is sever to use saline water in irrigation since high salinity impedes the plants from extracting water from the soil through the reverse osmosis mechanism. The lower control limit (LCL) is 700 µSemins. Below LCL there is no noticeable effect in using saline water in irrigation. Between LCL and UCL, the severity is slight to moderate to use saline water in irrigation.

From the results summarized in Table (14) and Table (15) and shown in Figure (18), it was found that the minimum EC reading was 1,550 μSemins while the maximum was 43,600 μSemins. 50% of samples are under slight to moderate restrictions for use in irrigation, while the remainders 50% of the readings have sever restrictions. The overall EC average was 6,530 and exceeds by far the standard range.

Apparently, EC values are higher in summer than in winter and this can be attributed to the fact that the storm water in winter mixes with wastewater and dilutes the concentrations of ions that produce the salinity. The extreme EC values are due to industrial wastewater that enters wastewater as slugs.

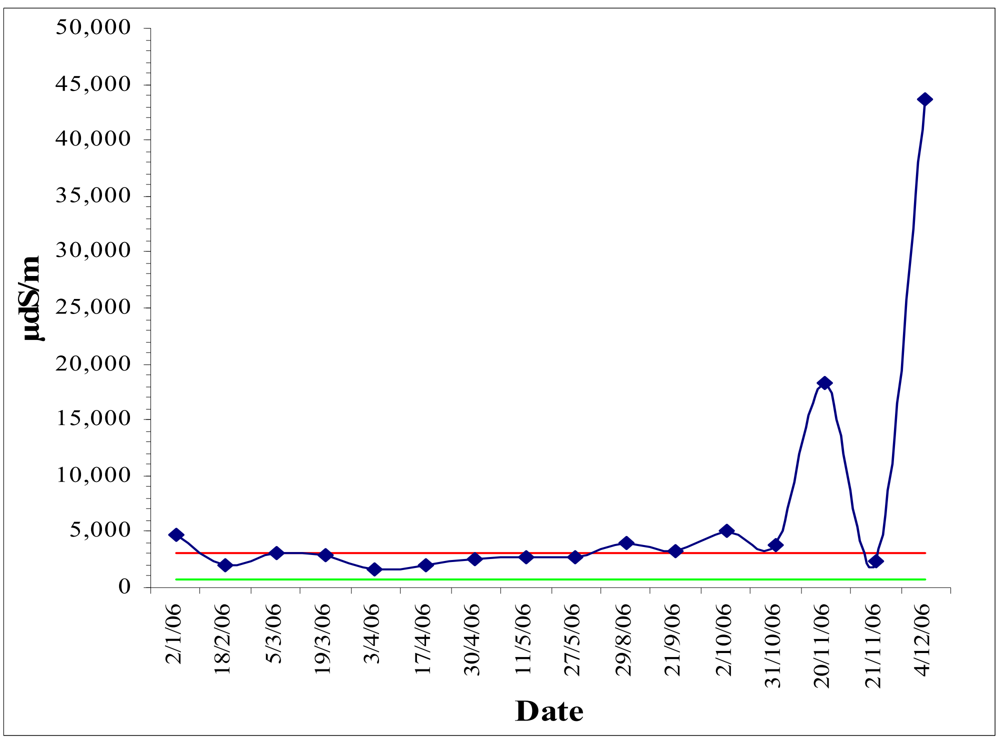

Figure (18): Temporal Variability of EC Values in Wastewater from the Main Outlet of Nablus City.

NO_3-N

Figure (19) depicts NO_3-N analysis results. NO_3-N was measured in eleven samples. The value of UCL of NO_3-N is 30 mg/l and the LCL value is 5 mg/l (FAO, 1992).

From the results summarized in Table (14) and Table (15), it was found that the minimum NO_3-N concentration was 60 mg/l while the maximum was 146 mg/l. Apparently; all the samples are under sever restrictions for irrigation use. The values become steadier in summer due to relative stability in discharged wastewater quantities.

The extreme NO_3-N values are due to industrial wastewater that enters the collection system from olive mills and the slaughterhouse.

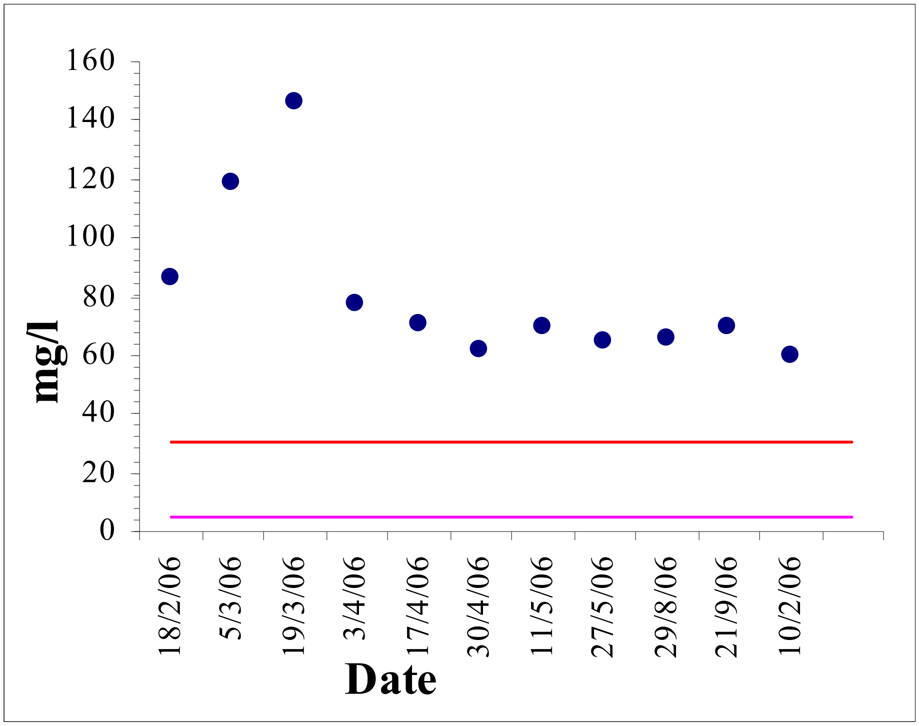

Figure (19): Temporal Variability of NO_3-N Values in Wastewater from the Main Outlet of Nablus City.

Chloride (Cl^-)

From the results that are shown in Figure (20), it was found that minimum chloride reading was 280 mg/l while the maximum was 17,944 mg/l. Around 19% of samples have slight to moderate restrictions to be used in irrigation, while 81% of readings are under sever restrictions. The overall average was 2,132 mg/l and exceeds the standard range. The concentration of chloride in summer is higher than that in winter due to the storm water that dilutes the wastewater and decreases the concentration of chloride ions.

The extreme chloride values are due to industrial wastewater such as textile industry, chemical detergents, tahina industry and diary products.

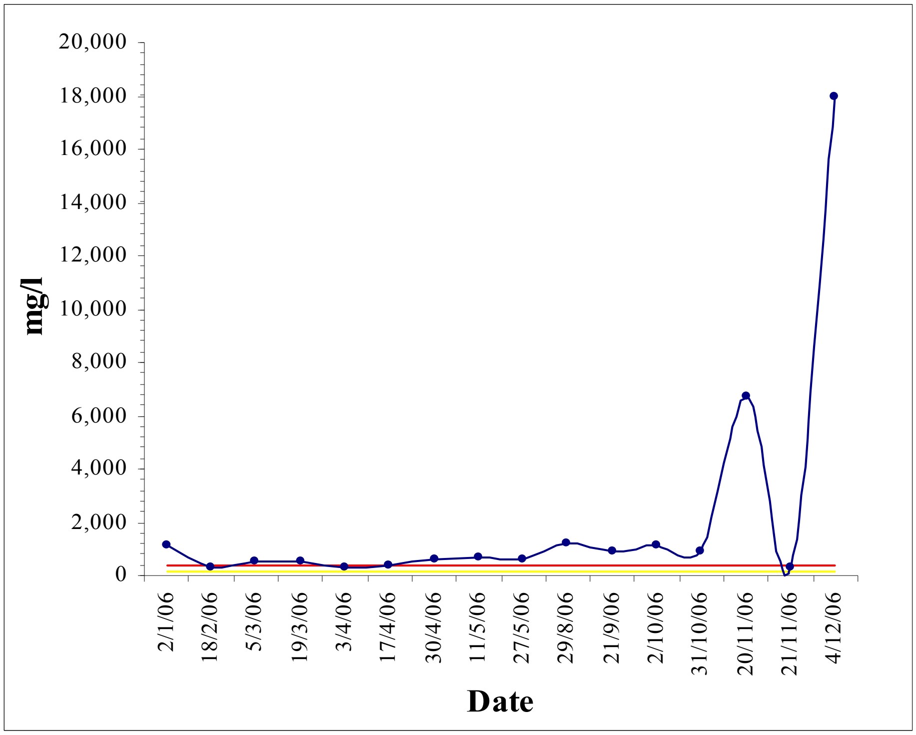

Figure (20): Chloride Concentration in Wastewater from The Main Outlet of Nablus City.

Total Phosphate (TP)

TP values were measured in 13 samples and results are depicted in Figure (21). It was found that the minimum TP value was 2.16 mg/l and the maximum was 19.4 mg/l with an average value of 10.3 mg/l. This implies that large amounts of phosphates in wastewater can be used as a fertilizers for plants.

There is a clear temporal variability in TP values depending on the discharged quantities from domestic and industrial sources. The main industrial sources for phosphate in the effluents of the study area come from chemical detergents and dairy products.

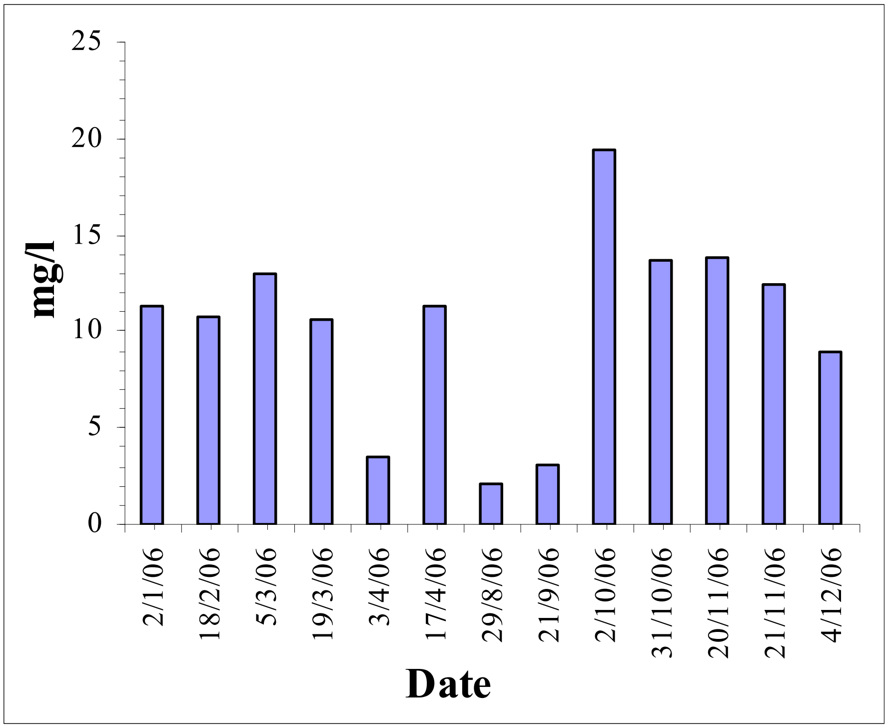

Figure (21): Total Phosphate Concentration in Wastewater from The main Outlet of Nablus City.

Hardness

From the results that are shown in Figure (22), it was found that the minimum hardness was 100 mg/l and the maximum was 2,000 mg/l, with an overall average of 423 mg/l. The value of hardness is important since it affects the irrigation method, where the precipitation of calcium and magnesium clogs the pipes and drips used for irrigation.

There are temporal variability in hardness values depending on the existence and sources of calcium and magnesium ions, dilution in winter and evaporation in summer. The extreme values of hardness are attributed industrial sources.

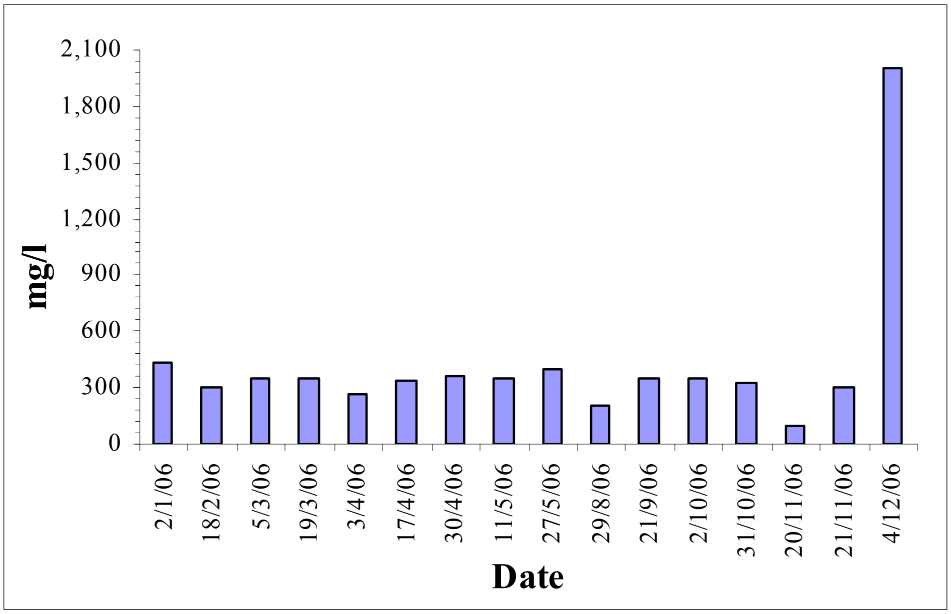

Figure (22): Hardness Concentration in Wastewater from The main Outlet of Nablus City.

Bicarbonate (HCO_3)

Bicarbonate was measured in 13 samples as depicted in Figure (23). The UCL is 519 mg/l and LCL is 92 mg/l. It was found that the minimum Bicarbonate reading was 219 mg/l and the maximum was 1,464 mg/l with an average value of 806 mg/l and a standard deviation of 312 mg/l.

Depending on bicarbonate readings, it was found that 15.4 % of the samples have slight to moderate restrictions for use in irrigation while 84.6 % of readings indicate sever restrictions.

As evidenced from the standard deviation, there is a clear temporal variability in carbonate values depending on the discharged quantities from domestic and industrial sources.

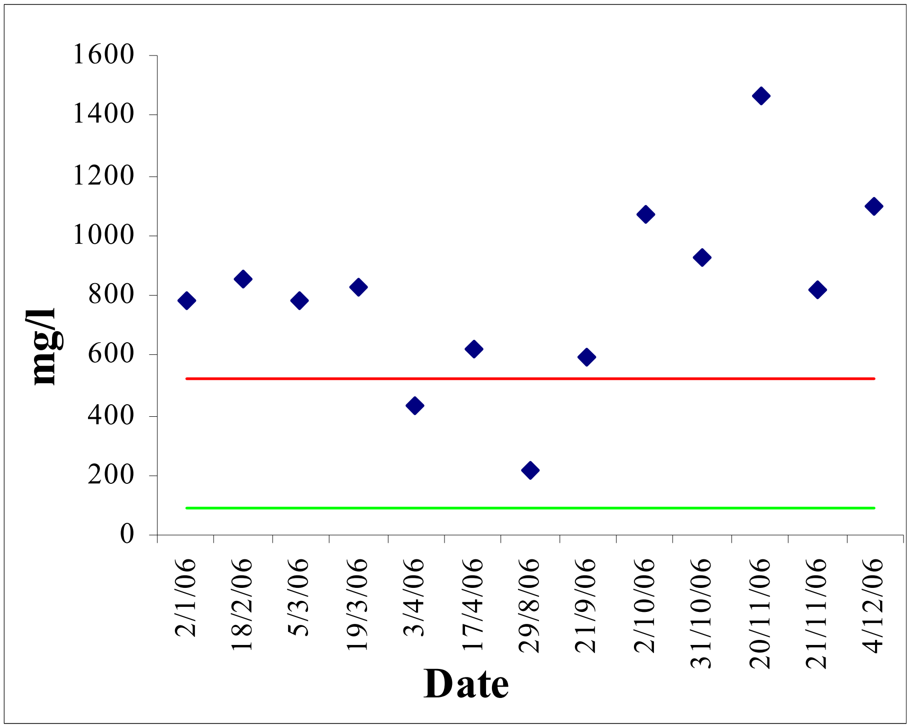

Figure (23): Bicarbonate Concentration in Wastewater from The main Outlet of Nablus City.

Sodium Adsorption Ratio (SAR)

Depending on the measured values of sodium, calcium and magnesium, SAR was calculated for 13 samples as depicted in Figure (24) by using the following formula:

$$\text{SAR} = \frac{Na}{\sqrt{(\frac{Mg + Ca}{2})}} \quad \text{(all units in meql/l)}$$

The values of UCL and LCL for SAR are 9 and 3, respectively.

The minimum SAR value was 3.82 while the maximum was 24.02 with an average of 12.49 and a standard deviation of 6.82 mg/l. it was found that

38.5 % of the samples have slight to moderate restrictions for use in irrigation while 61.5 % of readings indicate sever restrictions.

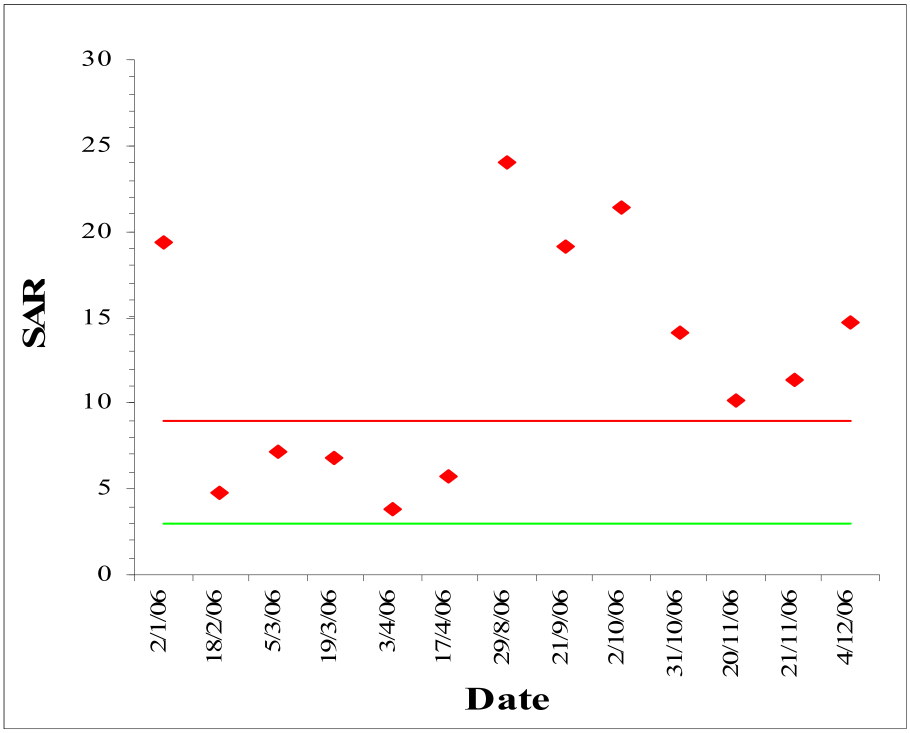

Figure (24): SAR Values in Wastewater at the Main Outlet of Nablus City.

The extreme SAR values are due to high values of sodium in domestic and industrial wastewater. The main industries that discharge sodium include textile, chemical detergents, vegetable ghee and vegetable oil. SAR values are not steady and with higher values in summer than in winter, depending on discharged quantities from industrial and domestic sources, degree of dilution in winter and high evaporation rate in summer that increase SAR values.

BOD_5

The values of BOD_5 are shown in Figure (25). The minimum BOD_5 value was 102 mg/l in January while the maximum was 940 mg/l in August. The overall BOD_5 annual average was 600 mg/l with a standard deviation of

255. The BOD_5 values vary temporally with higher values in summer. This reflects the effect of temperature on BOD_5. High temperature in summer makes the microorganisms more active so the consumption of oxygen increases. The relationship between temperature and BOD_5 are depicted in Figure (26**).**

All the measured BOD_5 values indicate severe restriction for the use in irrigation.

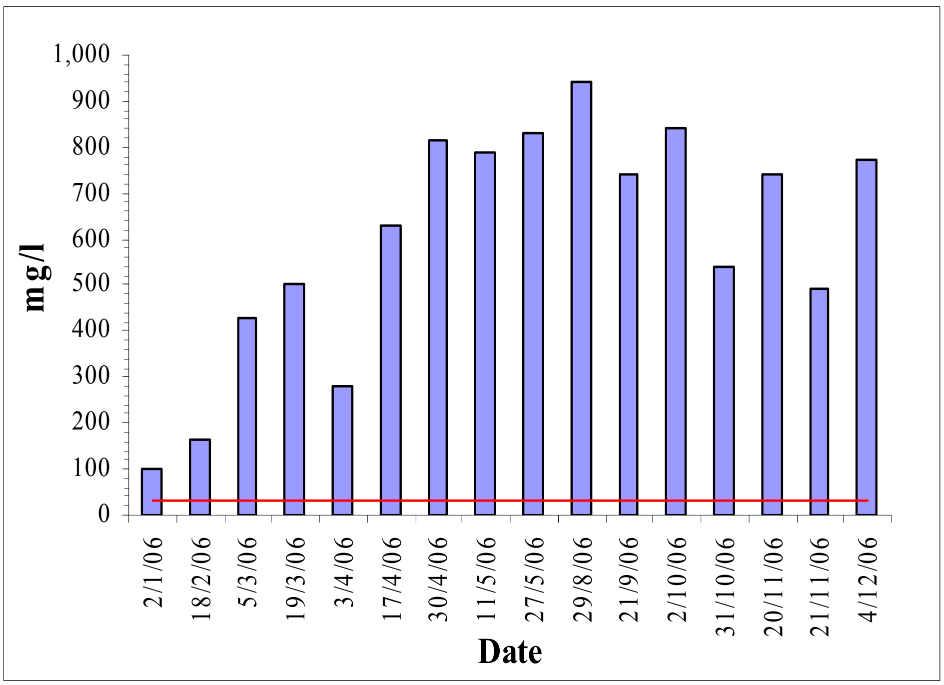

Figure (25): BOD_5 Values in Wastewater from The Main Outlet of Nablus City.

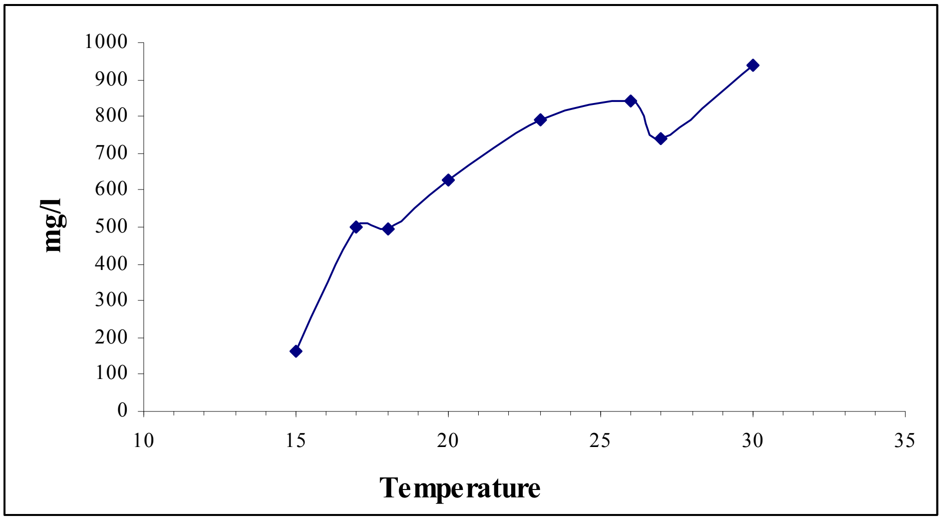

Figure (26): The Relationship between Temperature and BOD_5 Values.

Potassium (K)

K was measured in 13 samples as depicted in Figure (27). The minimum K reading was 28 mg/l while the maximum was 120 mg/l with a standard deviation of 28.03 mg/l and an overall average of 57.6 mg/l.

There is a clear temporal variability in K values depending on the discharged quantities from domestic and industrial sources, evaporation rate in summer that increases the concentration of wastewater constituents and the dilution with rain water in winter.

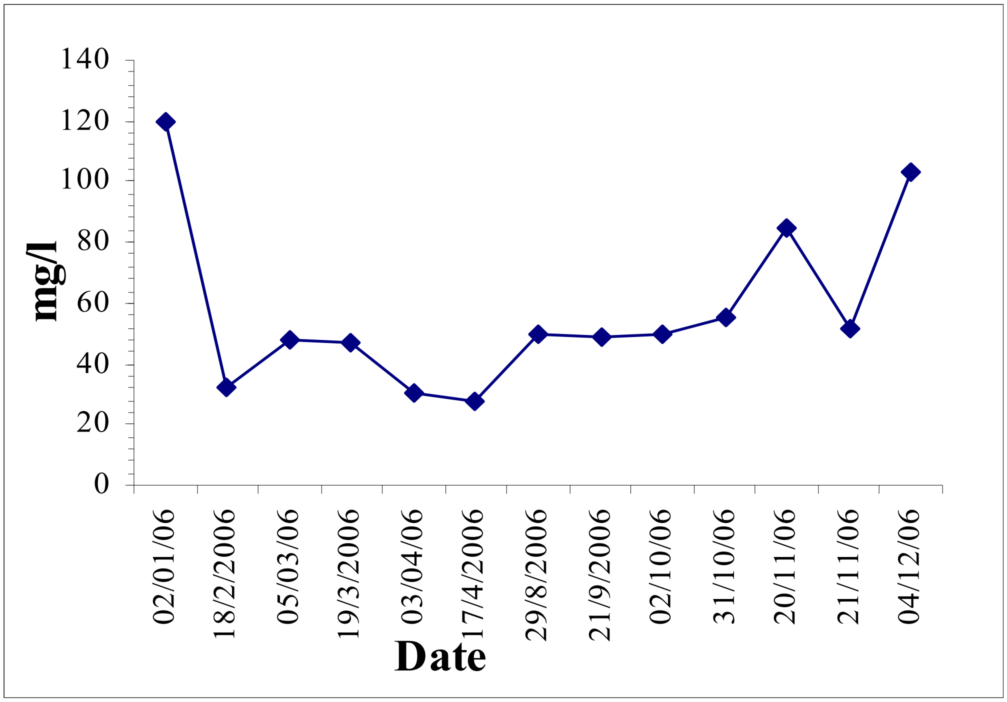

Figure (27): Potassium Values in Wastewater from The main Outlet of Nablus City.

Zinc (Zn)

As depicted in Figure (28), Zn was measured in 13 samples. The value of UCL is 2 mg/l. It was found that the minimum Zn reading was 0 mg/l and the maximum was 0.31 mg/l. All samples have no restrictions to be used in irrigation. 38% of samples have no detectable levels of Zn.

There is a clear temporal variability in Zn values depending on the discharged quantities from domestic and industrial sources and the dilution with rain water in winter season.

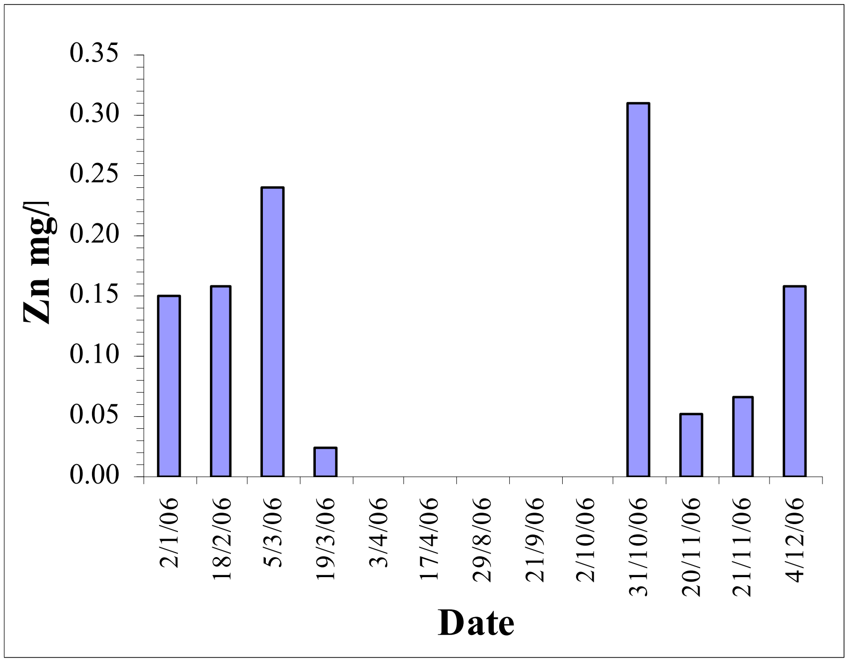

Figure (28): Zinc Values in Wastewater from The main Outlet of Nablus City.

Turbidity

The value of turbidity was measured in 9 samples as shown in Figure (29). The minimum reading was 30.2 ntu and the maximum was 51.4 ntu with an overall average of 45.88 ntu and a standard deviation of 7.01 ntu. The high values of suspended solids that increase the turbidity affect the irrigation method and indicator to use settling ponds for primary wastewater treatment.

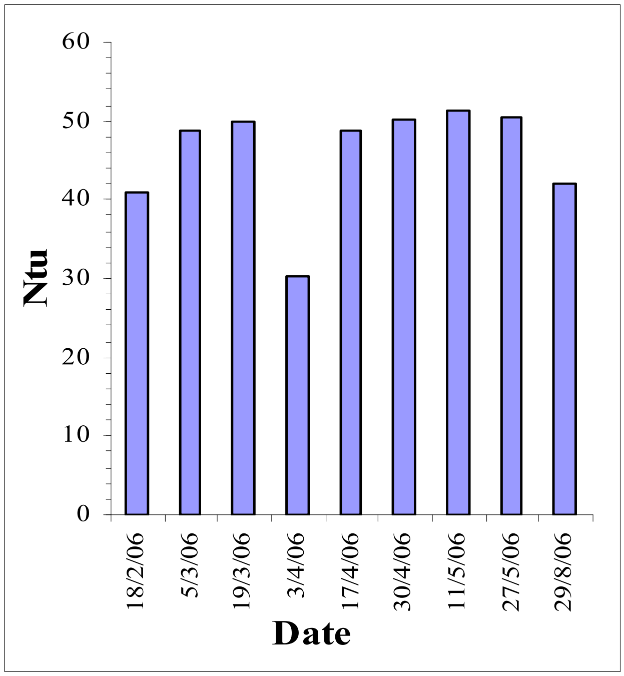

Figure (29): Turbidity Values in Wastewater from the Main Outlet of Nablus City.

Copper and Iron

All tested samples have no detectable levels of copper this may due to the unsuitable time for carrying out the sampling process. For iron, it was detected in some tested samples.

5.5.2 Spatial Variations in Wastewater Quality

In this type of analysis, the average values of pH, EC, Cl^-, TP, NO_3-N, HCO_3, Zn and BOD_5 for all samples that were collected from the locations shown in Figure (16) were analyzed. There are no significant changes in pH values as shown in Figure (31), since the measured pH average for raw wastewater very close to the average pH value for freshwater. The values of EC, nitrate, chloride and bicarbonate that shown in Figure (32), Figure (33), Figure (34), and Figure (36); respectively decline as we depart from the main outlet towards the Faria project. Apparently, the quality of wastewater indicates a conversion from full restriction on the use in irrigation to a state of slight to moderate restriction on use.

The significant changes occurred between the main outlet (ID=1) and Tahuna (ID=2), due to the following reasons:

- Part of the raw wastewater is used for irrigation near the main outlet which reduces the quantities of effluents that flow towards Tahuna location;
- The raw wastewater settles in a pool located in the middle distance between the main outlet and Tahuna locations as shown in Figure (30). This allows for the settling of organic and suspended solids and biologically treats the effluents.
- In winter, large quantities of surface runoff draining from adjacent mountains and upstream areas mix with the raw wastewater between the main outlet and Tahuna locations. As such, the concentrations of wastewater constituents decrease; and
- The effluent mixes with the freshwater that emerges from the group of springs located in the vicinity of the Tahuna location.

Figure (30): The Pool between the Main Outlet and Tahuna Location.

Between Tahuna (ID=2) and Al-Malaqi (ID=3) locations there are no significant changes because the two locations are close to each other and only evaporation may alter the quality parameters.

After Al-Malaqi (ID=3) location, farmers use the diluted wastewater, and a second new group of springs (Ein Sheble) discharge freshwater that mixes with the diluted wastewater that comes from Al-Malaqi. As such the dilution level increases and the parameter concentrations in general decrease towards Faria project (ID=4) location.

For the remaining parameters (TP, Zn and BOD_5) they have almost the same behavior and the above mentioned analysis applies well to them. Results are shown in, Figure (37) and Figure (38).

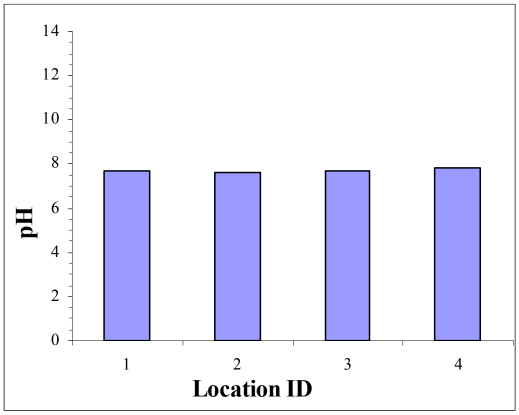

Figure (31): pH Values in Wastewater from Different Locations.

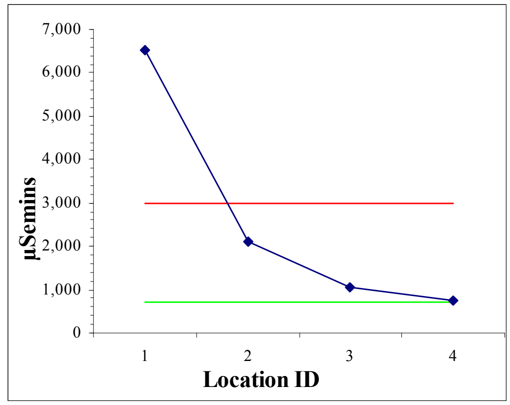

Figure (32): EC Values in Wastewater from Different Locations

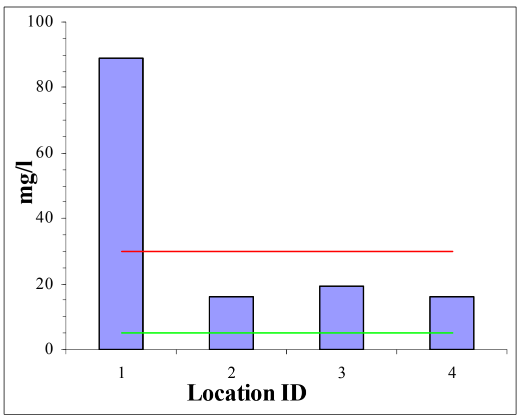

Figure (33): Nitrate Values in Wastewater from Different Locations.

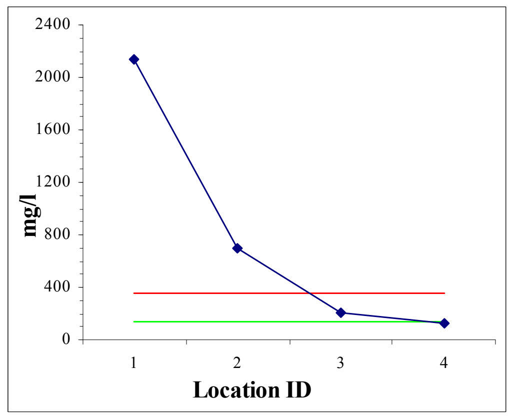

Figure (34): Chloride Values in Wastewater from Different Locations.

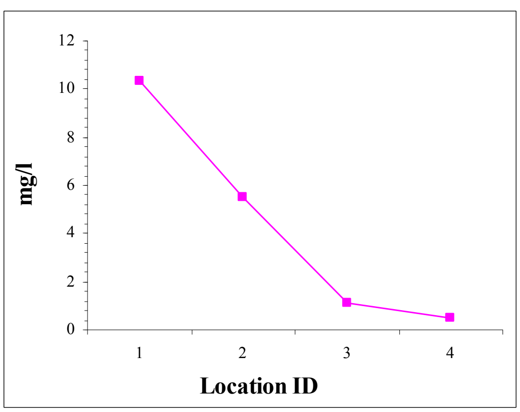

Figure (35): TP Values in Wastewater from Different Locations.

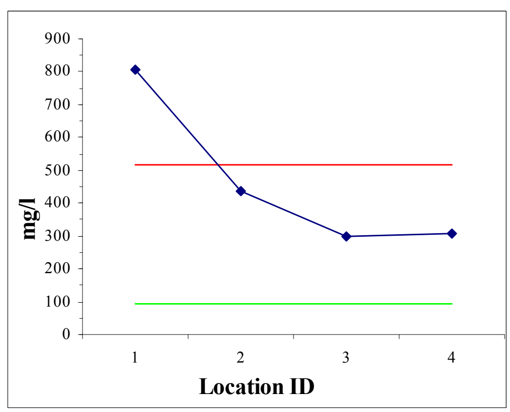

Figure (36): Bicarbonate Values in Wastewater from Different Locations.

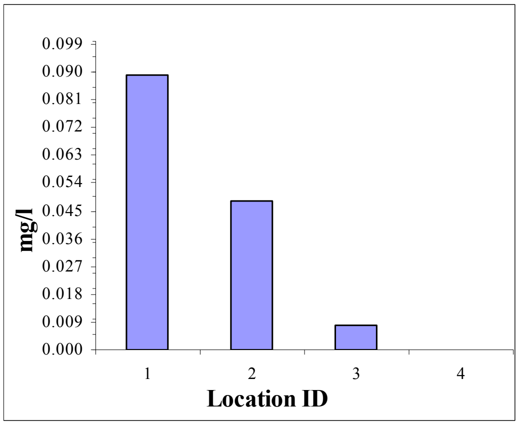

Figure (37): Zinc Values in Wastewater from Different Locations.

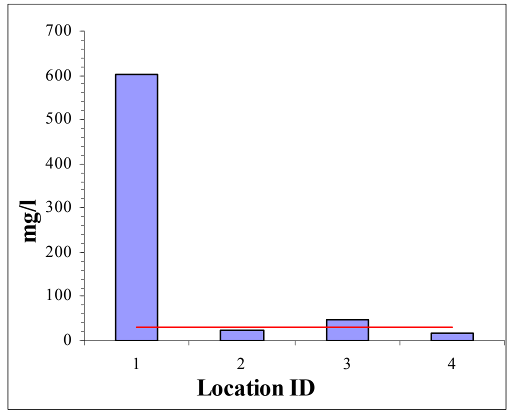

Figure (38): BOD_5 Values in Wastewater from Different Locations.

The GPS device was used extensively in Faria Catchment to specify the locations that were irrigated with different water qualities. Moreover, by using the capabilities of GIS program the collected data were converted to maps show the spatial distribution of the following tested parameters:

- Chloride as shown in Figure (39);
- DOD5 as shown in Figure (40);
- electrical conductivity as shown in Figure (41);
- Bicarbonate as shown in Figure (42);
- Nitrate as shown in Figure (43);
- pH values as shown in Figure (44);
- Total phosphate as shown in Figure (45); and
- Zinc as shown in Figure (46)

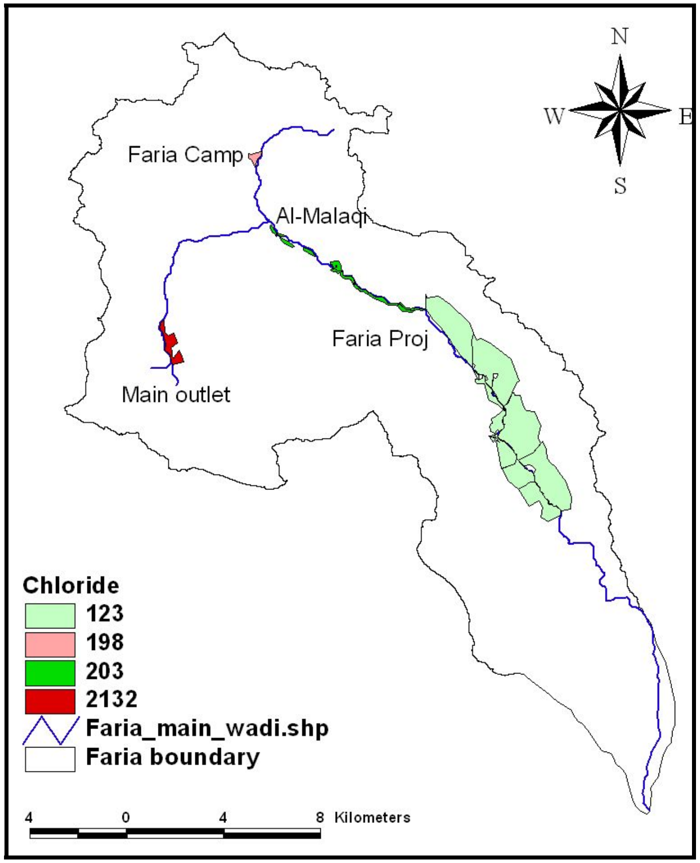

Figure (39): Chloride values in locations irrigated with wastewater

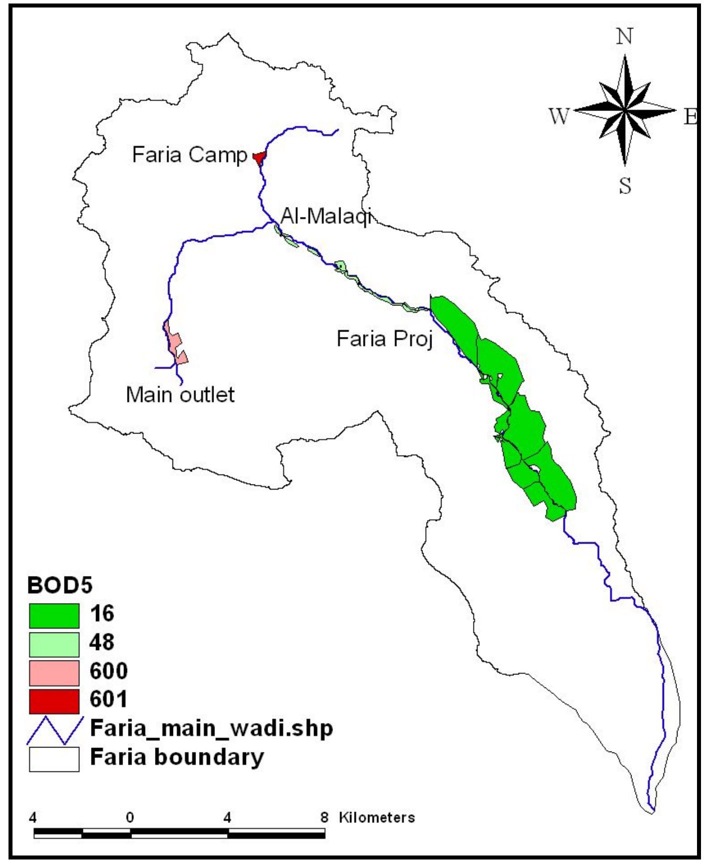

Figure (40): BOD_5 values in locations irrigated with wastewater

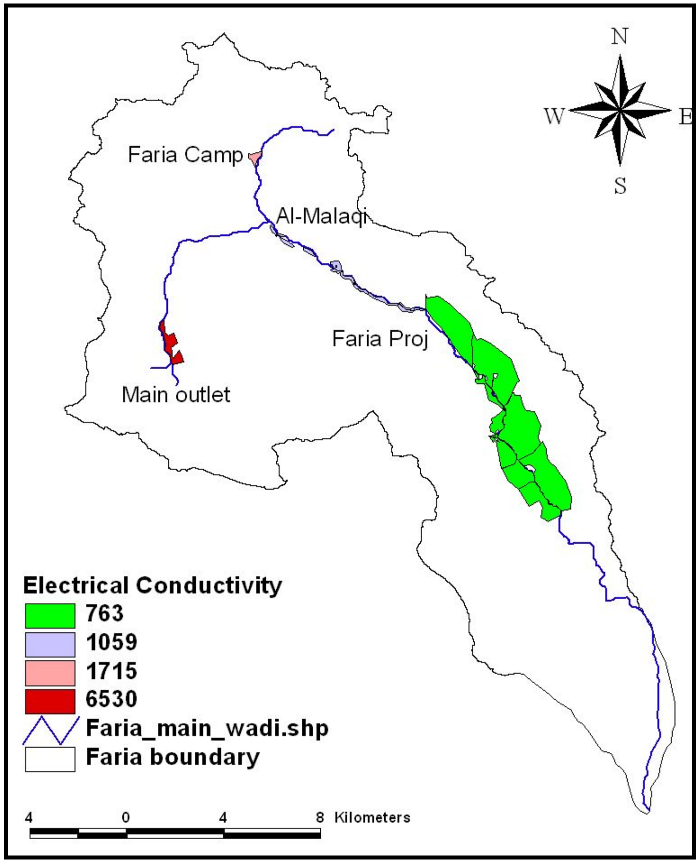

Figure (41): EC values in locations irrigated with wastewater

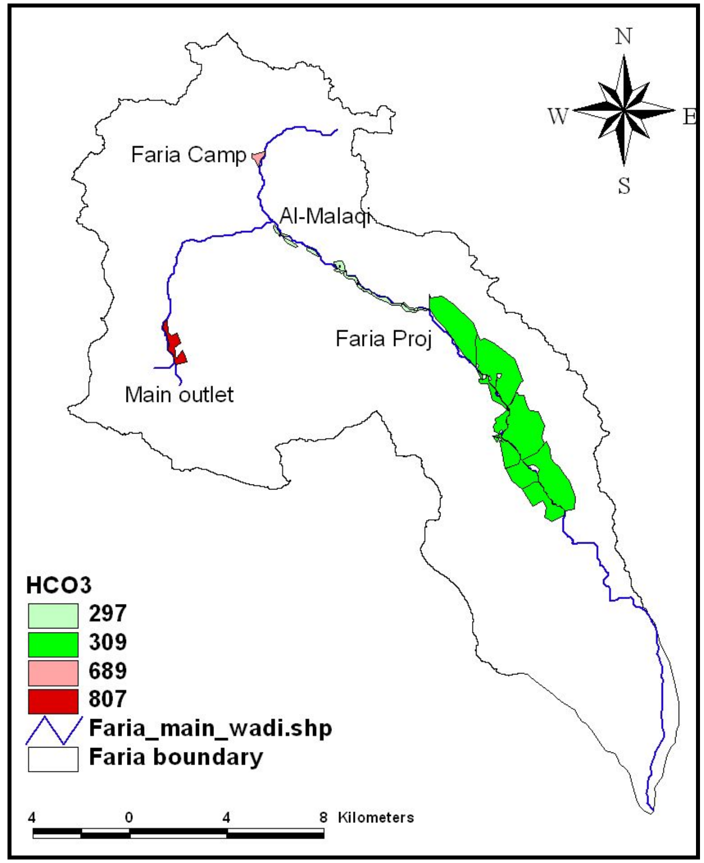

Figure (42): Bicarbonate values in locations irrigated with wastewater

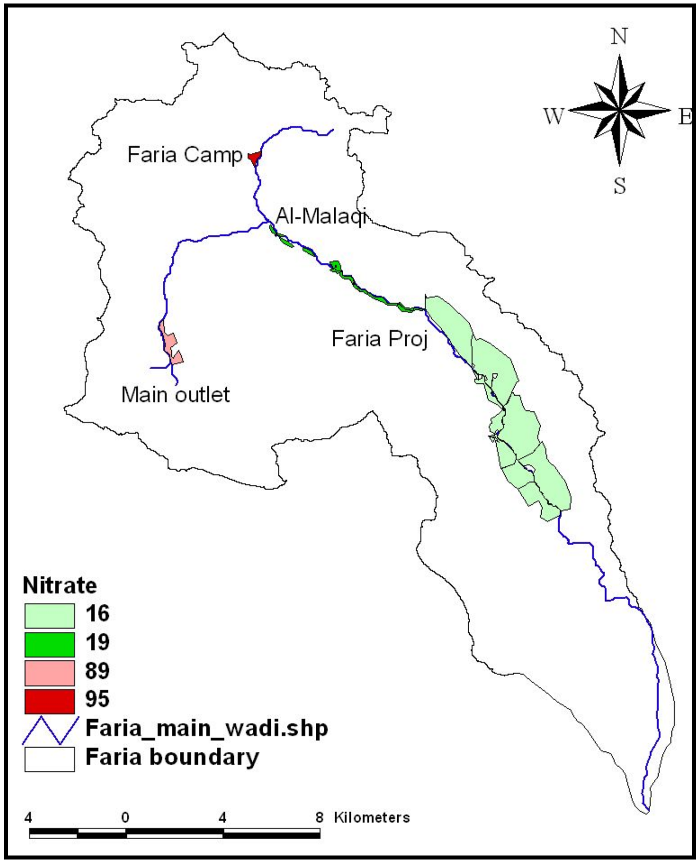

Figure (43): Nitrate values in locations irrigated with wastewater

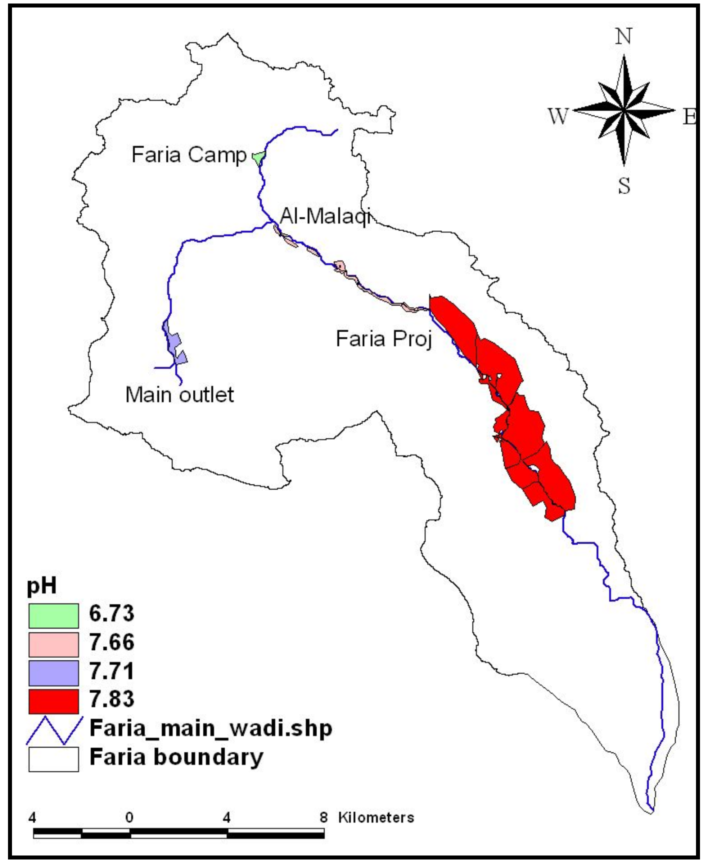

Figure (44): pH values in locations irrigated with wastewater

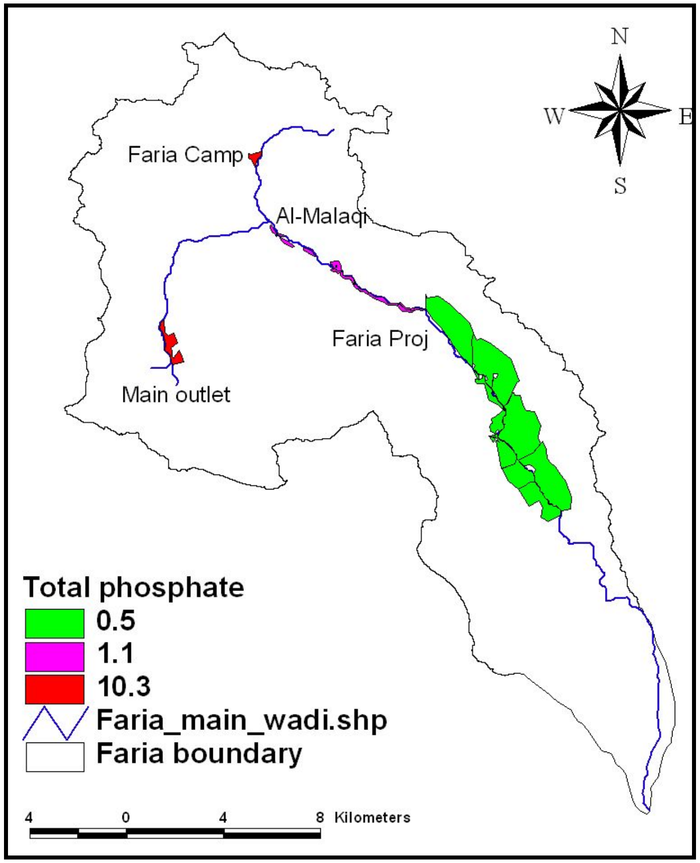

Figure (45): Total phosphate values in locations irrigated with wastewater

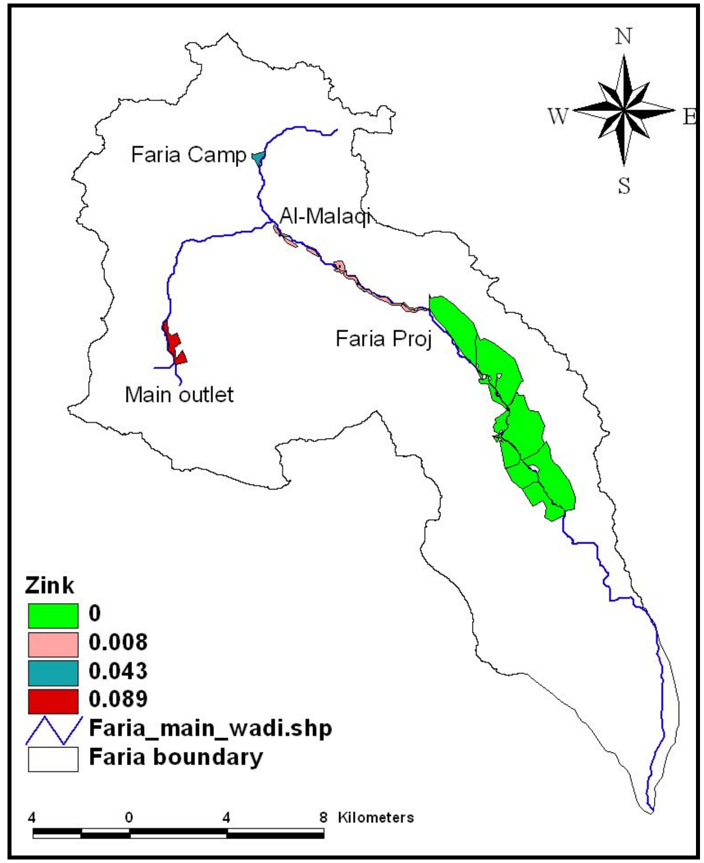

Figure (46): Zink values in locations irrigated with wastewater

CHAPTER SIX: Impact of Wastewater on Soil Properties

6.1 Introduction

Soil is a porous media that contains solids, liquids, and gases created at the land surface by weathering processes, derived from biological, geological, and hydrological phenomena (Sposito, 1989). Wang et al. (2003) define soil as the medium that supports plant growth, and modulates nutrients and pollutants in the environment. The soil also works as the main support and fixing agent for the plants body.

In the West Bank and elsewhere, the typical water used in agriculture is freshwater. However and due to the scarcity of water, limited utilization and the restricted accessibility to the water resources; many farmers use wastewater in agriculture at specific areas in the West Bank including Faria Catchment.

The main source of wastewater in Faria Catchment comes from the eastern part of Nablus City including the eastern Industrial zone, Balata, Askar, and Faria camps. Dilution of wastewater occurs when mixing with surface water coming from the springs of Faria Catchment.

Wastewater is being used for agriculture in many agricultural areas in Faria Catchment where the wastewater is raw and without treatment. From the results that were presented in chapter 5, it is shown that the quality of wastewater used in irrigation did not meet the international permissible limits for use in irrigation.

The use of wastewater for irrigation might have negative impacts on soil especially when used without control. The quality of water used for irrigation affects the physical and chemical characteristics of soil (Sharma et al., 2005). The most important impact on soil is the increase in salinity in the root zone, increase of organic components that can clog the soil pores, accumulation of heavy metals (Mapanda et al., 2004), and accumulation of nitrate that may reach groundwater.

The aim of this chapter is to investigate the effect of water quality used in irrigation on the following soil properties: pH, soil texture, total carbon, total nitrogen, and accumulation of lead, copper, zinc, cobalt, chromium, cadmium, nickel, and arsenic in soil profile.

Depending on water quality (freshwater, raw and diluted wastewater) used in irrigation and location accessibility (political and ownership permission) three locations were chosen for soil sampling. The soil sampling profile intervals were 0-15, 15-30, 30-50, 50-70, and 70-100 cm. Depth intervals were determined after profound discussions with Dr. Bernd Marschner of Ruhr University (Bochum, Germany).

This chapter investigates the impact of water quality used in irrigation on soil properties. The methodology used to carry out the study, description of sampling locations, sampling process, testing procedure and analysis of the results are all illustrated throughout chapter sections.

6.2 Chapter Objectives

The main objective of this chapter is to investigate the effects of using wastewater for irrigation on the soil in terms of:

1. Accumulation of heavy metals;
2. pH values at different depths;
3. Texture;

4. Total carbon and nitrogen ratios.

6.3 Chapter Methodology

The methodology used to achieve the aforementioned objectives includes the following steps:

1. Field visits to Faria Catchment were carried out in order to designate sampling locations. The following criteria were considered in site selection: (i) water quality considerations; (groundwater, raw wastewater, and diluted wastewater), (ii) irrigation method, (iii) soil type, (iv) site accessibility (ownership permission), and (v) area accessibility (not under closure or a military zone).

2. Soil sampling: this process involves the use of specific tools and following a specific protocol for soil sampling. The tools utilized herein are : (i) GPS in order to determine the coordinates of sample locations to be later used in developing a GIS shapefile for ease of visualization, (ii) Excavator: to dig the wholes, (iii) Tape measure: to specify the soil profile depth, (iv) Spade: to cut soft soil samples, (v) Metal rod: to cut hard soil samples, (vi) Plastic bags: for sample packaging, and (vii) Labels: to specify each sample name, depth and location identity.

The specific protocol followed in carrying out the soil sampling is summarized in the following:

- Determine X and Y coordinates for the sampling sites by using GPS. The coordinates of soil sample locations are summarized in

Table (16). Using GIS, the coordinates that were determined with GPS were transformed to a GIS shapefile. The map of soil sampling locations is shown in Figure (47).

Table (16): Locations of Soil Sampling sites

ID	Date	Location	X	Y	Z (m)
1	04/05/06	Azmot	179480	179632	459
2	21/05/06	Al-Aqrabanieh	186444	183874	24
3	21/05/06	Al-Aqrabanieh	186248	188514	0.0

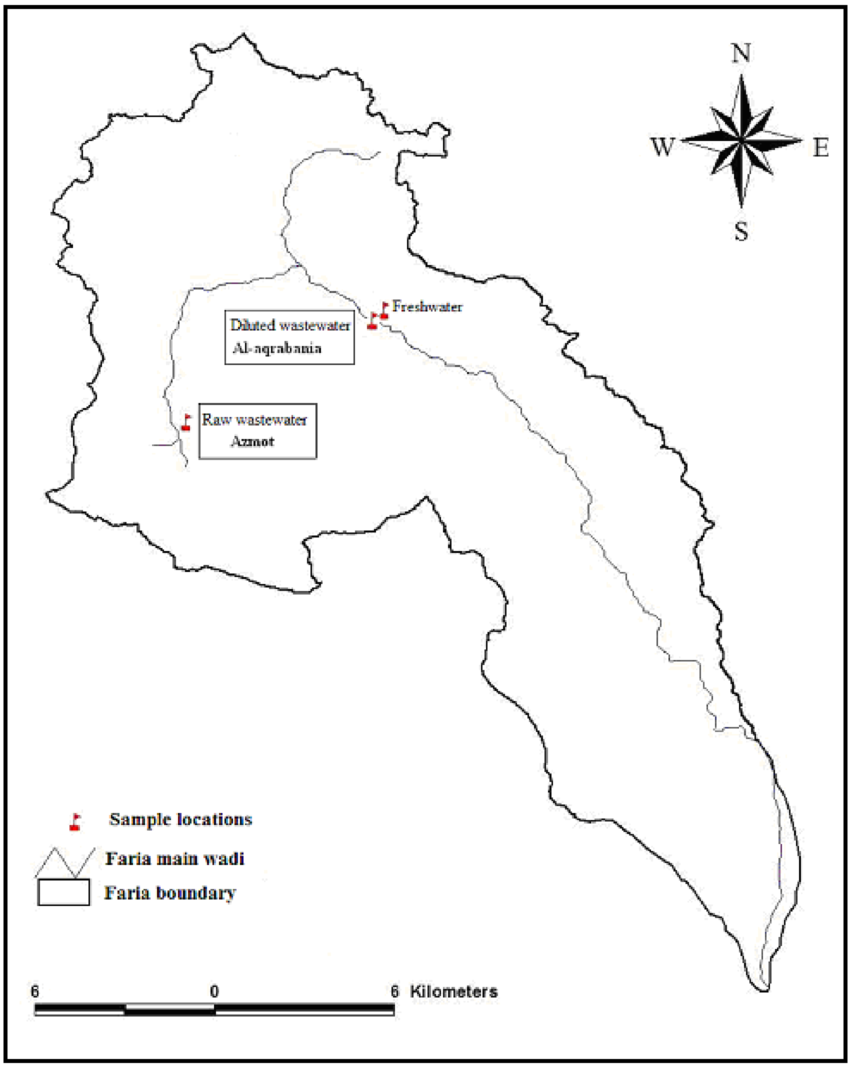

Figure (47): The Spatial Distribution of Soil Sampling Locations

- Three pits were dug in each site at different depth intervals of 0-15 cm, 15-30 cm, 30-50 cm, 50-70 cm, and 70-100 cm. A portion of soil from each interval was taken and then all samples taken from the same interval were mixed up to be representative to the location. Samples were then labeled to show the depth and location. Figure (48), Figure (49) and Figure (50) show the soil profiles in the three locations.

Figure (48): Soil Profile at the First Sample Location (ID = 1).

Figure (49): Soil Profile at the Second Sampling Location (ID = 2).

Figure (50): Soil Profile at the Third Sampling Location (ID = 3).

- Thereafter, aeration was performed on the soil samples in order to dry them out from moisture.

- A 2 mm sieve was used to sieve the soil samples. By using a scale, 500 gm of soil was taken from each sieved sample. Thereafter, the weighted up samples were packaged in plastic bags and were labeled.

3. All the packaged samples were sent to Ruhr University- Germany to carry out the specified analyses that are mentioned earlier.

6.4 Characteristics of Sampled Locations

The main characteristics that were noticed and encountered in the three soil sampling locations were summarized in Table (17). These characteristics include: soil type, agricultural method used in each location, irrigation method, water quality used in irrigation and the main agricultural products. Figure (51), Figure (52) and Figure (53) depict general view for the three sampling locations.

Table (17): The General Characteristics of the Three Soil Sampling Locations

ID	Location	General description	Soil type	Agricultural method	Irrigation method	Water quality	Main products
1	Azmot	Portion of top soil comes from cutting stone factories. The moisture increases as depth increases	Brown rendzinas	Landscaping	Flooding	Raw wastewater	Eggplants, radish and lettuce
2	Al-Aqrabanieh	This location is very close to the main street and to garage for fixing cars	Terra rossas	Mulch	Drip irrigation	Freshwater	Tomatoes and cucumbers
3	Al-Aqrabanieh	This location is very close to water table resources and diluted wastewater resource	Brown rendzinas	Landscaping	Flooding and drip irrigation	Diluted wastewater	Citrus, tomatoes and cucumbers

Figure (51): General View of the First Soil Sampling Location.

Figure (52): General View of the Second Soil Sampling Location.

Figure (53): General View of the Third Soil Sampling Location.

6.5 Testing Protocol of Soil Samples

Five samples from each location were obtained. From each sample, 500 gm was packaged in a plastic bag and labeled with its depth and location. To carry out the required tests, the packaged samples were shipped to Ruhr University- (Bochum, Germany).

Before starting the test process, all soil samples were sieved in 2 mm mesh sieve in order to clean the soil from stones and wastes. In addition, 10 gm from each sample was grinded by using soil mill to be suitable for carrying out tests of heavy metal accumulation, total carbon and total nitrogen. Thereafter, the following soil tests were carried out in the labs of natural science Department at Ruhr University- (Bochum, Germany): pH, Soil texture, Heavy metal accumulation, Total carbon and total nitrogen and microorganisms activity by using C^{14}.

6.5.1 pH

This test was performed to determine and investigate the effects of different water qualities used in irrigation on pH values in the different soil profiles. pH is rarely to be a problem by it self, but it is an indication of soil conditions such as mobility of heavy metals and availability of special ions that increase or decrease the pH value (Sposito, 1989).

The following protocol was followed to carry out this test:

- Add 25 ml $CaCl_2$ (0.01M) to a small spoon of soil in plastic bottle, and close the bottle;
- Shake the bottle for two hours by using a shaking machine;

- Calibrate the pH meter device at pH standard solutions that have the following values (2, 7, 9.3);
- Two readings for each sample were taken to assure accuracy.

6.5.2 Soil Texture

This test was carried out to determine the texture of the soil in the three locations. This is intended to investigate its suitability for using wastewater in irrigation and to see if there are any impacts of different water qualities used for irrigation on soil texture. The following protocol was followed to carry out this test:

- Weight 30 gm from the selected samples at depths of (0-15) cm and (15-30) cm from sample locations. Only these two depths were investigated for soil texture due to the limited time and fund;
- Add 20 ml of HCl (10% concentration) to the weighted soil to remove the carbonates;
- After two hours the acidity was checked. If pH was higher than 2, another 20 ml HCl was added and so on to achieve the desired acidity;
- After that when the acidity became less than 2, the washing process was started. Add 800 ml of distilled water to each sample and leave it to the next day;
- In the next day suck the water from the samples and add 800 ml of water until the pH becomes greater than 5;
- After that suck the water and put the samples in an oven at 60 °C until the samples become dry;
- Grind the soil by using mortar;

- Put the grinded soil after weighted it in special glass bottle with cover,
- Add 400 ml of water to each soil sample;
- Add the chemical compound ($Na_4P_2O_7$) to the sample and leave the samples after closing the bottles till next day;
- Take small glass cuds and put them in an oven 105 °C to dry out then weight it, for each sample;
- Put the samples in the closed bottles in the shaker for 2 hours;
- After that, use a special device to take part of the solution in the shaken bottle in different times:
  a) After 28 seconds;
  b) 4 minutes and 38 seconds;
  c) 52 minutes and 51 seconds;
  d) 3 hours and 40 minutes;
- Put samples in the oven to dry them in the small glass cups;
- All the excess quantities of solution are sieved by using sieves, with the following diameters; 2 mm, 0.063 mm, and 0.02 mm. These diameters were used to classify the soil particles into sand, silt, and clay;
- By using the soil pyramid, the texture is determined according to the percentage of sand, silt, and clay.

Figure (54) shows the device and the bottles used in the test of soil texture.

Figure (54): The Device and Bottles Used in Soil Texture Test.

6.5.3 Heavy Metal Accumulation

This test was performed to investigate the accumulation of arsenic, copper, cadmium, chromium, cobalt, nickel, molybdenum, lead and zinc in the different soil profiles. The following protocol was followed to carry out this test:

- Weight 0.5 gm of grinded soil for all depth intervals;
- Put the weighted soil in a special bottle that can withstand a pressure up to 40 bars;

- Add 10 ml of nitric acid 65% concentration to the samples in the bottle for oxidizing and digestion process to the next day;
- Close the bottles and put in the microwave in the following system; 3 minutes 140 degrees, 10 minutes 200 degrees, and finally 10 minutes 100 degrees;
- Take the bottles out of the microwave and put them in cooled water for cooling;
- After that open the bottles and add 10 ml of distilled water for dilution;
- Perform filtration using 0.45 micrometer cellulose nitrate filters;
- After that take the filtered portion to Atomic adsorption machine to measure the concentration of heavy metals.

Figure (55) shows the atomic adsorption machine.

Figure (55): The Atomic Adsorption Machine

6.5.4 Total Carbon and Total Nitrogen

This test was carried out to determine the effects of different water qualities used in irrigation on concentration of nitrogen and carbon in the soil. The following protocol was followed to carry out this test:

- Prepare five standard samples from acetyl aniline with weight (0.04 -0.069) gm, that are covered with silver sheet to calibrate the CN analyzing machine;

- Prepare two samples from each depth to assure from the results. Each sample weight must be between (0.04-0.069) gm, that are covered with silver sheet;

- After calibrating the CN analyzing machine, percentage of total carbon and total nitrogen in the soil samples were measured by burning the samples and calculating the percentage of carbon in the resulted CO_2.

6.6 Modeling of Heavy Metals in Soil

The relationship between arsenic, cadmium, cobalt, chrome, cupper, nickel, lead and zinc that were accumulated in soil with the effluents parameters that were used in irrigation that include: pH value, TDS, BOD_5, canal width and cross sectional area of the effluents canal; was built up by using nonlinear regression.

The statistical program SPSS was used to compute the coloration factors and to build up the non-linear relationship between accumulation of heavy metals in soil as dependents and effluent parameters as independents.

The first step of building these models is to compute the correlation factors between heavy metals values and the mentioned wastewater parameters. The correlation values showed that the relation between heavy metals values and effluent canal width and cross sectional area of the canal is very close to zero so they were excluded from the modeling.

The following equations represent the models that quantify the relations between the accumulation of heavy metals and the wastewater parameters used in irrigation.

$$\text{As}=\frac{0.000537\times(pH)^{4.435}\times(BOD_5)^{3.2963}}{(TDS)^{2.814}} \text{ ------------(1)}$$

$$Cd=\frac{0.0036\times(pH)^{5.0119}}{(TDS)^{0.1596}\times(BOD_5)^{2.62\times10^2}}\text{------------(2)}$$

$$Co=\frac{0.0009\times(pH)^{5.651}}{(TDS)^{0.0405}\times(BOD_5)^{9.19\times10^2}}\text{------------(3)}$$

$$Cr=\frac{0.00172\times(pH)^{4.4819}}{(TDS)^{8.112\times10^2}\times(BOD_5)^{2.677\times10^1}}\text{------------(4)}$$

$$Cu=\frac{0.00076\times(pH)^{5.056}}{(TDS)^{9.98\times10^3}\times(BOD_5)^{4.3\times10^2}}\text{------------(5)}$$

$$Ni=\frac{0.0003\times(pH)^{5.973}}{(TDS)^{0.0828}\times(BOD_5)^{8.3\times10^2}}\text{------------(6)}$$

$$Pb=\frac{0.00065\times(pH)^{1.0544}}{(TDS)^{9.203\times10^1}\times(BOD_5)^{3.059\times10^1}}\text{------------(7)}$$

$$Zn=\frac{0.0183\times(pH)^{2.637}}{(TDS)^{8.1\times10^2}(BOD_5)^{1.664\times10^1}}\text{------------(8)}$$

pH value effect

All models show that pH value is the most influential parameter, as the value of pH increases the accumulation of heavy metals in soil profile increases. This result supports the fact that heavy metals precipitate and has low mobility as pH move from acidic media to basic media (wild, 1996).

DOD_5 effect

In general, the relation between BOD_5 and accumulation of heavy metals is a reverse relation, as the BOD_5 value increases the heavy metal accumulation decreases. Wild (1996) found that microorganisms consume part of heavy metals and accumulate it in their cells, also heavy metals form complex compounds with organic matters and the adsorption rate increases with pH greater than 7.

Arsenic is a special case since its availability depends on external sources and not from the nature.

TDS effect

The models show that as TDS value increases the heavy metal accumulation decreases. This is related to the competition between dissolved ions and heavy metals on reactions and adsorption. Only for Pb, the effect of TDS is similar to the effect of pH.

6.7 Results and Analysis

After carrying out all the tests at Ruhr University labs, analysis results were presented and analyzed. pH, soil texture and heavy metal tests were carried out for the three locations. However, Ct and Nt tests were carried out for the locations ID = 1 and ID = 2 only due to lab capacity and time and fund limitations.

6.7.1 pH

Figure (56) shows the results of pH where the values range between 7.61 and 7.88. These results were expected since all the sampling locations are classified as Terra rossas and brown rendzinas soils. These soil classes generally have pH values between 7.5 and 8.1 since they are originally formed from limestone (PWA, 2004).

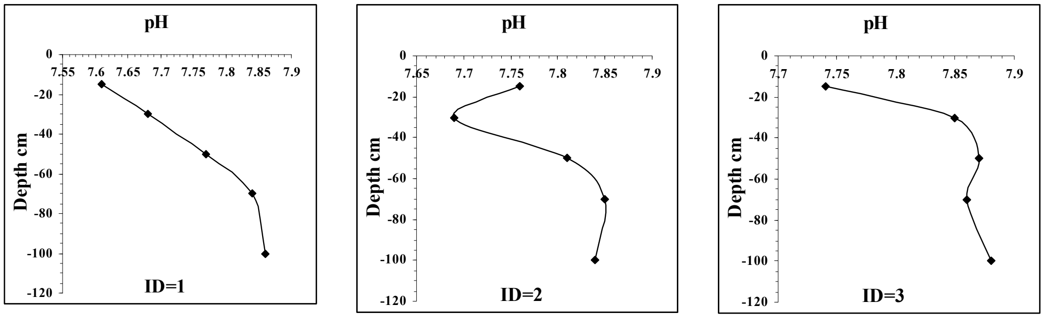

Figure (56): pH Values for Soil Profiles at the Three Locations.

pH values generally in all soil profiles increases as depth increase because we become closer to the original limestone rocks. Also, the top soils might be affected by the quality of the applied water for irrigation. The average pH values of the used water at locations ID = 1 is 7.7; ID = 2 is 7.43; and ID = 3 is 7.8.

There are no significant changes between pH values at all locations since the original rocks of these locations are the same and the pH values of water used in irrigation are very close to each other.

6.7.2 Soil Texture

Table (18) summarizes the results for the soil texture test. This test was made only for the depth intervals of (0 – 15) cm and (15 – 30) cm. The test for the first location took longer time since it contains high quantities of bicarbonate coming from the wastewater used for irrigation. Bicarbonate must be destroyed first with acid. From the results, it is clear that the quality of water used in irrigation affects soil texture especially the top layer. The sand particles that appeared in the first site in the texture came from sedimentation of raw wastewater such as wastewater discharged from quarries, tiles and concrete block factories. All the other locations have in general a clay texture.

Table (18): Texture of the Soil Profiles at the Three Locations

Site ID	Depth (cm)	Sand %	Silt %	Clay %	Classification
1	0-15	49.48	26.79	23.73	Sandy clay loam
1	15-30	11.59	54.44	33.98	Silty clay loam
2	0-15	7.15	46.84	46.01	Silty clay
2	15-30	10.53	34.16	55.31	Clay
3	0-15	9.13	34.98	55.88	Clay
3	15-30	21.93	36.02	42.05	Clay

The texture is a very important indicator to infiltration capacity and the ability of heavy metals to percolate towards groundwater. The texture of soil (sandy, silty, clayey) controls the rate of infiltration. For example, a sandy surface soil normally has a higher infiltration rate than a clayey soil (USDA Natural Resources Conservation Service, 1998). However; the use of wastewater in irrigation can add nitrogen and carbon to the top soil which can be readily used by plants as nutrients.

6.7.3 Heavy Metal Accumulation

This test was performed for the depth intervals (0 – 15) cm, (15 – 30) cm, (30 – 50) cm and (70 – 100) cm. Results of analysis for arsenic, copper, chromium, lead, zinc, cobalt, cadmium and nickel are summarized in the following subsections.

6.7.3.1 Arsenic

The concentrations of arsenic in all soil profiles are presented in Figure (57). Arsenic was detected at locations which are irrigated with raw wastewater and in the location that is irrigated with diluted wastewater. The main source of arsenic in the wastewater of the study area comes from the industrial sources. The main industrial source of arsenic is the tannery factory in the eastern industrial zone of Nablus City.

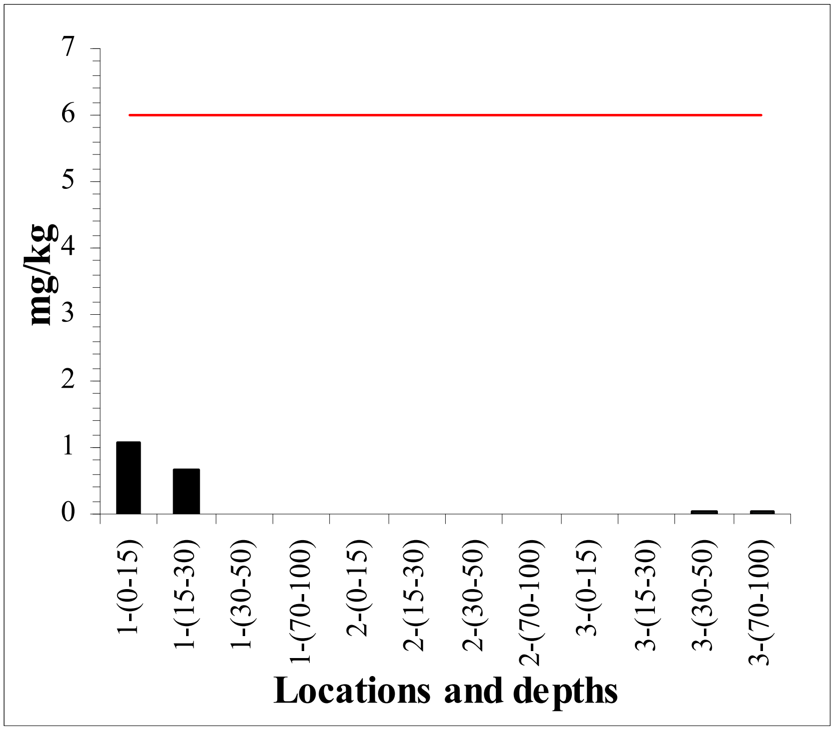

Figure (57): Arsenic Concentration in the Different Soil Profiles.

It is apparent that as depth increases arsenic concentration decreases. This is due to the fact that arsenic precipitates and has low mobility at pH greater than 7. The detected arsenic quantities in soil is not harmful to human or plants, since it is less than the typical concentration of 6 ppm that is shown in Table (3). However, it is an indicator to the fact that the use of raw wastewater for irrigation without any type of treatment can result in accumulation of hazardous heavy metals in soil.

6.7.3.2 Copper

Figure (58) depicts the concentration of copper. Cu was detected at all locations and in all depths. This indicates that Cu is found naturally in the

Faria soils. The concentration of Cu at the location irrigated with raw wastewater is higher than the other two locations. This might be attributed to the discharged quantities of wastewater from domestic and industrial sources. The main source of Cu is the domestic wastewater (Sorme and LagerKvist, 2002).

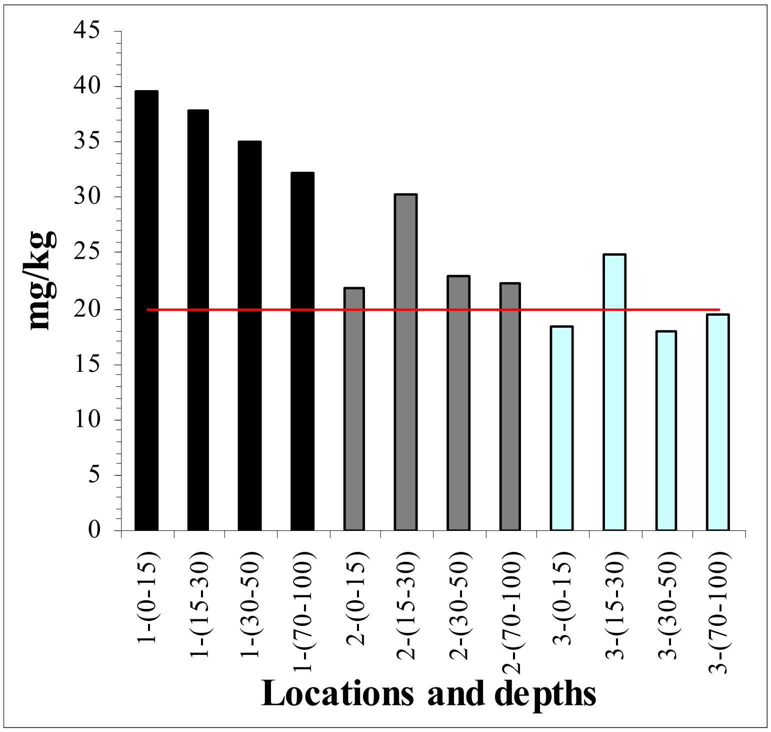

Figure (58): Copper Concentration in the Different Soil Profiles.

The concentration of Cu decreases as depth increases. This can be attributed to the fact that Cu is strongly adsorbed by organic matter (Wild, 1996) and that Cu precipitates when pH is greater than 7. The variability in the concentrations of Cu in the other locations is almost negligible since Cu is naturally available.

The detected Cu concentration at the location irrigated with raw wastewater is harmful to plants, since it is higher than (T) = 20 ppm as is shown in Table (3). However, it is an indicator to the fact that the use of raw wastewater in irrigation without any type of treatment can result in accumulation of hazardous heavy metals in soil. Special attention must be given to Cu because it is the most toxic heavy metal after mercury.

As shown in chapter five, in all raw wastewater samples, the concentration of Cu can not be detected since it is very low, so the concentration of Cu in diluted wastewater will be less and has no significant effect on the accumulation of Cu in soil. However, the concentration in soils irrigated with freshwater is higher than the location irrigated with diluted wastewater.

6.7.3.3 Chromium

Figure (59) depicts the concentration of Chromium in soil profiles at the different locations. Cr was detected at all locations. This indicates that Cr is found naturally in the Faria soils. The concentration of Cr in the location irrigated with raw wastewater is higher than at the other locations.

The concentration of Cr decreases as depth increases. This can be attributed to the fact that Cr is strongly adsorbed by organic matter and that Cr precipitates when pH is greater than 7.

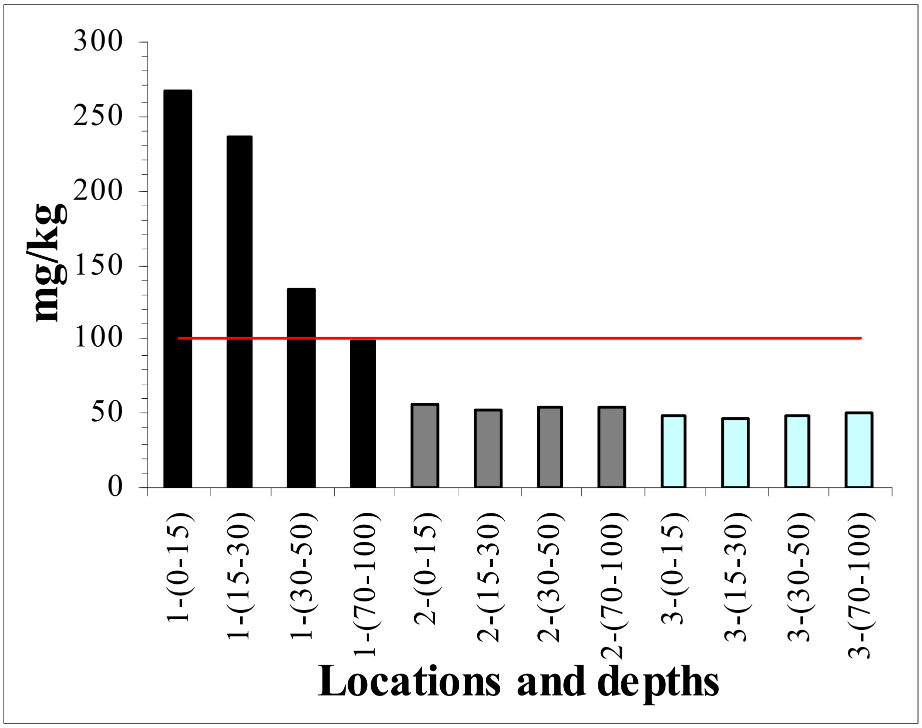

Figure (59): Chromium Concentration in the Different Soil Profiles.

The concentrations of Cr at the locations irrigated with fresh water and diluted wastewater are almost the same since there are no external sources for adding Cr to the irrigated locations. However, the concentration of Cr in soils irrigated with freshwater is higher than the location irrigated with diluted wastewater.

The detected Cr concentration at the location that is irrigated with raw wastewater is harmful to plants since it is higher than (T) = 100 ppm.

Special attention must be given to Cr since it is a toxic heavy metal and is not required for plant growth (Pettygrove and Asano, 1984).

6.7.3.4 Lead

Figure (60) depicts the concentration of Lead in soil profiles at the different locations. Pb was detected at all locations. This indicates that Pb is found naturally in the Faria soils. The concentration of Pb in the location irrigated with raw wastewater is higher than the other locations.

The concentration of Pb decreases as depth increases since lead is of low mobility in the soil. This low mobility is due to the adsorption to the surfaces of iron, manganese oxides and clay aluminosilicates (wild, 1996). Lead also reacts with organic matter to form complex compounds with low solubility. Pb precipitates in neutral and alkaline conditions as Pb $(OH)_2$ $PbCO_3$ and lead sulphate. Lead also can be up taken by plants (Wild, 1996).

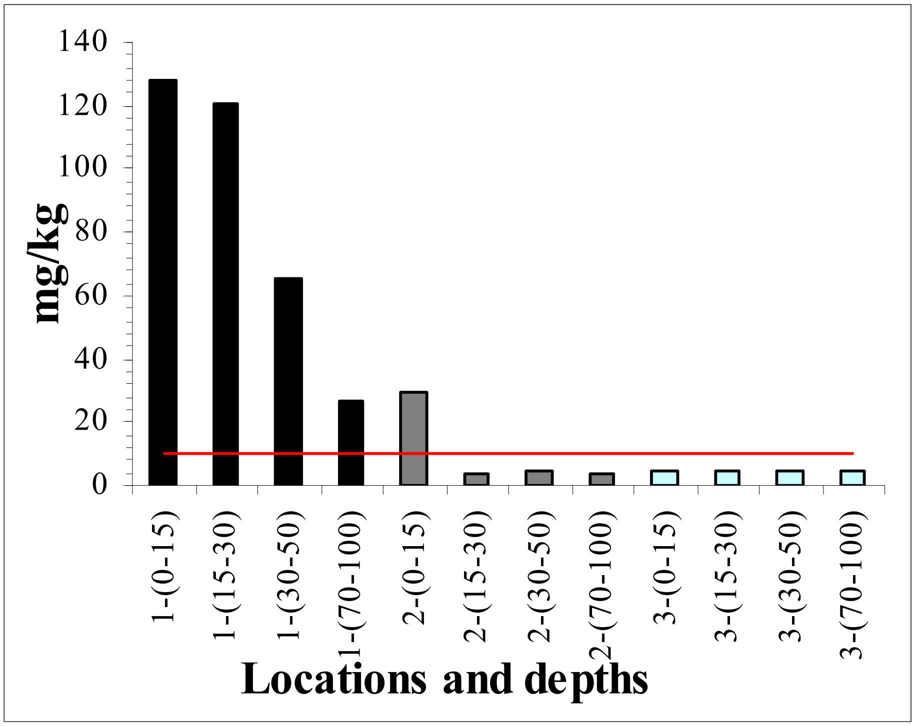

Figure (60): Lead Concentration in the Different Soil Profiles.

The concentration of Pb in the top soil of the location that is irrigated with freshwater is high. There are external source of Pb from composition of vehicles fuel. This location is 10 m away from the main road and 30 m away from a garage for fixing cars.

The concentration of Pb at the location irrigated with diluted wastewater is almost steady. The detected Pb concentration at the location irrigated with raw wastewater is harmful to plants, since it is higher than (T) = 10 ppm. Special attention must be given to Pb because it is a toxic heavy metal and is not required for plant growth (Pettygrove and Asano, 1984).

6.7.3.5 Zinc

Figure (61) depicts the concentration of Zinc in soil profiles at the three locations. Zn was detected at all locations. This indicates that Zn is found naturally in the Faria soils. The concentration of Zn at the location irrigated with raw wastewater is higher than the other two locations.

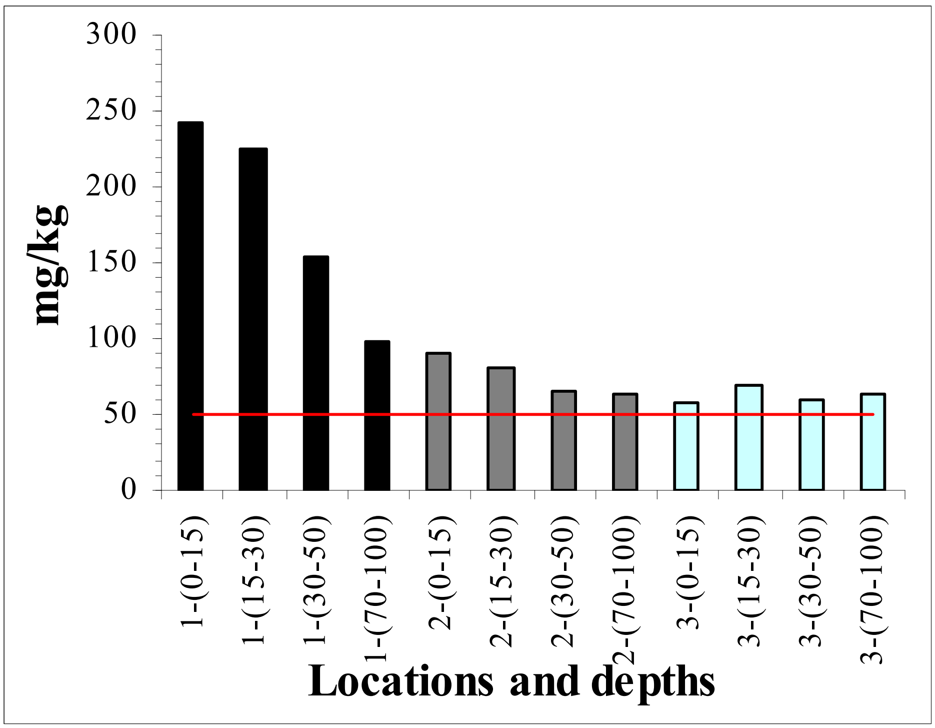

Figure (61): Zinc Concentration in the Different Soil Profiles**.**

The concentration of Zn decreases as depth increases because Zn is strongly adsorbed as $Zn(OH)^{+}$ onto iron, manganese oxides and clay aluminosilcates, Zn form complex compounds with soil organic matter and the adsorption rate increases with pH greater than 7 (Wild, 1996).

As shown in chapter five, Zn was detected in 62% of the tested raw wastewater samples but it was very low, so the concentration of Zn in the diluted wastewater is expected to be negligible.

The concentration of Zn in the soil at the location that is irrigated with freshwater is higher than the location that is irrigated with diluted wastewater. The detected Zn concentration at the location irrigated with raw wastewater in harmful to plants since it is higher than (T) =200 ppm (Pettygrove and Asano, 1984).

6.7.3.6 Cobalt

Figure (62) depicts the concentration of Co in the soil profiles at the three locations. The Co concentrations at all locations were above the T = 8 ppm. Co was detected at all locations, which indicates that Co is found naturally in the Faria soils. The concentration of Co in the location irrigated with raw wastewater is higher than that at the other locations.

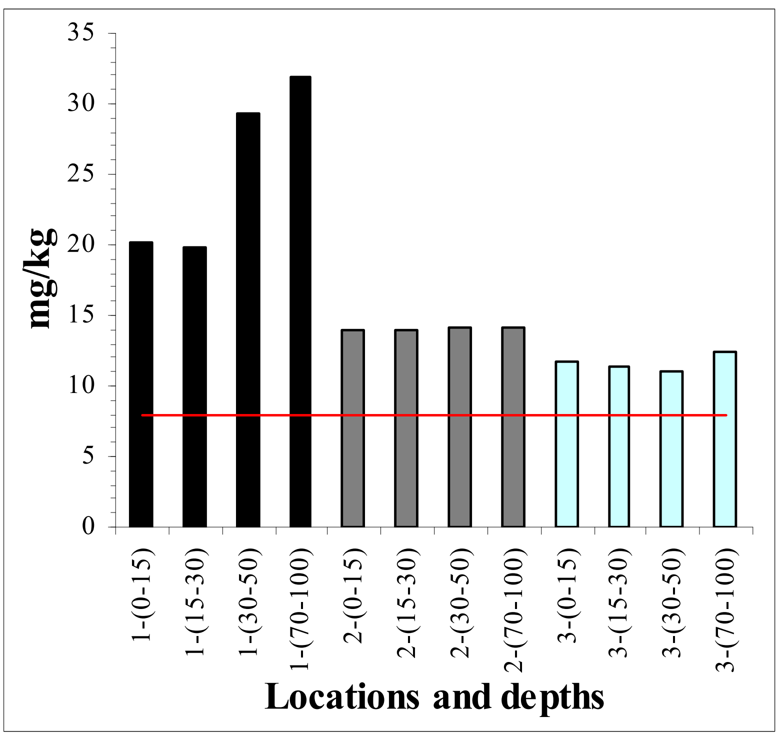

Figure (62): Cobalt Concentration in the Different Soil Profiles.

In the location irrigated with raw wastewater, the concentration of Co increases as depth increases depending on the pH value of irrigation water, solubility and adsorption of Co. however; in the other location, Co is almost constant since Co in these locations is part of soil structure and not from external sources.

6.7.3.7 Cadmium

Figure (63) shows the concentration of Cd in soil profiles at the three locations. The measured concentration of Cd in soil is within the range that can be found in soil 0.01 mg/kg - 7 mg/kg. Cd was detected at all locations, which indicates that Cd is found naturally in the Faria soils. The concentration of Cd in the location irrigated with raw wastewater is higher than that at the other two locations.

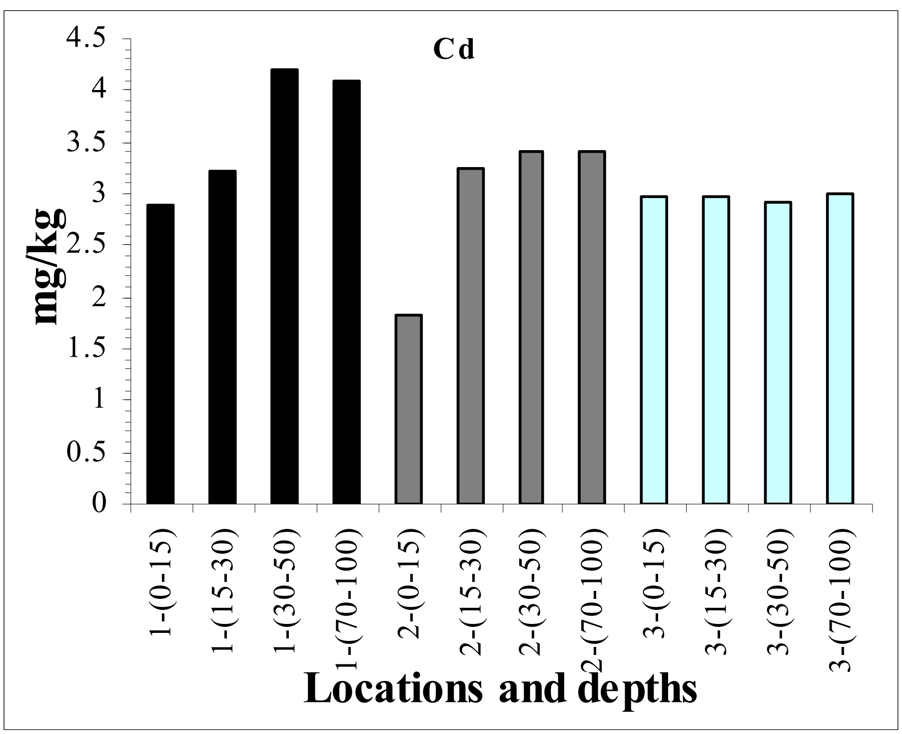

Figure (63): Cadmium Concentration in the Different Soil Profiles.

In the first and the second locations, the concentration of Cd increases as depth increases. This is due to the availability of organic matter in the top soil that adsorbs Cd. In addition, Cd is adsorbed into clay minerals including iron, aluminum and manganese oxides. This adsorption increases with pH (Wild, 1996). Also Cd is strongly adsorbed into calcium carbonate (Wild, 1996). In the third location, Cd is almost constant in soil profiles since Cd in this location is part of soil structure and not from external resources.

Cadmium is very toxic and its harmfulness comes from its ability to accumulate in human body, if it enters through contaminated water or food chain. Cadmium needs 10 to 30 years to be excreted from human body (Dojlido and Best, 1993).

6.7.3.8 Nickel

Figure (64) depicts the concentration of Ni in soil profiles. Ni was detected at all locations, which indicates that Ni is found naturally in the Faria soils. The concentration of Ni in the location irrigated with raw wastewater is higher than the other two locations and higher than T = 40.

The main sources of nickel in the location irrigated with wastewater are industrial sources that include: crude oils and petroleum products and households such as disposal batteries. Ni concentration at the locations that are irrigated with raw and diluted wastewater increases as depth increases since Ni is adsorbed into clay minerals including iron, aluminum and manganese oxides. This adsorption increases with pH value and Ni is strongly adsorbed into calcium carbonate (Wild, 1996). At the location that is irrigated with freshwater, Ni concentration is almost constant in the soil profile.

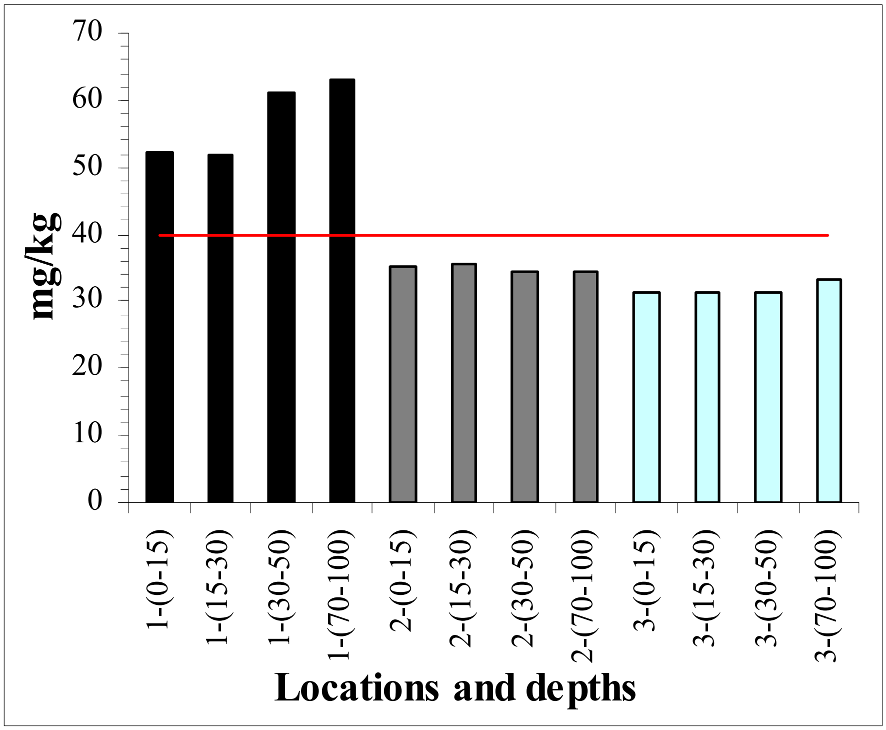

Figure (64): Nickel Concentration in the Different Soil Profiles.

6.7.4 Total Carbon (Ct) and Total Nitrogen (Nt)

Ct and Nt were detected in soil profiles, which indicate that C and N are parts of soil composition. The values of Ct and Nt are summarized in Table (19).

The results of Nt and Ct are presented in Figure (65) and Figure (66) respectively. The values of Nt and Ct were higher at location irrigated with raw wastewater due to the following reasons: (i) the area has been irrigated with raw wastewater with an average BOD_5 of 600 mg/l which indicates that there are high quantities of organic and inorganic materials; (ii) the average turbidity of reused raw wastewater is 45 Ntu which means that large quantities of organic and inorganic materials will precipitate on the top soil layer; (iii) the average nitrate concentration in wastewater being used in irrigation is 89 ppm which adds high quantities of nitrogen to the soil.

Table (19): Total Carbon and Total Nitrogen in the Different Soil Profiles

Site ID	Name of Sample	Nt %	Ct %	Ct/Nt ratio
1	1, (0-15)	0.35	6.965	19.9
	1, (15-30)	0.275	5.745	20.9
	1, (30-50)	0.215	2.835	13.2
	1, (50-70)	0.15	1.86	12.4
	1, (70-100)	0.145	2.31	15.9
2	2, (0-15)	0.165	3.78	22.9
	2, (15-30)	0.13	2.895	22.3
	2, (30-50)	0,105	2.37	22.6
	2, (50-70)	0,09	2.67	29,7
	2, (70-100)	0,095	2.815	29.6

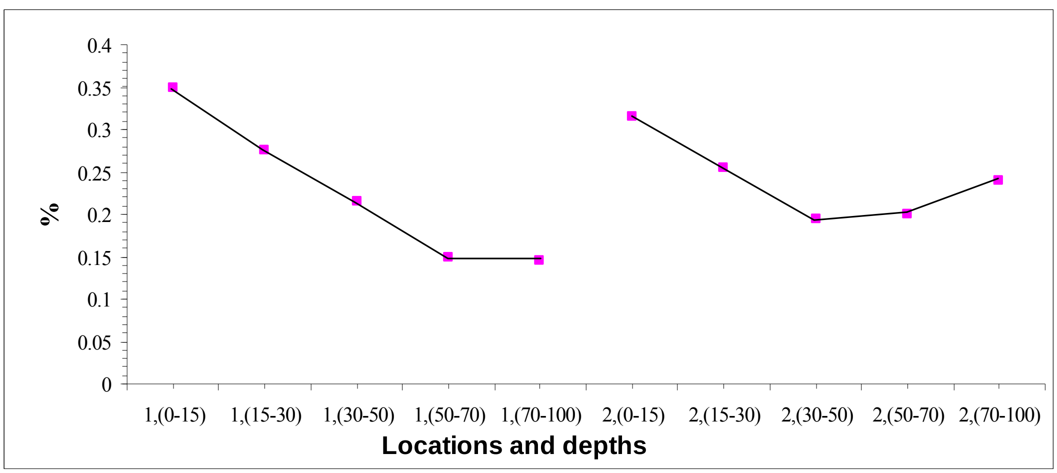

Figure (65): Total Nitrogen Percentage in the Different Soil Profiles.

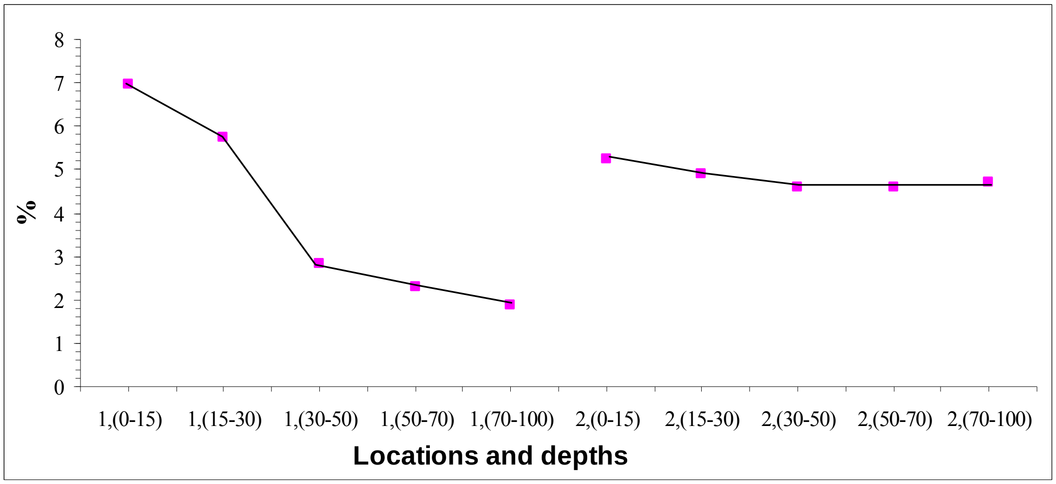

Figure (66): Total Carbon Percentage in the Different Soil Profiles.

The values of Nt and Ct are decrease as depth increases. This can be attributed to the following:

1) The arid and semi arid regions are poor of carbon and nitrogen (Hagin and Tucker, 1982);

2) The clay soil originally is poor of carbon and nitrogen;

3) The excess quantities of nitrogen and carbon in the top soil are from external sources such as raw wastewater at location ID = 1 and from dung in location ID = 2;

4) Nitrogen can also be added to the soil from atmosphere;

5) Carbon and nitrogen react with heavy metals in the top soil and form stable compounds.

A special test was carried out by using radio active C^{14} depending on micro organism respiration. It was found that the organic carbon detected in the location that was irrigated with raw wastewater is in a form that can be easily used by plants and micro organisms.

The ratios of Ct to Nt that are shown in Table (19) are just only used as indicators of suitability of soil for agriculture. From the agricultural standards, if the ratio is greater than 15% then the soil is suitable.

CHAOTER SEVEN: Conclusions and Recommendations

7.1 Conclusion

The following are the research main conclusions:

1. The analysis of wastewater constituents shows that the concentrations vary spatially. The highest concentrations were encountered at the main outlet of the sewage system of Nablus City. With increasing the distance from the outlet, the concentrations of constituents decrease;

2. There is a temporal variability in the concentration of the wastewater constituents. The low concentrations were encountered in winter while the high concentrations were in summer;

3. There were extreme concentration values of wastewater constituents found in some measured samples due to the doses of wastewater from industrial activities such as textile and chemical industries;

4. The soil tests showed that the quality of water used in irrigation affects the soil texture through increasing the concentrations of some constituents such as bicarbonate, adding sand particles to the soil;

5. The use of raw wastewater in irrigation results in accumulation of heavy metals in soil profile. The most hazardous accumulated heavy metals were arsenic, lead and cadmium; and

6. The use of raw wastewater in irrigation increases the nitrogen and carbon contents in soil profiles.

7.2 Recommendations

Based on the outcome of this thesis, the following can be recommended:

1. In-site treatment of industrial wastewater should be considered since the industrial activities in the eastern part of Nablus City are responsiple for the existence of heavy metals in wastewater in general.

2. To legalize the reuse of wastewater in agricultural irrigation, a wastewater treatment plant should be constructed at the eastern part of the City;

3. Enforcement of laws that regulate the reuse of treated wastewater should be prompted and the prohibition of the use of untreated wastewater in irrigation should be priotized;

4. Additional studies are needed to model and simulate the fate and transport of heavy metals in the soil under different scenarios and boundary conditions; and

5. Public education regarding the hazards of reusing raw wastewater in irrigation should be emphasized on.

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جامعة النجاح الوطنية

كلية الدراسات العليا

خصائص المياه العادمة وتأثيرات استخدامها للري على خصائص التربة- منطقة الدراسة الفارعة

إعداد

محمد صبحي محمد أبو بكر

إشراف

د. محمد نهاد المصري

قدمت هذه الأطروحة استكمالا لمتطلبات نيل درجة الماجستير في هندسة المياه والبيئة بكلية الدراسات العليا في جامعة النجاح الوطنية في نابلس، فلسطين.

2007

خصائص المياه العادمة وتأثيرات استخدامها للري على خصائص التربة- منطقة الدراسة الفارعة

إعداد
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الملخص

يعتبر استخدام المياه العادمة للري نمط شائع في عدة دول في العالم، وفلسطين إحدى هذه الدول. ويعود سبب استخدام المياه العادمة للزراعة في فلسطين للأسباب التالية: (أ) نقص مصادر المياه العذبة التي يمكن أن تغطي الحاجات المنزلية والزراعية، (ب) التحكم الإسرائيلي بمصادر المياه المتوفرة، (ج) إمكانية استخدام المياه العادمة للري بدون ثمن، (د) غياب وضعف تنفيذ القوانين والتشريعات التي تحدد وتنظم عملية استخدام المياه العادمة لأغراض الزراعة. تعتبر منطقة الفارعة مثال حي لاستخدام المياه العادمة في فلسطين.

الهدف الأول من هذا البحث هو تحديد وقياس تركيز العناصر الموجودة بالمياه العادمة المستخدمة في الري والتي تشمل: درجة الحموضة، التوصيل الكهربائي، الكلورايد، النايترات، الفوسفات الكلي، أيونات المنغنيسيوم، أيونات الكالسيوم، عسر المياه، البايكربونات، أيونات الزنك، أيونات البوتاسيوم، أيونات الصوديوم ونسبة امتصاص الصوديوم وعكورة المياه. لمقارنة تركيز هذه العناصر مع المواصفات العالمية لاستخدام المياه العادمة للري . الهدف الثاني تحديد تأثير استخدام المياه العادمة علي خواص التربة التالية: حموضة التربة، تركيبة التربة، تراكم العناصر الثقيلة وحركتها بالتربة، و تركيز الكربون والنيتروجين الكلي بالتربة.

أظهرت نتائج هذا البحث أن تركيز عناصر المياه العادمة المستخدمة للري متغيره مكانيا و زمانا. و يمكن التعميم أن قيم هذه العناصر أعلى من الحدود المسموح بها لري المزروعات. تعمل كميات المياه العادمة القادمة من المنشآت الصناعية على رفع تركيز بعض العناصر بصورة ملحوظة مثل نسبة امتصاص الصوديوم، التوصيل الكهربائي والكلورايد. استخدام هذه المياه العادمة للري اظهر تأثير واضح على تركيبة سطح التربة، وعلى تراكم العناصر الثقيلة بالتربة، وكذلك على نسبة الكربون والنيتروجين الكلي بالتربة.