BIRZEIT UNIVERSITY

Institute of Environmental and Water Studies

A case study of urban wastewater balancing to study wastewater pollution loads and groundwater pollution in the city of Nablus-East (Palestine)

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A case study of urban wastewater balancing to study wastewater pollution loads and groundwater pollution in the city of Nablus-East (Palestine)

موازنة مياه الصرف الصحي في المناطق الحضرية لدراسة مقدار التلوث من
الصرف الصحي وتلوث المياه الجوفية في شرق نابلس

By

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The findings, interoperations and conclusions expressed in this study do not necessary express the view of Birzeit University, the view of individual member of the MSc-committee or the view of their respective employers.

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ABSTRACT

Analyzing the urban water cycle is crucial for adequate urban water management and pollution control of the natural water cycle. Nowadays, increasing concerns are raised about the contribution of untreated sewage to groundwater recharge and pollution, especially in under developed countries with poor infrastructure. In the West Bank of Palestine only 30% of the population is served with sewerage networks, mainly in the urban areas, while only 6% is served with wastewater treatment plants. This has resulted in blaming sewage for increasing nitrate concentrations in groundwater. Literature search clearly revealed that knowledge about exfiltration from sewer network is very limited; but the few available studies indicate that exfiltration pollution loads pose un-counted serious threat to groundwater. The research was carried out on Nablus-East with a population of 94,910 inhabitants as a case study to assess the pollution load of wastewater exfiltration from the sewers network and outlets.

The study area is divided into seven catchment areas based on topography. The investigations were carried out mainly on two catchments; a sub-main catchment, which is a small neighborhood, and a main catchment that represents 86% of Nablus-East. The wastewater produced from the sub-main catchment was quantified at the sewer outlet. The sub-main catchment was small enough to allow measuring rather accurately the amount of consumed water and turned over wastewater to be further generalized on the large catchment area, assuming that exfiltration from the small catchment is negligible since the sewer network is very new and of small length. For the main catchment, the wastewater flow was

measured at the outlet for four days, and the water consumed was obtained from the water meters records of Nablus Municipality. The water consumption records were provided by the municipality as ArcMap software shapefiles for the seven catchments. Wastewater samples were collected from the main and sub-main catchments' outlets. Water and nitrogen mass balances were carried out on the both main and sub-main catchment areas.

The water mass balance revealed that 82.2% of the consumed water ends up in the sewer network, while 17.8% is used outdoor. The exfiltration wastewater from the sewer network represent12.8% of the consumed water, while 65.2% drains to wadi Al-Sajor through the outlets, and 4.2% ends up in cesspits. As an exfiltration rate, the daily exfiltration per kilometer is 0.02 m^3/day for the average of 25cm diameter.

The specific pollution loads exfiltrated from the sewered part of Nablus-East were 2.4(g N/c.d), 0.25 (g TP/c.d), 23.5(g CODt/c.d) and 13 (g BOD/c.d). The total nitrogen load of the produced wastewater from Nablus-East is 1.88 (kg N/ha*day), out of which 1.49 (kg N/ha*day) reaches the outlets as a major point source pollution. The remaining 0.39 (kg N/ha*day) routes into exfiltration from sewer network of 0.29 (kg N/ha*day) and in cesspits is 0.10 (kg N/ha*day). The calculated annual urban nitrogen loading of Nablus-East wastewater is 688 (kg N/ha*yr), which is very high as compared with figures reported in literature for urban areas in Europe and Africa, due to high population density in Nablus East.

Therefore, in order to abate the pollution loads fluxes from Nablus East municipal wastewater, a treatment plant should be constructed as a first priority. Companying efforts should also be given to sewers network upgrade and rehabilitation to protect groundwater quality.

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LIST OF ABBREVIATIONS

°C	Degree Celsius
As	Arsenic
BOD_5	Biochemical Oxidation Demand at 5 days
Ca	Calcium
Cd	Cadmium
cm	Centimeter
Co	Cobalt
COD	Chemical Oxygen Demand
Cr	Chromium
Cu	Copper
DO	Dissolved Oxygen
GIS	Geographical Information System
gm	Gram
kg	Kilogram
km	Kilometer
m^3	Cubic Meters
mg/L	Milligram per Liter
mm	Millimeter
Ni	Nickel
Pb	Lead
PCBS	Palestinian Central Bureau of Statistics
ppm	Part per Million
PWA	Palestinian Water Authority
TN	Total Nitrogen
TP	Total Phosphate
UNRWA	United Nations Relief and Works Agency
WWTP	Wastewater Treatment Plant
WHO	World Health Organization
Zn	Zinc

Chapter One: Introduction

1.1 Background

The West Bank is a meeting point of many escalating environmental threats. Long-term environmental degradation has occurred over recent decades. Over 94% of sewage is discharged untreated to the environments. This has contributed to increasing nitrate concentrations in groundwater, which is the critical water source (Borst *et al*., 2012).

Untreated sewage can contribute a significant proportion to urban groundwater recharge, via on-site sanitation facilities and sewer exfiltration. Urban areas with sewer networks, can contribute to groundwater pollution due to wastewater that leaks from the sewer network (exfiltration). This is due to old sewer network, poor workmanship, and wastewater travel time to the outlets. The exfiltration is a source of pollution to groundwater and may contribute as a non-point source of pollution (Rutsch *et al*., 2006; Rueedi *et al*., 2009).

Municipal wastewater presents a significant threat to groundwater and surface waters of the West Bank as most wastewater is disposed to cesspits or through sewer network with minimal or no treatment into the environment. Groundwater samples have revealed disturbingly high level of contaminants in some areas of the West Bank. Particularly nitrogen, which has been shown to have an increasing trend over time (Anaya *et al*., 2009).

Nitrate has been identified as major groundwater quality parameter in West Bank. The contribution of non-agricultural source is becoming an essential. However, there is less information available on urban loads of nitrogen due to exfiltration, and the objective of this research is to identify the urban pollution due to exfiltration (Anaya *et al*., 2009).

The annual quantity of wastewater that flows from Nablus-East towards Fara’a Catchment is around 2.5 million cubic meters (mcm) from domestic sources (PWA, 2010). Fara’a Catchment in the eastern part of Nablus City stands as an example for the untreated urban wastewater that recharges to the environment, and can be a representative base model.

Nablus-East is divided into seven catchment areas according to the topography. The research approach focused on two representative catchment areas. The main catchment, which covers 74% of Nablus-East with 428 hectare area, and a sub-main catchment, which is a small manageable area with 6.3 hectare area. Wastewater flow measurements and sampling were taken for both catchments.

The research is part of post doc research that aims to describe, evaluate, and quantify contaminants from wastewater and runoff in Wadi Fara’a catchment of the West Bank in order to better understand groundwater contamination processes. The purpose of this MSc. study is to generate data to provide an overview of the wastewater situation in Nablus East. Specifically it is to create water, wastewater and nitrogen mass balance for Nablus East.

1.2 Objectives

The main objective of this thesis is to quantify the wastewater that leaks from the sewer network before it drains through the outlets to the wadi Al-Sajor and to identify the urban pollution due to exfiltration in Nablus-East.

The specific objectives are to:

- quantify the wastewater exfiltrated from the sewer system to the in order to determine the pollution load; and
- characterize the effluent wastewater that drains to wadi Al-Sajor from the main and sub-main catchments.
- quantify the fraction of consumed water that ends up in the sewer system within the main and sub-main catchments;

1.3 Research Question

The goal of this research is to study and to answer the following questions conveniently:

- What is the percent of wastewater that exfiltrates from the sewer network?
- How water, wastewater, and wastewater characteristics are fractionated in an urban environment served with a sewer network?
- What is the specific water consumption? How much is the wastewater production?

1.4 Research Motivation

The following are the research motivations:

- Groundwater is the primary source of water for the Palestinians; thus a reliable quantification of recharge is vital (Abed and Wishahi, 1999); and

- Groundwater nitrate levels in the West Bank frequently exceed safe concentrations and have an increasing trend over time (Anayah and Almasri, 2009).

1.5 Significance

This research will demonstrate the fate of water, wastewater, and estimate wastewater characteristics within an urban environment. It is also to quantify the recharge process and its impact on groundwater qualitative aspects. The results will provide a basis for quantifying and characterizing water and contaminant transport within an urban environment. The methodology and the result provide very valuable tool for sustainable management of Palestinian water and environment. It lays the basis for similar urban areas as a model and factors.

1.6 Beneficiaries

The main expected beneficiaries from this research are:

- **Nablus Municipality:** to provide information for the design of the proposed wastewater treatment plant to serve the eastern portion of Nablus City;
- **Palestinian Water Authority**: to find out the potential use of wastewater and its suitability as a non-conventional water resource;
- **Farmers:** Will be aware regarding the potential impacts of using untreated wastewater; and
- **Academic and research sector**: This work deemed to be the first carried out in the West Bank. It will stimulate the interest to carry out similar works at different locations.

1.7 Obstacles and Problems

There have been several obstacles that did effect the research and thesis preparation. Most of these obstacles and problems are related to the field work and data collection. Below summaries the main of these:

- It took a long time and effort to find a good and accurate device for sewage quantifying. Unfortunately, we did not find such device either in Birzeit University or any other Institution;
- The outlets are located in an un populated area with no infrastructure and full of wild animals. It is located in an impassable and step area.

1.8 Structure of the thesis

This thesis is comprised of five chapters including this introduction. Chapter two presents a comprehensive literature review about methods, techniques and previous studies. Chapter three provides a description of the study area, the research methodology used to carry out the study. Chapter four presents discuss the results. Research conclusions and recommendations are summarized in chapter five.

Chapter Two: Literature Review

2.1 Introduction

Literature Review involves the reviewing of past research results, method and other published data related to sampling, mass balance modeling, characterizing of wastewater. This, on the other hand, helps in checking latest experiences in this field and elaborates on the methodologies adopted in such situations.

Sewered areas can also contribute to groundwater pollution, via sewer exfiltration and untreated end-of-pipe dumping. Sewer exfiltration remains poorly understood and characterized (Rutsch *et al.*, 2006, Rueedi *et al.*, 2009). However, it is gaining recognition as a source of pollution to groundwater (Wakida and Lerner, 2005). A number of different case studies have estimated that up to 10% of the wastewater flow leaks to groundwater via exfiltration, potentially contributing 30–40% of total annual groundwater recharge or more in arid areas where natural recharge is low (Lerner 2002, Ellis *et al.*, 2004, Rueedi *et al.*, 2009).

However, there is scarce research to evaluate or model the fate of contaminant loads from wastewaters, despite the fact that several studies have suggested human sewage to be the primary origin of nitrogen in groundwater (Anaya *et al.*, 2009; Khayat *et al.*, 2006). Areas and communities with sewer network can also contribute to groundwater pollution, via sewer exfiltration and untreated end-of-pipe dumping. (Rutsch *et al*., 2006, Rueedi *et al*., 2009)

Nablus-East catchment area indicates that sewage contribute as much as 50% of total recharge to groundwater. This was estimated based on cesspits. Nitrogen pollutant loads as function of area are up to 60% as much as those originated from agriculture. About 22% of total wastewater flow directly infiltrates into the ground via cesspits and sewer exfiltration (Borst *et al*., 2012).

The understanding of wastewater characteristics is necessary in the engineering management of environmental quality (Metcalf and Eddy, 1991). The water and wastewater mass balance gives better knowledge of the threats on groundwater in terms of quantum and pollution by wastewater. Groundwater is the primary source of drinking water in the West Bank and the sole supply of potable water in the rural communities. Therefore, it is essential to protect the groundwater from any potential contamination. Contamination by different pollutants might render groundwater unsuitable for use and put human and the whole environment at risk. Nitrate is the most frequently introduced pollutant into groundwater systems (Solley *et al*., 1993).

The existence of WWTP does not necessary protect groundwater from wastewater contamination. Sewer exfiltration may have high impact on groundwater quality as well as cesspits, which remains poorly understood and characterized (Rutsch *et al*., 2006, Rueedi *et al*., 2009).

2.2 Wastewater Sampling

The analytical results of a sample are only as accurate as the quality of the sample taken. By sampling according to set procedures, the chance of error can be reduced and the accuracy of the sample results will be improved (Industrial Pretreatment Program, 2010).

Composite sampling can substantially reduce analytical costs because the number of required analyses is reduced. This is done by compositing several samples into one and analyzing the composited sample (Shaarawi and Piegorsch, 2002).

An adequate sampling and compositing procedure can give wastewater of a truly average composition. Information from samples can be valuable for understanding the effect of the untreated wastewater on the groundwater and surface water (Shaarawi and Piegorsch, 2002). Compositing simply refers to physically mixing individual samples to form a composite sample, as visualized in Figure 1.

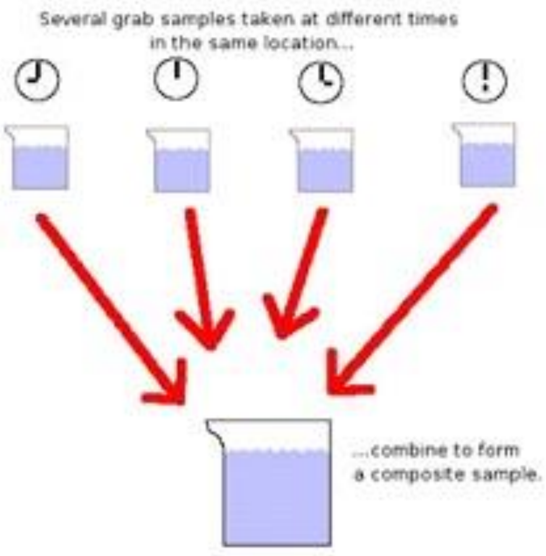

Figure 1: Composite sampling concept

The greatest strength of composite samples is their ability to take into account changes in flow and other characteristics of the wastewater over time. It gives a more representative sample of the characteristics of water at the plant over a longer period of time.

A single analysis is performed on the composite, which is used to represent each of the original individual samples. This helps the operator gain an overall picture of the total effects that the influent will have on the treatment process of a WWTP and that the effluent will have on the receiving water (El-Shaarawi and Piegorsch, 2002).

2.3 Wastewater Quantification

Different methods and instruments can be used in order to measure the wastewater flow. The methods mainly depend on the condition of the measurement location and section, where the budget limits the instruments options.

Zimmo (2010) was aiming at assessing quality and quantity of the wastewater of Tulkarem and Wadi Zeimar. The methodology of the study includes a flow rate measurement which was calculated based on the continuity equation and Bernoulli Equation. The method of quantification was applied to the cross sections of the measurement section.

Qaqilia Municipality in the year 2012, conducted a study that aimed to measure the wastewater flow based on hourly measurements. The manning formula was used in order to measure the wastewater flow rate on the outlets using the velocity as the variable to be measured. Tulkarem Municipality in the year 2012, conducted the same study as Qaqilia Municipality that aimed to measure the wastewater flow.

2.4 Wastewater Characteristics

The selection of parameters is based on the previous studies, researches and Birzeit University lab capabilities. The wastewater parameters were selected in order to fulfill the research requirements which include calculating the pollution load, make a characterization for the wastewater, and to find if Fara'a catchment is suffering from heavy metals problems from Nablus East wastewater.

2.4.1 Pollution Load

Groundwater samples have revealed disturbingly high level of contaminants in some areas of the West Bank (Anayah *et al*., 2009). Particularly nitrogen, which has been shown to have an increasing trend over time (Anayah *et al*., 2009). As such, it is necessary to investigate and analyze wastewater quality to determine elements concentration in order to better identify the associated impacts on water resources (Stuart and Milne, 2001).

Abu Baker (2007) used TN and BOD_5 parameters as part of the characterization of the wastewater that drain to Fara'a catchment in order to determine the contaminant and pollution loads on the groundwater. The results shows high pollution loads in term of the TN and BOD_5. Taebia and Droste (2004) used TP, TN, and BOD_5 parameters as part of the pollution loads in urban runoff and sanitary wastewater research. Singh (2005) applied Chemometric data analysis of pollutants in wastewater research and used Cd, Cr, NO_3, PO_4 and F parameters in order to assess the pollutants.

2.4.2 Heavy Metals

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). Heavy metals appear in the wastewater from industrial facilities. Heavy metals become toxic and harmful at high concentrations (FAO, 1992). Table 1 summarizes the Permissible Heavy Metals Concentration in the Environment

Table 1: WHO Permissible Heavy Metals Concentration (WHO Guidelines, 2012)

Parameter (mg/l)	Recommended Limits WHO (mg/l)
Manganese	0.4
Lead	0.01
Copper	2.0
Zinc	3.0
Cadmium	0.003
Chromium	0.2

- Arsenic

Arsenic in wastewater originates 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).

- Copper

Copper may be present in wastewaters from a variety of chemical manufacturing processes, mine drainage, paint and pigment manufacturing and mainly from tape water in urban areas (Metcalf and Eddy, 2003). Copper in wastewater is from industrial sources such as alloys manufacturing and heat exchangers and from households such as pipes and tips. Sorme and LagerKvist (2002) 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 was generated in households.

- Lead

Lead (Pb) is a hazardous element employed in many processes. The main sources of lead in wastewater are industrial sources. The main industrial application is in the production of batteries, especially for cars (Piccirillo, 2011). 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 Kvist, 2002).

- Zinc

The Zn concentration values are depending on the discharged quantities from domestic and industrial sources (Abu Baker, 2007). Sorme and Kvist (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.

- Cadmium

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). Cadmium may come from Household detergents resources (Sorme and Kvist, 2002).

- Nickel

Nickel as a heavy metals that has many industrial and commercial uses. The main sources of nickel in wastewater are industrial sources that include production of metallurgical, chemical and food processing industries. Nickel presences in the household’s wastewater is mainly due to the disposal of oil and fats (Cempel and Nikel, 2005).

- Chromium

Chromium is one such toxic pollutant due to its harmful effects on human health, especially in its hexavalent form (Ting *et al.*, 2010).

2.5 Water and nitrogen mass balance

The research done by Borst *et al.* (2012) studied the wastewater pollution loads and groundwater pollution for Nablus East. The research was done using available data with no real measurements for the wastewater as quantity and quality parameters. The purpose of their study was to offer a primary estimate of the quantity of wastewater as recharge and the extent of nutrient loading from wastewater in the eastern catchment of the city of Nablus.

Nitrogen mass balance for seven lakes and 20 forested catchments in central Ontario was monitored between 1977 and 1989 as part of a long-term study of the effects of atmospheric deposition (Dillon and Molot, 1990). The results shows that the nitrogen loads is 0.9 (kg N/ha*day).

A water and nitrogen balance model estimates the daily ponded water depth, the daily losses and the uses of NH_4–N and NO_3–N in their transformation processes (Antonopoulos, 2008). Wakida and Lerner (2005) found for the city of Nottingham (UK) that the urban nitrogen loading rate as per area is 216 kg/ha*yr. A mass balance was conducted in order to calculate the nitrogen loading. The outdoor water usage (garden), and water used for cooking and drinking as have been indicated as, 15% as an outdoor usage (garden), and 4% as for cooking and drinking (Nazer *et al.*, 2008).

In the presented time, literature review clearly showed that knowledge about exfiltration from sewer network is very limited; but the few available studies indicate that exfiltration pollution loads pose un-counted serious threat to groundwater which will continue to increase over time.

Chapter Three: Material and Methods

3.1 Study Area

3.1.1 Description

Fara'a Catchment is a semiarid to arid catchment located in the north-eastern part of the West Bank. It extends from Nablus East in the western part, and ends up in the Jordan River east of the West Bank as shown in Figure 2. The total area of Fara'a Catchment is 330 km^2 and extends over Nablus East, Tubas and Jericho governorates. Fara'a Catchment is mainly contained within the Eastern Aquifer Basin.

Figure 2: Location of Nablus and Fara'a Catchment within the West Bank (Abedel-Karrem, 2005).

The generated wastewater quantities in Fara'a Catchment are highly variable. The main sources of effluents in Fara'a Catchment are the eastern part of Nablus City, Balata and Askar camps.

The city of Nablus is one of the largest municipalities in the West Bank. The city is divided into two basins regarding the sewage drains. The western part of the town drains via Wadi Zoimar and ultimately to the Mediterranean Sea. The other basin, which the study did focus on, is the eastern part of Nablus city including Balata and Askar camps, where its sewage drains on Al Fara'a Catchment through Wadi Al Sajor.

Nablus east is considered as a residential area featuring also industrial/ commercial activities. The total population of the study area is 94,910 (PCBS, 2007; Nablus Municipality, 2012). Table 2 shows the population, water and sewerage connections in the study area, based on 2007 census data.

Table 2: Population and sewerage connections (PCBS, 2007)

	Total Population 2007	Total Population 2013 Estimated	Study Area %	Water Network Coverage (%)	Sewage Network (%)
Nablus-East	32,130	56,067	71	100	98
Rujeib	4,138	4,883	18	100	45
Kafr Qalil	2,414	2,940	6	100	85
Balata camp	15,010	17,682	2	100	100
Askar camp	11,430	13,330	3	100	100
Total	65,120	94,910	-	100	<90

Most of Nablus municipal wells lie outside of the study area to the northeast of the city. Never the less, sewage infiltration within the study area may threaten municipal water wells, because the city of Nablus lies above the Eocene aquifer, which flows northeast (Qannam, 2003; Najem, 2008).

3.1.2 Main Environmental Problems in Fara'a Catchment

Al Fara'a catchment is suffering from ongoing environmental problems due to the drains of the untreated wastewater. It is under severe problematic conditions that need to be addressed in order to set up proper strategies and management policies (Abu Baker, 2007). The major problems can be summarized as follows:

1. Untreated domestic wastewater that drains to Fara'a Catchment (wadi Al-Sajor) from Nablus East, Balata and Askar refugee camps;
2. Discharg of the wastewater vacuum tankers from surrounding villages;
3. The use of untreated wastewater in irrigation is an ongoing practice at some agriculture fields within the area; and
4. The Eastern Industrial Zone of Nablus City which drains its untreated chemical sewage to wadi Al Sajor.

3.1.3 Nablus-East Wastewater Collection System, Cesspits and Outlets

Nablus sewage collection system is a separate system for the collection of wastewater and storm water and covers approximately 98% of the City (GIETIC, 2012). The water network covers 100%, with intermittent water supply for most of the study area.

The sewer network of Nablus East has seven different outlets that drain to wadi Al-Sajor without any treatment. Figure 3 shows the sub-catchments area and the different outlets.

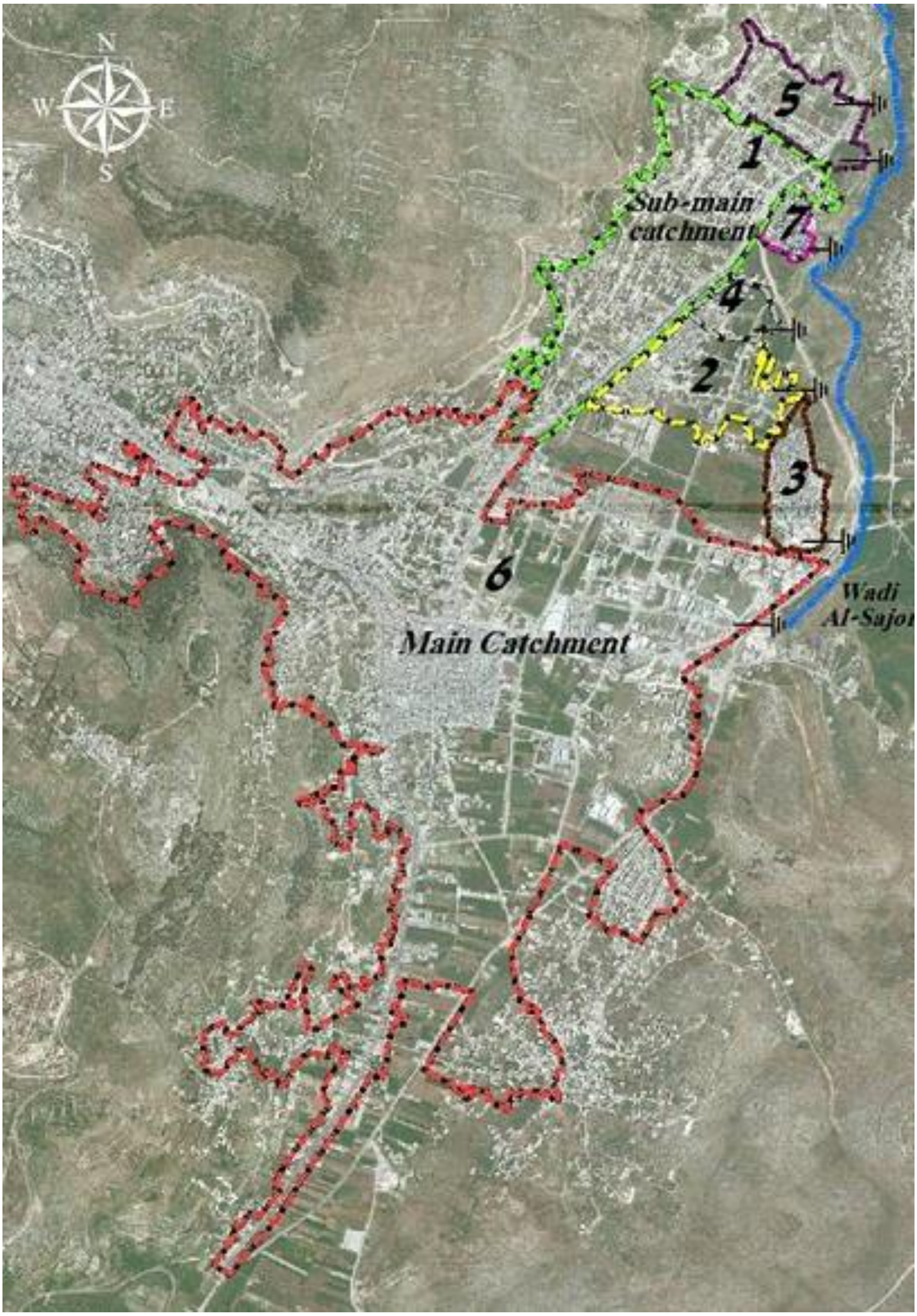

Figure 3: Study area catchments and sewage outlets; 1-5: sub-catchments; 6: main catchment; 7: sub-main catchment (Nablus Municpality,2012)

The entire study area includes Nablus-East, Balata and Askar refugee camps, and the villages of Rujeib and Kafr Qalil, which are directly adjacent to the city. Balata and Askar camps are within the municipal orders of Nablus but are served by UNRWA rather than the municipality and are therefore accounted for separately.

Therefore, Nablus East was divided into seven sub-catchments, according to the outlets. Each sub-catchment area has its own outlet. The main catchment area includes most of Nablus East, Balata refugee camp, and Kafr Qalil. The sub catchment includes a small neighbor of Nablus-East. As shown by Figure 3. The other five sub catchments where numbered from 1 to 5. These catchments represent 14% of the Nablus-East generated wastewater, distributed among the five different outlets.

The sub-main catchment is located in the northern area of Nablus East. The main idea of including the sub-main catchment in the study is to have more accurate data, measurements and results that can be compromised and reflected on the main catchment.

The total area of the sub-main catchment is 0.062 km^2 and the sewer network in this catchment is serving, about 380 PE within the study period. This Catchment is a residential area and it does not contain any commercial or industrial areas. The sub-main catchment represents 0.4% of Nablus-East generated wastewater.

Figure 4 and Figure 5 show the sub-main catchment area boundary, the sampling and the measurement outlet location. The sewage form the sub-main catchment drains to wadi Al-Sajor in a free fall situation. The diameter of the outlet pipe is 350mm as seen in Figure 5.

Figure 4: Sub catchment outlet and boundary

Figure 5: Sub Catchments measurements and sampling location

Most of the sewage that drains to wadi Al-Sajor which contributes to Fara'a Catchment is from the main catchment of Nablus East. The sewer network covers 98% of the total residential area of Nablus-East, and it drains to the main outlet. The total area of the main catchment is 4.2 km^2 and drains a sewer network serving about 60,000 PE, and different commercial and other facilities. It contributes with 86% of the generated wastewater of Nablus-East. For better understanding of the main catchment outlet condition see Figure 6.

A small industrial area in Nablus city is within the main catchment area. There are 115 industrial facilities. The wastewater generated from these facilities drains to the main catchment outlet. The industrial facilities of Nablus-East produce wastewater that is similar to domestic wastewater while other industries produce wastewater of specific quality that necessitates special attention and pretreatment (Abu Baker, 2007).

Figure 6: Main Catchment measurements and sampling location in Nablus-East

The outcomes of the main and sub catchments results were used in order to determine the pollution loads for the other five sub catchments in Nablus-East. Mainly, the percentage of the water consumption that ends up in the wastewater network and the exfiltration percentage.

Table (3) represents the data and characteristics of the main, sub-main catchments and the other five sub-catchments in Nablus East. It gives the estimated population, the number of water meters as registered at Nablus municipality, and the areas.

Table 3: Population and Water Meter Data within Nablus East sub-Catchments derived from GIS shapfile (Nablus Municipality, 2012); 1-5: sub-catchments as per figure 3

Catchment ID	Total Population 2013 Estimated	Number of water meters	Area (ha)	% Study Area
Main	59,500	5,862	428	73
Sub-main	380	61	6.3	1
1	25,330	1,821	94.8	16
2	7,000	372	14	3
3	1,100	95	29.8	5
4	1,380	97	7.8	1.5
5	220	28	2.0	0.5
Total Nablus-East	94,910	8,336	582.7	100

Most of the cesspits are located in Rujeib village. The new sewer project was conducted in 2012 has increased the sewage connection up to 45%. Rujeib and Kafr Qalil villages are within the main catchment boundry and share the same outlets as well as Ballata refugee Camp and part of Askar refugee Camp. Table 4 lists the results of applying the technical described above in estimating the number and percentage of the cesspits within each of the catchment areas.

Table 4: Estimated Cesspits within Nablus-East; 1-5: sub-catchments as per figure 3

Catchment ID	Number of water meters	Number of cesspits	% Households with cesspits	Average Daily water use (m^3/day)
Main	5,862	438	7.3	315
Sub-main	61	0	0	0
1	1,821	24	1.3	7
2	372	0	0	0
3	95	0	0	0
4	97	0	0	0
5	28	0	0	0
Total Nablus-East	8,336	462	5.6	322

The 5.6% indicate that 94.4% of the households and consumers of Nablus-East are served by the sewage collection network. This is reasonable as all official Figures supports this percentage. It is also known that the number of un-connected households in Nablus-East is higher than that of Nablus-West.

3.2 Methodology

The overall research methodology covers three components: data collection (which includes wastewater flow measurements and sampling), data analysis and output analysis. Figure 7 depicts the flowchart of the research methodology.

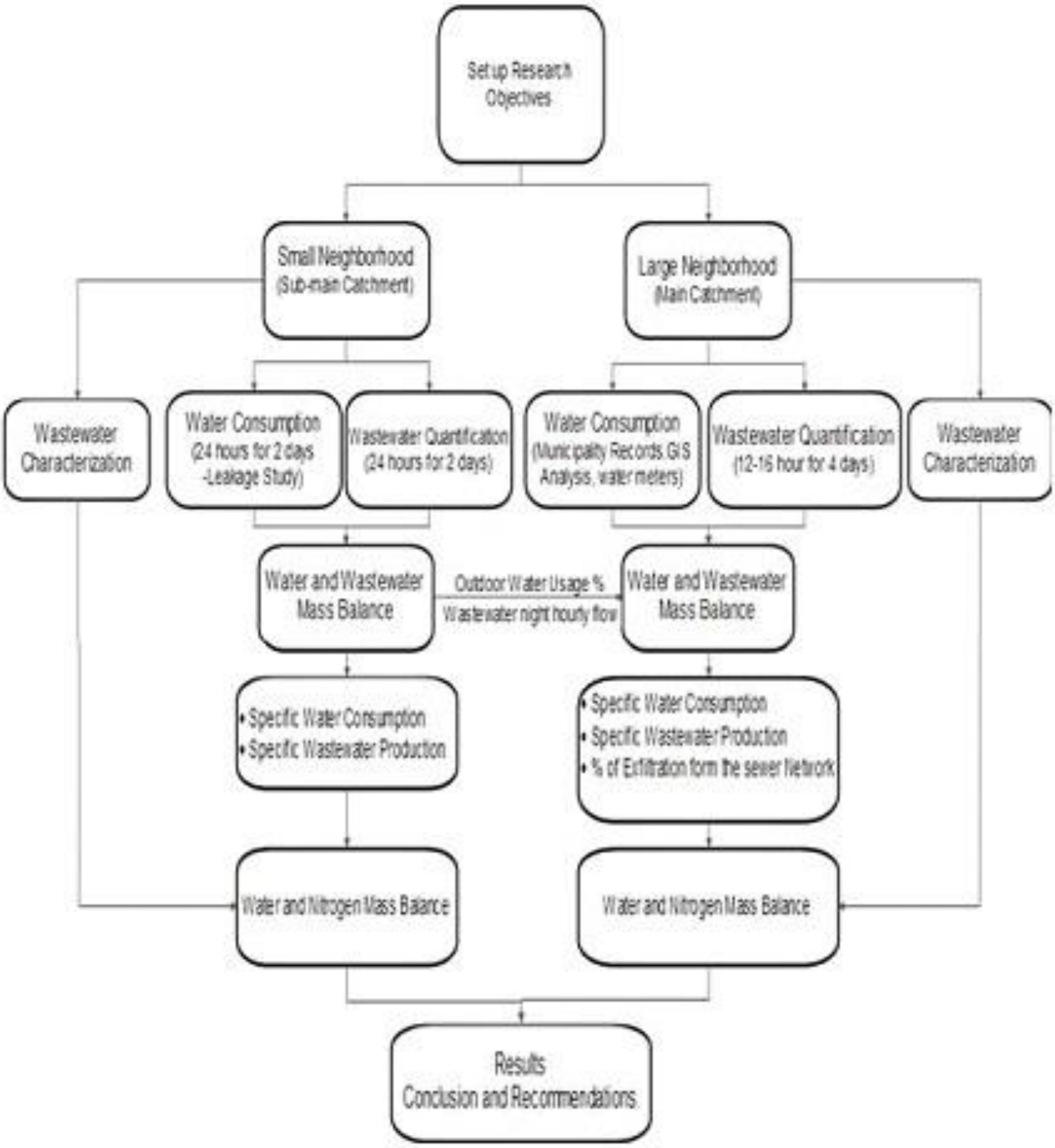

Figure 7: Flowchart of the Research Methodology

The research methodology is based on studying two catchments. The main idea of studying and conducting the mass balance for the sub-main catchment is to have an accurate small scale catchment, which are relatively easier to manage and control. The results and factors which are mainly the outdoor water usage percentage and the wastewater night hourly flow can be then used on the main catchment mass balance.

The wastewater flow for the sub-main catchment was quantified for five days including a non-working day. Two days was for 24 hours in accordance with the leakage study that was conducted on the same period for the sub-main catchment. The leakage study was the source of the daily water consumption for the sub-main catchment. The mass balance was applied on these two days as to identify the outdoor water use percentage, and the wastewater night hourly flow. The wastewater flow measurement for them other three days was conducted for 12-16 hour as to identify the daily wastewater flow for the sub-main catchment.

For the main catchment, the wastewater flow was measured between 12-15 hours for four days including a non-working day. The gap was estimated from the wastewater night hourly flow that was identified in the sub-main mass balance. The water consumption for the main catchment was identified form the water recorder of Nablus Municipality. The water consumption records were provided as ArcMap software data base (shapefile). The mass balance was applied on the main catchment for the average daily wastewater flow with the average daily water consumption. The wastewater flow and the exfiltration as percentage of the water consumption were identified, and were used for the pollution load calculations.

Samples were collected from the main and sub-main catchments outlets. The composite sample method was applied in order to have representative results over a day and over a week.

Water and nitrogen mass balance was applied on the main and sub-main catchment. The daily pollution loads form the exfiltration and form the wastewater flow that drains to wadi Al-Sajor, were determined. It was calculated from the average daily wastewater flow and the average daily concentration for the measured wastewater parameters (total Nitrogen, total phosphorus, etc.).

In order to cover all Nablus-East, the results of from the main and sub-main catchment areas were applied on the other five sub-catchments. The water consumption for these catchments was identified from the water meters GIS data.

3.2.1 Data Collection

The data collection consists of collecting of all available data such as GIS data, population data, industrial facilities, and water consumption figures. It also includes several site visits and meetings for better understanding of the study area and to specify sampling locations. Most of the data were provided by the Water Supply and Sanitation Department (WSSD) at Nablus Municipality.

The data includes shapefiles for the water network, water meter, sewer network, satellite map of 2012, and water consumption for the years 2010, 2011and 2012 connected by code with the water meters. The water meters and water consumption shapfile were the major input in the study regarding the main catchment. It was used as the best available accurate data regarding the water consumption for the main catchment.

The demography data for the main catchment that related to the research was provided from the last published census of (PCBS, 2007) and was modified according to the population growth up to 2013.

In order to have better understanding of the study area, several Interviews and personal communications were conducted with members from Nablus Municipality, water and wastewater department, and some people who live within the sub-main catchment boundary.

3.2.2 Data input and analysis in ArcMap 9.3

The Shapfile data that was provided from Nablus Municipality was analyzed using ArcMap 9.3 software. Maps obtained as image files were geo-referenced and then digitized into shapefiles in ArcMap. Using ArcMAp, the sewer network for Nablus-East was used to determine the catchment areas and the outlets and to calculate the travel time in the sewer network.

ArcMAp was used also to determine the water consumption within every catchment area. The water meter shapfile includes the water consumption records as spatially coordinated. The main outcome was the annual, monthly, and the average daily water consumption for the main catchment.

A proximity analysis was conducted using ArcMap to determine the number of cesspits within the study area. The 2007 census recorded the number of cesspits Nablus; however no spatial data was available to determine how many of these cesspits were located within Nablus-East.

A distance of 50 m from the tertiary of the sewer line should be an adequate distance to assume no connection, however it was unclear whether the spatial distribution of sewer lines collected from the municipality represented tertiary, secondary, main lines, or some combination of all three.

3.2.3 Water Consumption Approach

Two different approaches were conducted in order to identify the water consumption for the main and sub-main catchment.

3.2.3.1 Sub-Main Catchment

The water consumption for the sub-main catchment was determined by benefiting from a leakage study that has been conducted a nearby catchment by Nablus Municipality (2012). The leakage study was conducted using pressure gages and observations of the water meters of the consumers within the catchment. The sub-main catchment area was part of the overall leakage study area of this study, which has a continuous water supply. It is connected to the main feeder line that supplies most of Nablus-East; however the houses have roof tanks that are functioning as storage and balancing the pressure.

The Leakage for the sub-main catchment was conducted for two days. The outcome that were used from the leakage study is the water consumption for the sub-main catchment as a total flow over a day for two days (48 hours), indicating the variation of water consumption all over the day (hourly).

3.2.3.2 Main Catchment

The water consumptions for the main catchment were determined by benefiting from the GIS data that was provided by Nablus municipality. The GIS shapfile consists of water meters subscriptions, including ID code and water consumptions recordes for each water meter. The water consumptions data were analyzed using ArcMap (GIS software) as a tool in accordance with the different catchment areas (Figure 8). This helped to find the yearly and monthly water supply for each catchment.

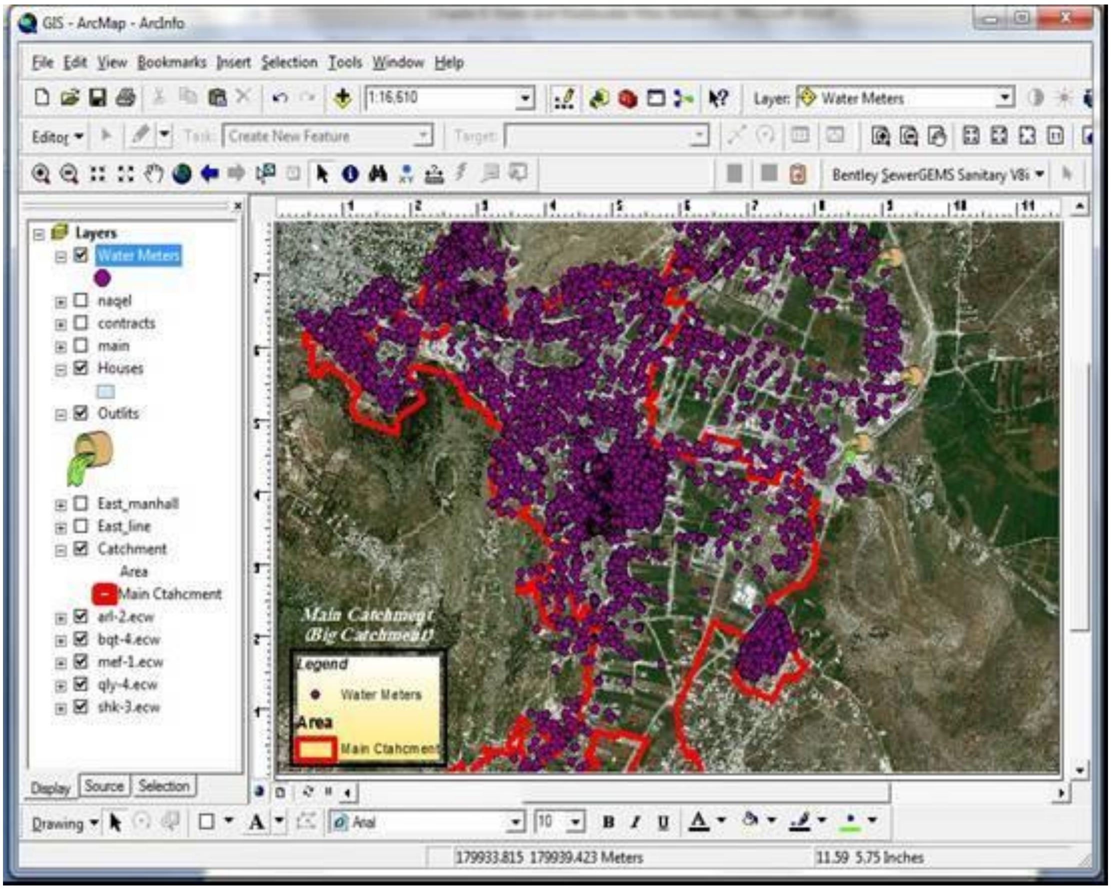

Figure 8: Water consumption and water meter analysis using ArcMap software

3.2.4 Wastewater Flow Measurements

The wastewater flow measurement was a major concern for the main and sub-main catchments. This was because of the lack of accurate and advanced instruments for measuring wastewater flow. Two different methods were applied for the measuring of the wastewater flow. Each method was applied in order to fulfill the research requirements and according to the nature and condition of each different catchment outlets.

3.2.4.1 Sub-Main Catchment

The condition of the sub-main catchment outlets is much different than the main catchment outlets. The wastewater drains to wadi Al-Sajor in a free fall condition through a 350 mm circular UPVC pipe. The need for an accurate wastewater flow results was reflected by the applied wastewater quantifying method.

The Volumetric flow rate equation (Eq. 1) was used for wastewater quantifying for the sub-main catchment. The idea is to collect the wastewater in a Barrel/Container-with 0.85m^3 volume- benefiting the free fall conditions and have a frequently measurement at certain times, every 15 min or when the Barrel/Container is full.

Equation 1: Volumetric Flow Rate Formula (SI-System)

$$Q = \frac{V}{t}$$

Where:

Q: Wastewater flow rate (m^3/s)

V: Wastewater Volume (m^3)

t : Time (sec)

The flow measurement was conducted for 24 hours for two days including a non-working, and for 12-14 hour for the other four days of the week. Figure 9, illustrate the sampling procedure applied and shows the used container.

The outcome of the measurement gives the hourly wastewater flow frequency at the outlet (hourly), and the total wastewater flow over the day. An average of the measurement periods was taken in order to quantify the daily wastewater production that drains out of the Sub-main catchment to wadi Al-Sajor.

Figure 9: Sub-main catchment outlet sampling method in Nablus-East

3.2.4.2 Main Catchment

The wastewater quantification campaign for the main catchment was conducted during May and June 2013. The water consumptions for these two months are not yet computerized by Nablus Municipality. Until the sampling and measurement day, there are 5589 subscriber within the main catchment area. It includes small industrial facilities, commercial and other consumptions in additional to the domestic.

The outlet of the main catchment has a concrete rectangular shape conduct with (0.6m x 1.45m) dimensions. It has a total length of 43 m, with 0.14 m as elevation differences between the channel entrances and exit. The level difference was taken by using survey instrument and the slope was calculated at 0.325%.

Manning Formula (Eq. 2) was used is order to quantify the amount of wastewater flowing through the rectangular concrete at the exit of the main catchment. This was done by measuring the depth of the flow over a day (hourly) and over a week (daily).

Equation 2: Manning Formula (SI-System)

$$Q = \frac{1}{n}\ Rh^{\frac{2}{3}}\ S^{\frac{1}{2}}\ A$$

Where:

Q: Wastewater flow rate (m^3/s)

n: the Manning coefficient, (0.013 for Concrete)

R_h: the hydraulic radius

S: the slope of the water surface (channel) for uniform flow conditions

Manning's equation is the only applicable and available method for quantifying the wastewater for the main catchment in term of the un-availability of modern devices and consideration of the research budget limitations.

A survey Ruler staff was installed in the rectangular section at the entrance of the outlet, as seen in Figure 10. A single reading for the depth was taken every half hour for 12-14 hour over 6 days including one non-working day (Friday).

The outcomes of the measurement give the hourly wastewater flow variation at outlet and the approximate total wastewater flow over the day. An average of the measurements period was taken in order to quantify the daily wastewater production that drains out of the main catchment to the Wadi.

Figure 10: Main catchment outlets quantification method

3.2.5 Sampling Method and Wastewater Characterization

All the analysis was carried out in the laboratories of Institutes of Environment and Water Studies of Birzeit University to characterize the wastewater samples.

Samples were collected from the main and sub-main catchments outlets. The composite sample method was applied in order to have representative results over a day and over a week.

The Time interval composite samples were conducted every two hours from 8:00 am to 2:00 pm on Friday, Sunday, and Tuesday for three weeks during the period of 30 May 2013. In this way, the daily and the weekly fluctuation of pollutants concentration are considered.

Eighteen wastewater samples from the main and sub-main catchment were collected and analyzed for different parameters at different dates during the study period.

Samples of 1 liter were collected; 250 mm grap sample was collected from each location for each cycle and combined in a liter plastic containers. The samples were kept directly in an onsite refrigerator and then transported to Birzeit Lab refrigerator. On a non-working day, the samples were kept until the following day. Temperature and pH were measured immediately onsite

A list of parameters was determined for sample analysis. The parameters are briefly illustrated along with the method of measurement, and summarized in Table 5.

Table 5: The Selected Parameters for Samples Analysis

No.	Parameters measured	Unit
1	Temperature	Degrees Celsius (^oC)
2	PH	-
3	Dissolved Oxygen	$mg \cdot L^{-1}$
4	COD_T	mg/L
5	COD_D	mg/L
6	TVS	mg/L
7	Nitrates	mg/L
8	Total Kjeldahl Nitrogen	mgN/L
9	Sulfates	mg/L
10	Heavy metals*	mg/L
11	PO_4	mg/L
12	NH_4–N	mg/L

* Heavy Metals: Ni, Pb, As, Zn, Cr, Cu, Cd

Analysis of the wastewater characteristics was carried out to find the pollution loads regarding the different parameters for both the main and sub-main catchments. The sampling process was carried out for the two samples from the two outlets.

The applied sampling method considered having daily and weekly fluctuation of pollutants concentration. This helps to fulfill the research requirements.

The sampling process was carried out at the two outlets of the main and sub-main catchments contributing to Fara'a with the intension to cover the spatial and temporal variations of the tested parameters.

Finally, excel software was used as a tool for the interpretation, presentation, and analysis for the obtained chemical laboratory of the results wastewater characteristics and pollution parameters.

Table 6 summaries the information of the sampling and measurements conducted as part of this research. It lists the parameters measured, used instruments, method of analysis applied, location of the sampling and references. It is to consider that all analytical parameters cited were carried out in different laboratories; some of these were tested at Birzeit University Labs, and some were tested at IEWS lab and others are onsite.

Nitrate test is a measure of nitrate concentration as (nitrogen), to investigate if the value is within the acceptable range. The Detection limit for concentration of nitrate in wastewater is 50 ppb. The analysis of the all the samples that were taken for the two catchment area shows that all the Nitrate concentration is below the detection limit. CIA method was used in the testing lab in order to analysis the nitrates. The available method for analyzing the heavy metals is ICP and it was tested at Birzeit University labs.

Table 6: Methods used and Wastewater characteristics parameters measured for the Main and Sub-main Catchments samples

Parameters measured	Instruments used for analysis	Methods of analysis	Location of analysis	References
Temperature pH Dissolved Oxygen	Temperature meter pH meter D.O meter	Direct testing and readings of instrument	Sampling Location	Direct measurement as manufacturer procedure
Organic material COD_T COD_D TSS	Hach COD reactor Spectro photometer Evaporation Spectro photometer Oven Dray	Standard procedures and testing	IEWS lab	APHA (2005)
Nitrates	Capiling ion analysis	Capiling ion analysis (CIA)	BZU testing lab	APHA (2005)
Total Kjeldahl Nitrogen	TKN	Official method of analysis 17edth (AOAC)	BZU testing lab	APHA (2005)
Sulfates	Capiling ion analysis	Capiling ion analysis	BZU testing lab	APHA (2005)
Heavy metals* (Ni, Pb, As, Zn, Cr, Cu, Cd)	Perkin-Elmer Optima 3000 ICP-OES	Inductively Coupled Plasma has been(ICP)	BZU testing lab	APHA (2005)
PO_4	Spectro photometer	Capiling ion analysis	IEWS lab	APHA (2005)
NH_4-N	Spectro photometer	Capiling ion analysis	IEWS lab	APHA (2005)

3.2.6 Mass Balance Calculations

This section is discussing the equations that were used for applying the mass balance on the main and sub-main catchment. Equation 3 was used in order to determine the percentage of the wastewater that ex-filtrates from the sewer network to the ground and the wastewater quantities (daily flow) that end up to the wadi. The equation was developed from the formula that was applied by (Borst *et al*., 2012).

Equation 3: Water and Wastewater Mass Balance

$$WW_{\text{to Wadi}} = WC - WW_{\text{Ex-filtrate}} - (WC_{\text{outdoor}})$$

Where:

$WW_{\text{to Wadi}}$: Daily flow of wastewater that ends up to the wadi (m3/s)

WC: Water consumption

$WW_{\text{Ex-filtrate}}$: Wastewater that infiltrate from the sewer network

WC_{outdoor}: water lost via outdoor water usage, cooking and drinking

Equation 3 was applied first for the sub-main catchment. The resulting data and field work measurements can give more accurate results and factors that were reflected later on the analysis and results of the main catchment. It shows the relation between the water consumption and wastewater flow for the main and the sub-main catchments of the study area. It presents the results of the field work and data analysis in terms of water consumption as a volume, reflect it to the amount of the wastewater that ex-filtrates from the sewer network and that drains to the wadi.

3.2.7 Recharge and Pollutant Load Estimations

Equations 4 and 5 were used in order to calculate the different parameters pollution loads for the wastewater that drains to the wadi and the wastewater that infiltrate from the network system or from cesspits. The parameters are TN, TP, COD_T, and BOD_5.

Equation 4: Pollution Loads Calculation to the Ground

$$Pa_{\text{Load to the ground}} = WW_{\text{to ground}} * Pa \text{ concentration in wastewater}$$

Equation 5: Pollution Loads Calculation to the Wadi

$$Pa_{\text{Load to the Wadi}} = WW_{\text{to Wadi}} * Pa \text{ concentration in wastewater}$$

Where:

Pa: Pollution load via parameter

WW: Wastewater flow (m^3/day)

Chapter Four: Results and Discussion

4.1 General

This chapter summarizes and discusses the results from the wastewater flow measurements, water consumptions, and the water and wastewater mass balance on the main and sub-main catchment. The Water and nitrogen mass balance was applied accordingly and the results were generalization on the other five sub-catchment in Nablus-East.

4.2 Water and Wastewater Mass Balance

The main result is the wastewater quantities (daily flow) that ex-filtrates from the sewer network to the ground and the wastewater quantities (daily flow) that end up to the wadi. The results were used later in the calculation of the pollution load resulting from each of the two catchments.

4.2.1 Sub-main Catchment

The results from the water and wastewater mass balance in the sub-main catchment are calculated as the amount of water in percentage that does not end up in the sewer network (both the outdoor, cooking and drinking uses). The ex-filtration (losses) can be neglected as the sewer network in the sub-main catchment, which can be considered as a new network and has a short travel time in the sewer network (7 minutes). This provides the factors and the percentages that were applied for the main catchment.

Figure 11 and Figure 12 show the water consumption on a non-working day which is Friday and a working day for the sub-main catchment. The results show high variation between these two days in terms of hourly and daily consumption. The total daily consumed water (volume) resulting from the leakage study was used for the analysis procedure for the purposes of this MSc. Research and thesis.

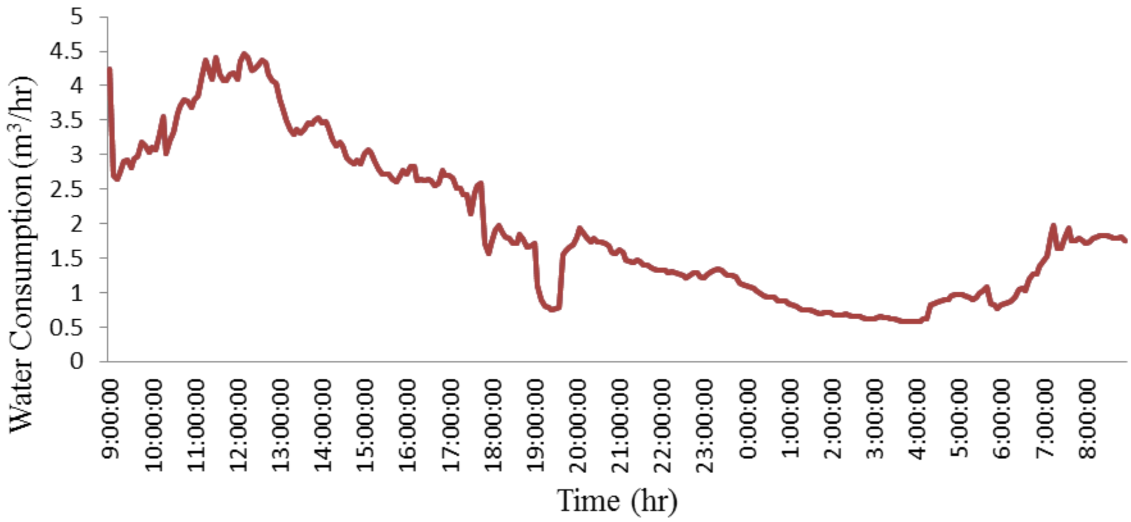

Figure 11: 24 hour's water consumption for on a non-working day in the sub-main catchment in Nablus-East

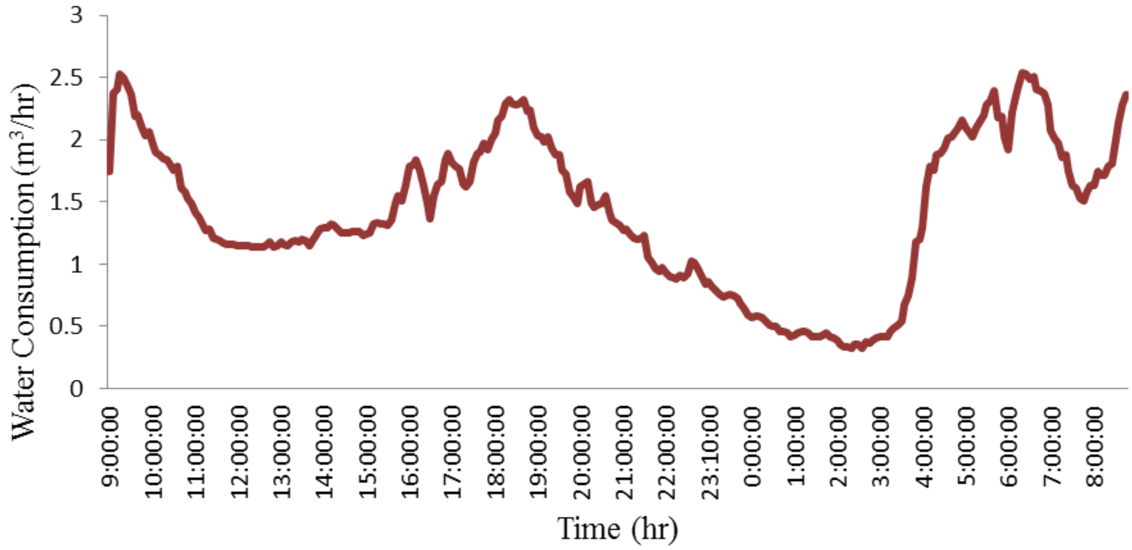

Figure 12: 24 hour's water consumption on a working day in the sub-main catchment in Nablus-East

The total amount of water consumed for the sub-main catchment on a non-working day (Friday) is 47.54 m^3 resulting a consumption per capita at 125.76 l/c. The hourly peak is that the peak hourly factor for Friday is about 1.8 showing one main peak at noon time, shortly before the Friday prayer.

For the working day, it has shown three moderate peaks at 9:00 morning, 18:00 evening and 6:30 on the next day of Sunday. This reflect the social behaviors of the inhabitants. On the weekend of Friday, the people are at home preparing for Friday prayer shortly before noon time, where most of the activities are.

The total amount of water consumed on a working day is 33.78 m^3 indicating a daily peak factor between a Friday and a Saturday at 1.4. The daily consumption per capita on this day is 89.36 l/c. Nevertheless the result was used as the average daily consumption for the sub-main catchment. The peek consumption can be found at 9:00 am for Saturday and between 5:00 and 6:00 pm for an official working day (Sunday).

On Saturday, although government's offices and banks are closed, but it is a working day, where all private enterprises are open and people are mostly outside. It is clear that Saturday started later morning at 9:00. The early morning of Sunday was started between 6:00 and 7:00 am, where the people are preparing for going to work and schools.

Wastewater quantification campaign for the sub-main catchment was conducted for five days. All the measurements sheets and calculations are presented in Annex 1.

Wastewater flow measurements were done during the same two days in accordance with the leakage study for 24 hours (Friday/ Saturday) and (Saturday/Sunday) from 13 to 15 April 2012. The measurements were taken every half hour. The results were used to determine the outdoors and cooking/drinking water use as percentages in order to use it as a factor in the main catchment analysis.

Figure 13 and Figure 14 show the measured wastewater flows and quantities on the non-working day of Friday and on Saturday for the sub-main catchment. Every hour in these figures represent the total wastewater volume in that hour. As the method of quantification took the cumulative volume of the wastewater flow.

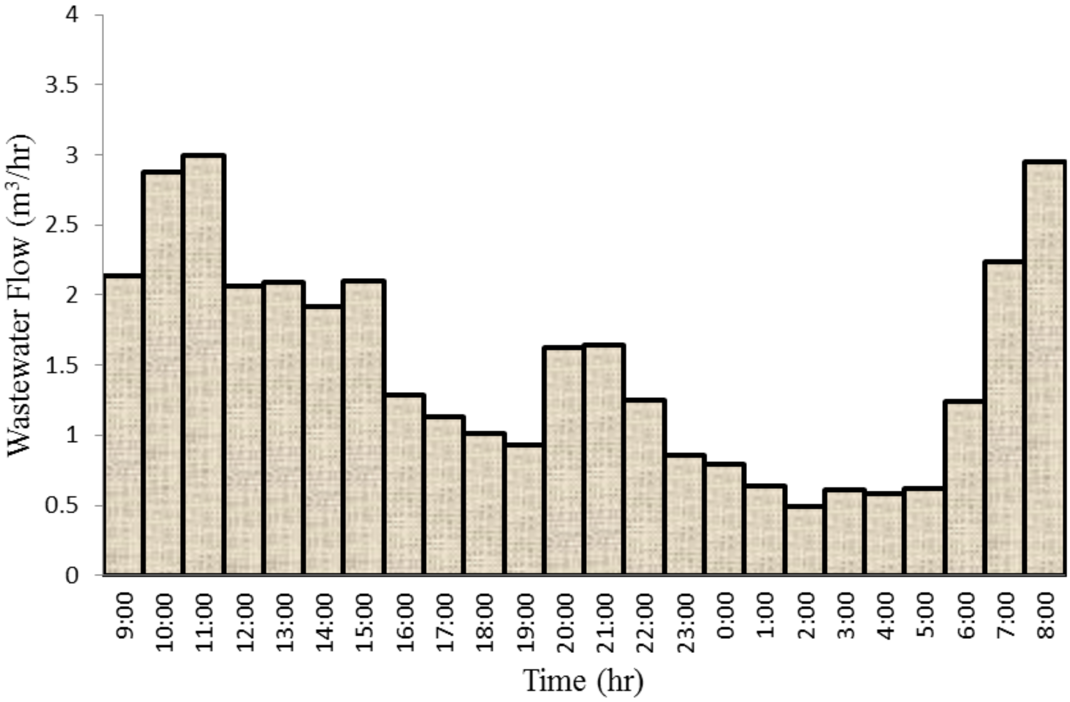

Figure 13: 24 hour's wastewater flow on a non-working day in the sub-main catchment in Nablus-East

The total daily consumed water (volume) is what will be used for the analysis procedure. The total amount of wastewater flow in the sub-main catchment on Friday was 36.08 m^3. The results show that 76% of the total consumed water that ends as wastewater in the sewer network on a non-working day (Friday). In addition it was estimated that 24.1% is consumed as an outdoor and/or cooking/drinking water use.

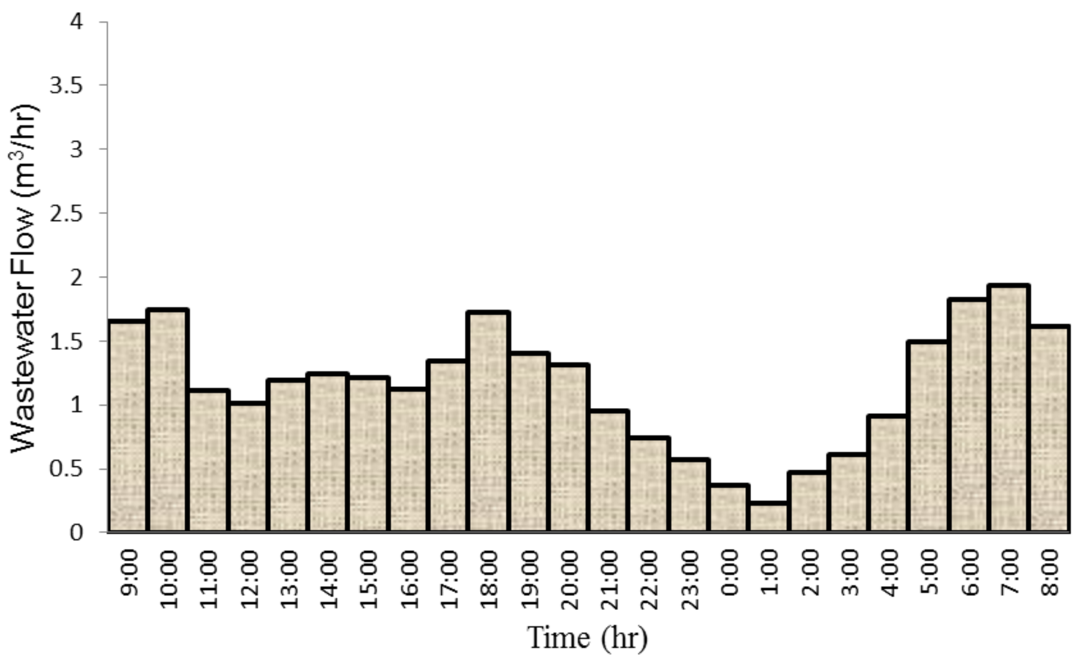

Figure 14: 24 hour's wastewater flow on a working day in the sub catchment in Nablus-East

The peak flow for the wastewater and water consumption has a time shift with no more than 15 minutes. This can be explained as the sub-main catchment has a short travel time in the sewer network (7 minutes).

The total amount of wastewater flow in this catchment on a working day is 27.76 m^3. The results show that 82.2% of the total consumed water ends up in the sewer network on the working day, while 17.8% as an outdoor and cooking/drinking. The daily average wastewater production was used in the calculation of the pollution loads. Figure 15 scheme the output of the water and wastewater mass balance for the sub-main catchment.

The other four days of the wastewater flow measurements campaign are Monday, Tuesday, Wednesday and Tuesday of a later week. The quantification campaign for these days was conducted for 12-14 hours. All the results including the hourly wastewater quantification sheets are presented in Annex 1.

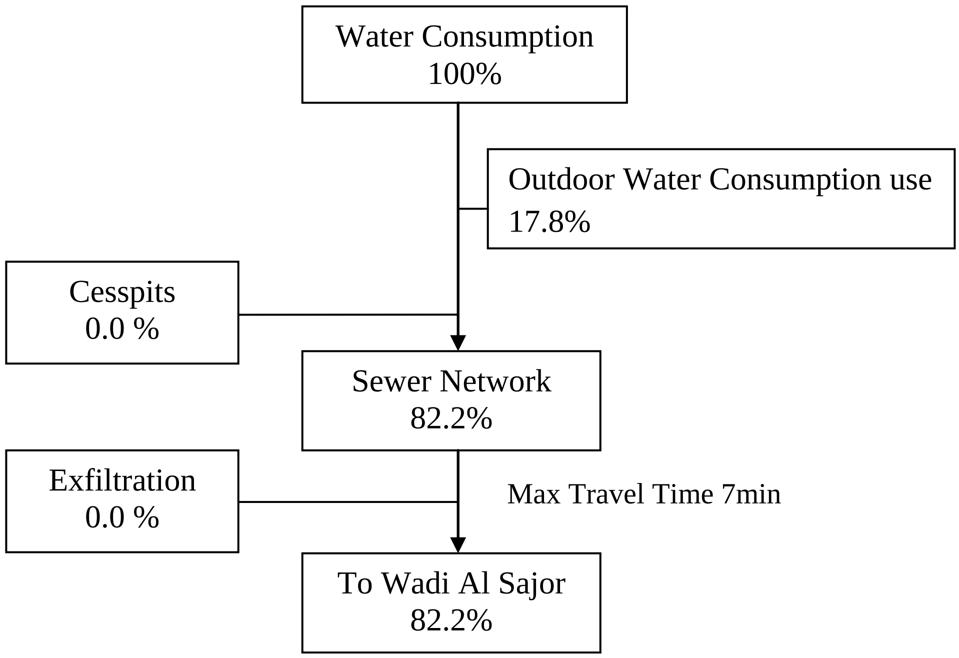

Figure 15: Water and wastewater mass balance for the sub-main catchment in Nablus-East

4.2.2 Main Catchment Mass Balance

The water consumptions for the main catchment were determined from the water consumptions records provided by Nablus municipality. The data was provided as GIS data. The water consumptions for these two months are not yet computerized by Nablus Municipality. The average daily consumptions for these two months of the 3 years 2010, 2011 and 2012 are presented in Table 7.

From Table 7, the % of increase in the annual water increase in the annual water consumption is 7-8% annually. June is higher than May by about 3-4%. Accordingly, the estimated water consumption for May and June/ 2013 is 6311 m^3 and 6586 m^3, respectively. The estimated average daily consumption all over the year of 2013 considering the yearly increasing rate is 6425 m^3 for the main catchment area.

Table 7: Average daily consumption for May and June (Nablus Municipality. Water consumption for Nablus City for the year 2010, 2011, 2012)

Average Daily Consumptions (m^3/day)					
2010		2011		2012	
May	June	May	June	May	June
5,156	5,321	5,572	5,708	5,908	6,183

The wastewater quantification campaign for the main catchment was conducted during May and June 2013. Until the sampling and measurement day, there are 5589 subscriber within the main catchment area. Wastewater quantification campaign for the main catchment was conducted for four days. All the results including the hourly wastewater quantification sheets are presented as Annex 2.

The wastewater quantification campaign was conducted in parallel with the sampling campaign for four days, two Monday, Wednesday, and Friday. The measurements were taken every half an hour during the day and for 12-14 hour; except one day where the measurement where taken for 16 hour. This fluctuation was due to the current conditions at the outlets and other measurement and site difficulties.

Figure 16 shows the average hourly wastewater flow over the wastewater quantification campaign on a working day for the Main catchment as resulted from the quantification campaign. The figure indicates a peak at noon time giving a total wastewater flow of about 500m^3/hr.

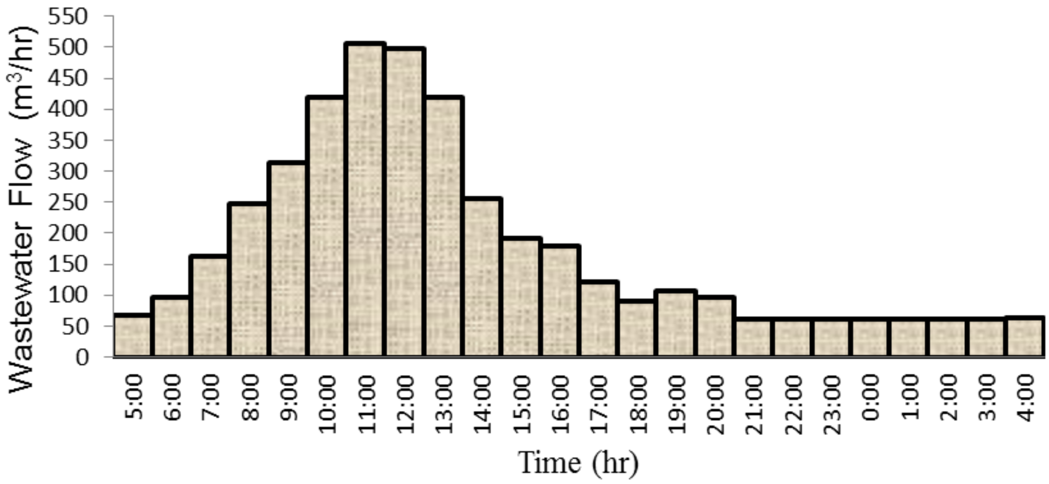

Figure 16: Average hourly wastewater flow on a working day for the main catchment in Nablus-East

The daily average wastewater that drains from the main catchment is calculated at 4270 m^3/day. It was observed that the variation of wastewater flow over a day (hourly) is very minimal for working days over the week. The measurement shows different hourly wastewater flow on Friday (non-working day), with higher wastewater flow other than the working days. The total average wastewater flow is 4231 m^3/day.

Figure 17 shows the average hourly wastewater flow on a non-working day for the main catchment, with a maximum of about 600 m^3/hr at noon time. It show that the daily peak factor is 600/500 resulting 1.2, which is the same obtains for the water consumption figures. This supports the results and accuracy of the measurement campaign.

As to the measurements, 66% of the total consumed water ends up in the sewer network on a working day. This means that 17% ends up as exfilitration to the ground from the sewer line and cesspits. The wastewater losses from the sewer network as exfiltration is 12.8%. The cesspits are 4.2%.

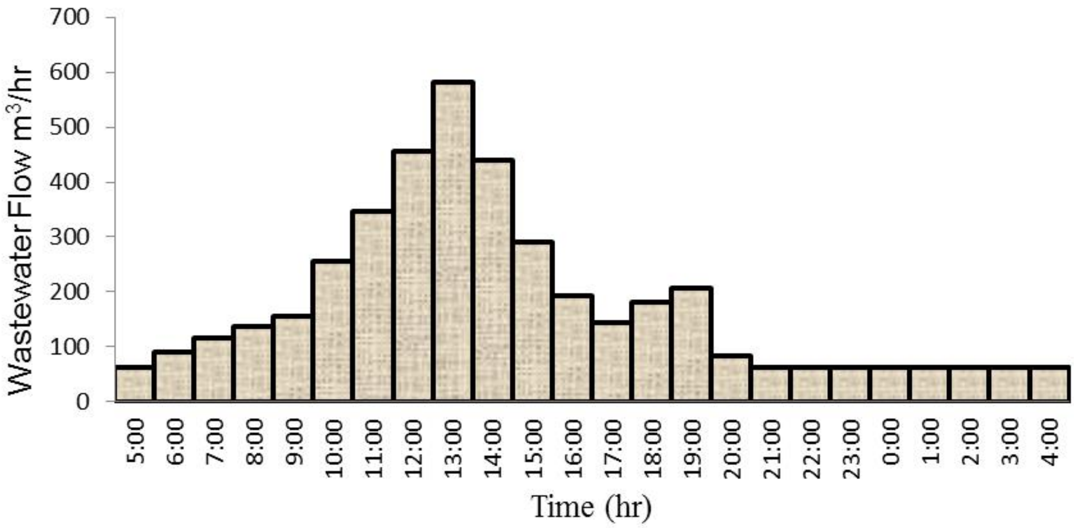

Figure 17: Average hourly wastewater flow for the main catchment on a non-working day in Nablus-East

Figure 18 scheme the output of the water and wastewater mass balance for the main and sub-main catchment.

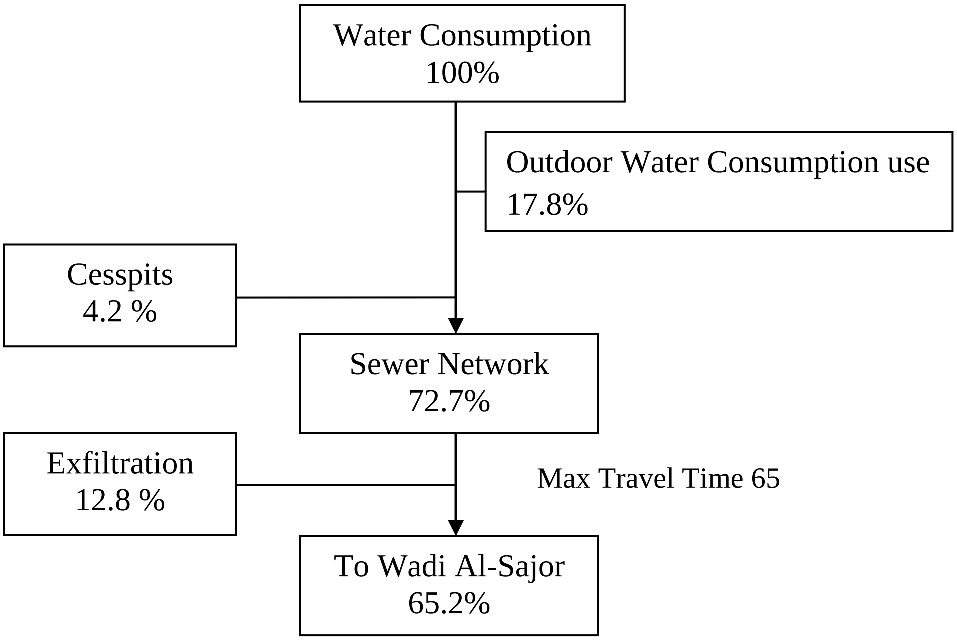

Figure 18: Water and wastewater mass balance for the main catchment in Nablus-East

4.2.3 Summary of Water and Wastewater Mass Balance Results

This section is concluding the water consumption data and links it with the wastewater production for the main and sub catchments. Also covers the estimated wastewater production for the other five sub-catchments. The outcomes form the measurements for the main and sub-main catchments were applied in order to estimate those for the sub catchments.

ArcMap software was used for analyzing the water consumption data. Table 8 lists the yearly water consumption for the last 3 years of the different catchments covered by this study. The water consumptions for 2013 were estimated applying the average yearly. The idea is to specify the water meters that are within each catchment and determine the water consumption within these catchment.

Table 8: Nablus East annual Water Consumptions

Catchment	Average Daily water use (m^3/day)			
Years	2010	2011	2012	2013
Main	4,924	5,483	5,991	6,547
Sub-main	32	38	40	41
1	514	578	642	721
2	102	116	122	132
3	31	39	44	46
4	34	42	49	51
5	11	14	16	16
Total Nablus-East	5,766	6,310	6,904	7,554

The average daily wastewater production for Nablus East is 4,270 m^3/day. Table 9 lists the results of the wastewater quantification campaign for the main and sub-main catchments.

Table 9: Summary of wastewater quantification campaign results for the main and sub-main catchments in Nablus-East

Catchment	Main Catchment				Sub-main Catchment				
	31 May 2013 - 12 June 2013				13 April 2012 – 23 April 2012				
Measurement day	Friday 31 May	Monday 3 June	Monday 10 June	Wednesday 12 June	Friday 13 April	Saturday 14 April	Monday 16 April	Thursday 19 April	Monday 23 April
Daily Avg. Wastewater flow	4,231	4,705	4,045	4,101	36.08	27.76	33.2	32.2	31
Total Daily Average	4,270 m^3/day				32 m^3/day				

The percentage of 18% as outdoor use and 17% as exfiltration and cesspits were used in the calculations for the five other sub-catchments. Table 10 summarize the identified and measured water use (2013) and wastewater quantities for Nablus-East including the water of fractions leaking to ground and discharged to the wadi at the outlets. The total amount of 1,276 m^3/day are wastewater losses that exfiltrate from the sewer network to the ground. In addition there are amounts of 122 m^3/day as exfiltration through the cesspits.

Table 10: Daily water use and wastewater quantities that goes to the ground and discharged to the wadi at the sewage outlet point, expressed in absolute quantities and as a function of area in Nablus-East; 1-5: sub-catchments as per figure 3

Catchment	Total Daily water use		Wastewater (m^3/day)			Wastewater (m^3/ha*day)		
	m^3/day	m^3/ha*day	Total	To Ground	To Wadi	Total	To Ground	To Wadi
Main	6,547	15	5,382	1,112	4,270	359	74	285
Sub-main	41	6.5	32	0	32	5	0	5
1	721	7.6	593	122	471	78	16	62
2	132	9.4	108	22	86	11	2	9
3	46	1.5	38	8	30	25	5	20
4	51	6.5	42	9	33	6	1	5
5	16	8	13	3	10	2	0	1
Total Nablus-East	7,554	13	6,210	1,276	4,932	10.6	2.2	8.4

4.3 Characterization of Wastewater Quality

This section concludes the characteristics of raw wastewater that drains from the sewer system to the Wadi (Fara'a Catchment). One type of analysis was conducted. A temporal variations for the main and sub-main catchment outlets locations were considered, which includes all the measured parameters. A total of 18 raw wastewater samples were taken from the two selected catchment outlets of the sewage system of Nablus City. The average concentration was used for each wastewater parameters as to expresses the daily concentration all over the month and all over the year.

Table 11 shows the concentrations for TN, TP, COD_t, and BOD_5 for the main and sub-main catchments. The results of these parameters show convergent average concentrations for the main and sub-main catchments. The concentrations of the main catchment area were generalized for the other East Nablus catchments as to calculate the pollution loads.

Table 11: Summary of chemical parameters for pollution load calculations for the main and sub-main catchment area

No.	Parameters		Main catchment				Sub-main catchment			
		Unit	Min.	Max.	Avg.	Non-working day Avg.	Min.	Max.	Avg.	Non-working day Avg.
1	Total Nitrogen	mg/L	73	304	178	200	142.4	245	180.4	188
2	Total phosphorus	mg/L	10.6	33.6	18.9	15.1	5.2	28.78	19	20
3	COD_t	mg/L	906	2706	1747	2017	1373	3073	2197	1984
4	BOD_5	mg/L	323	1647	985	-	-	-	-	-

Table 12 shows statistical concentrations for measured parameters for the Main and Sub catchments.

Table 12 : Summary of chemical parameters used for Wastewater Characterizations for the main and sub-main catchment

No.	Parameters measured	Unit	Min.		Max.		Average	
			Main	Sub-main	Main	Sub-main	Main	Sub-main
1	Temperature	^oC	23.5	26.6	27.6	27.1	26.4	27
2	pH	-	6.45	6.89	7.53	8.06	7	7.5
3	Dissolved Oxygen	mg/L	0.18	0.23	5.1	0.9	1.8	0.54
4	COD_d	mg/L	440	606	1706	1740	1158	1162
5	TSS	mg/L	584	352	1356	836	855	538
6	Sulfates	mg/L	52.2	76.9	183.6	124	122	97.5
7	Ni	mg/L	0	0	0.7	0.142	0.167	0.02
8	Pb	mg/L	0	0	0.704	0.22	0.17	0.024
9	Cr	mg/L	0	0.345	0.35	1.36	0.06	0.7
10	Zn	mg/L	0.246	0	1.13	0.11	0.51	0.02
11	Cu	mg/L	0	0.046	0.586	0.66	0.196	0.205
12	NH_4-N	mg/L	47	114.8	217	166.3	148	141

- **pH**

pH values were measured for the main and sub-main catchment area. The results show higher value of pH for the sub-main catchment compared with the main catchment. The highest value of pH was measured for the sub-main catchment on a non-working day. Figure 19 shows the temporal variability of pH values for the measured samples.

The overall average for the main catchment was 7.0 and fall within the standard range. However the overall average for the sub-main catchment was 7.5 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 (Abu Baker, 2007).

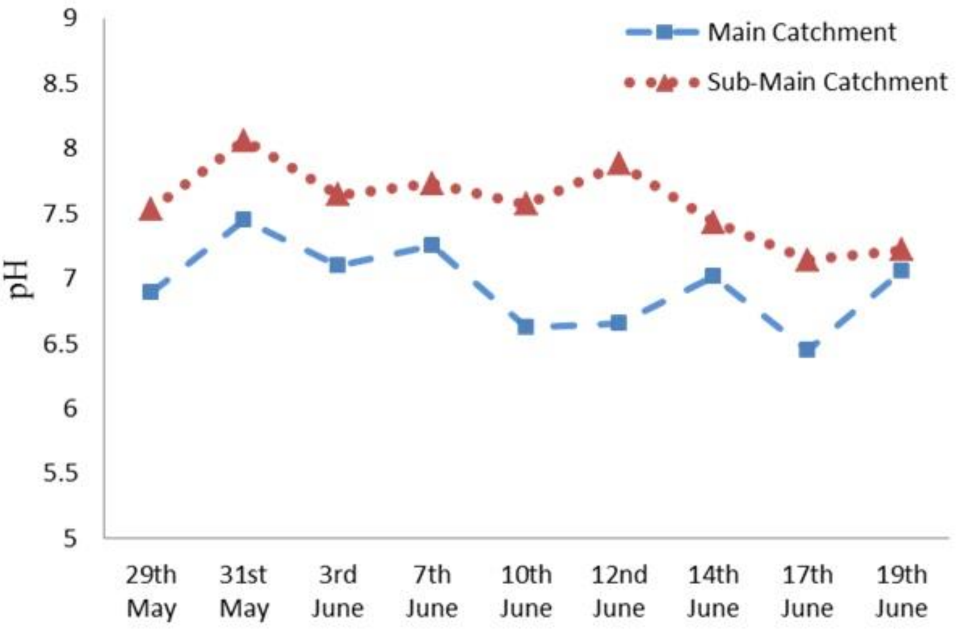

Figure 19: Temporal variability of pH values for the main and sub-main catchments

- **COD_t and COD_d**

Untreated wastewater discharged from urban areas, industry or agricultural practice into the environment is linked to groundwater pollution. COD concentration is a responsible for increasing the concentrations in nutrients and organic carbon in groundwater or surface water (Bellos and Sawidis, 2005).

Figure 20 and Figure 21 depict the temporal variability of COD_t and COD_d values for the Main and the Sub Catchments. The COD values for the Main catchment indicate and show high concentrated wastewater with a daily average of CODt= 1747.2 mg/L and COD_d= 1158.22 mg/L. For the Sub catchment area, the results also show high concentrated wastewater with a daily average of CODt= 2197.26 mg/L and COD_d= 1162.63 mg/L.

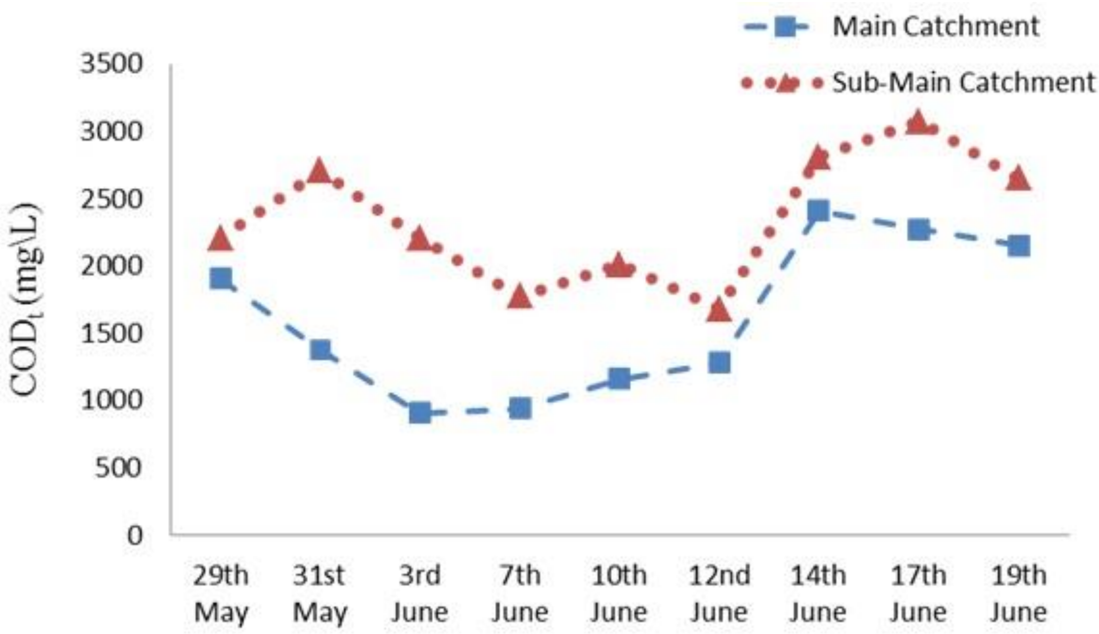

Figure 20: Temporal variability of COD_t values for the main and sub-main catchments

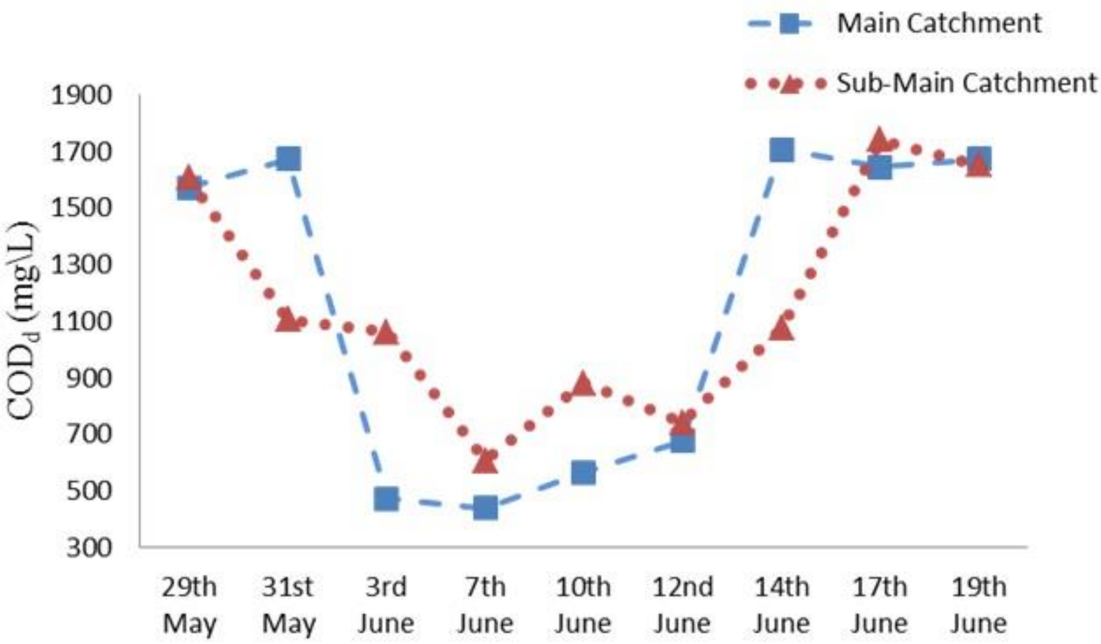

Figure 21: Temporal variability of COD_d values for the main and sub-main catchments

- **TSS**

Domestic wastewater usually contains large quantities of suspended solids that are mostly organic in nature. Industrial wastewater may result in a wide variety of suspended impurities of either organic or inorganic nature.

Immiscible liquids such as oils and greases are often constituents of wastewater.

Figure 22 depicts the temporal variability of TSS values for the Main and the Sub Catchments.

The TSS values for the Main catchment indicate and shows high concentrated wastewater with a daily average of TSS= 854.9 mg/L. For the Sub-Main catchment area, the results also shows high concentrated wastewater with a daily average of TSS = 538.55 mg/L.

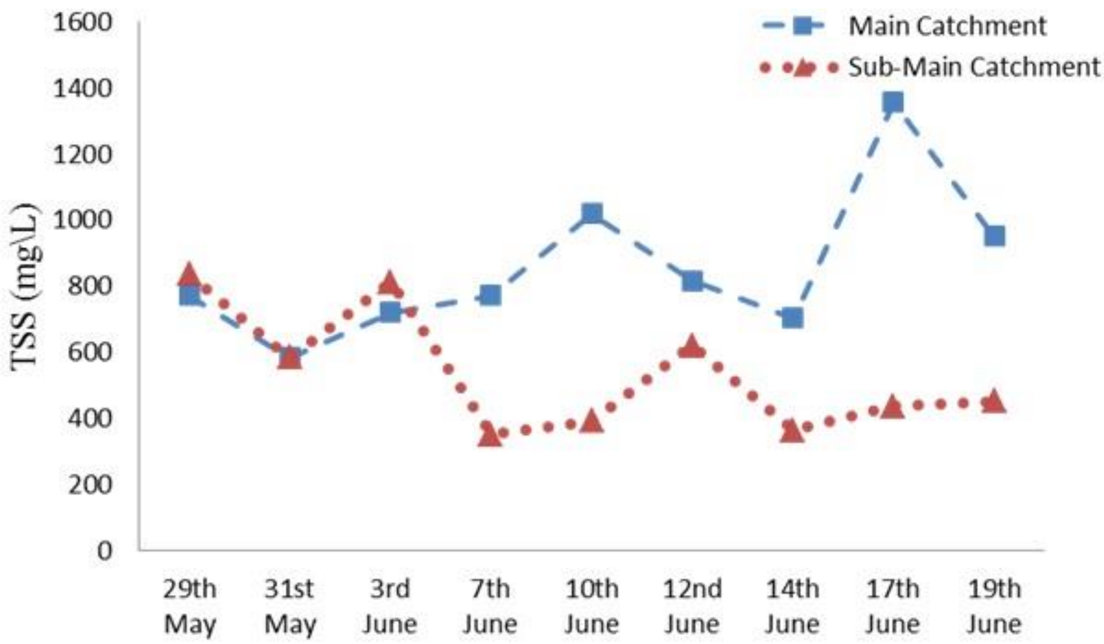

Figure 22: Temporal variability of TSS values for the main and sub-main catchments

- **Sulfates**

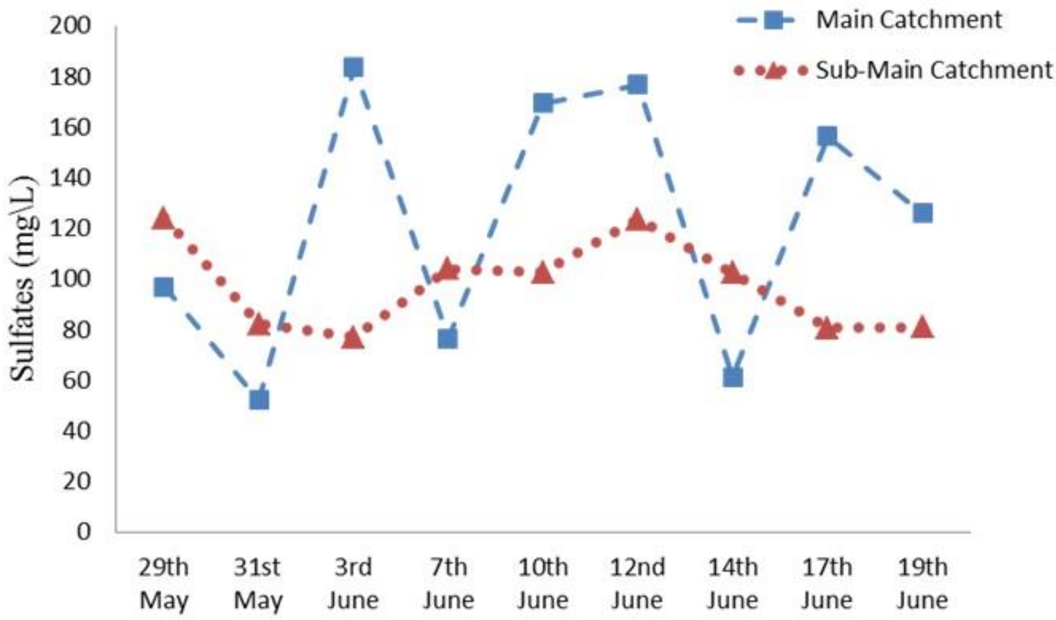

Figure 23: **Temporal variability of Sulfates values for the main and sub-main catchments**Figure 23 depicts the temporal variability of Sulfates values for the measured samples. The results show high variability between working days and non-working days in the main catchment.

The Sulfates values for the Main catchment indicate and show a daily average of 122 mg/L. For the Sub-Main catchment area, the daily average concentration of Sulfates is 97.4 mg/L.

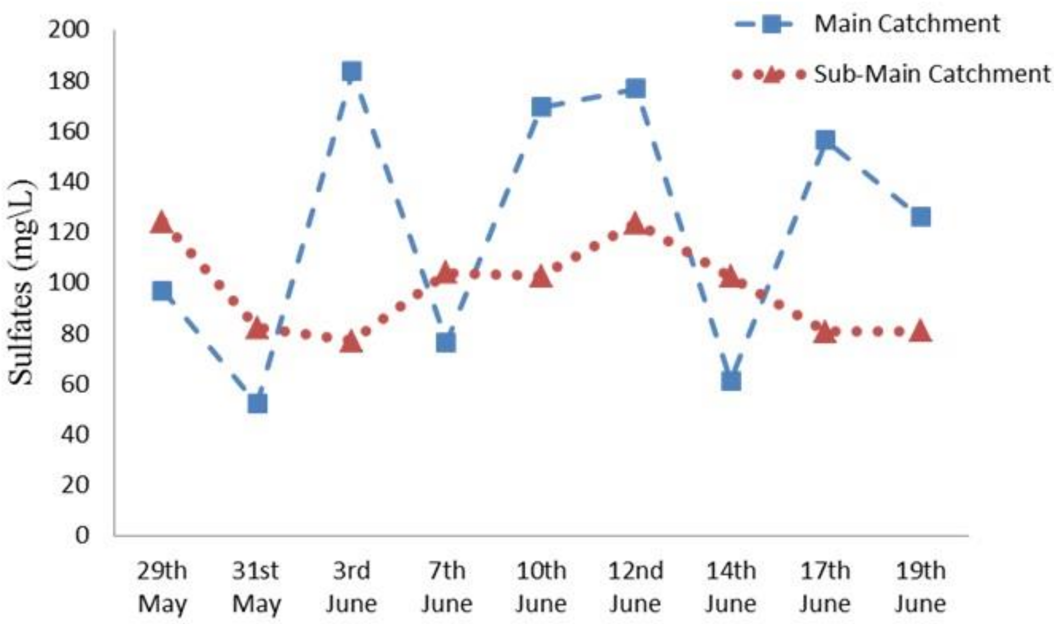

Figure 23: Temporal variability of Sulfates values for the main and sub-main catchments

- **PO_4^{3-}**

Phosphate inputs typically come from agriculture (fertilizers and animal wastes), municipal wastewater discharges (treated and untreated) and industrial sources. Figure 24, shows the temporal variability in Phosphate values for the Main and the Sub-Main catchments.

The Phosphate values for the Main catchment indicate and show high concentrated wastewater with a daily average of 18.93 mg/L. For the Sub catchment area, the results also show high concentrated wastewater with a daily average of 19.05 mg/L.

Since other phosphorus compounds are in a low ppm range, it can be said that the value of total phosphorus represents the PO_4^{3-}.

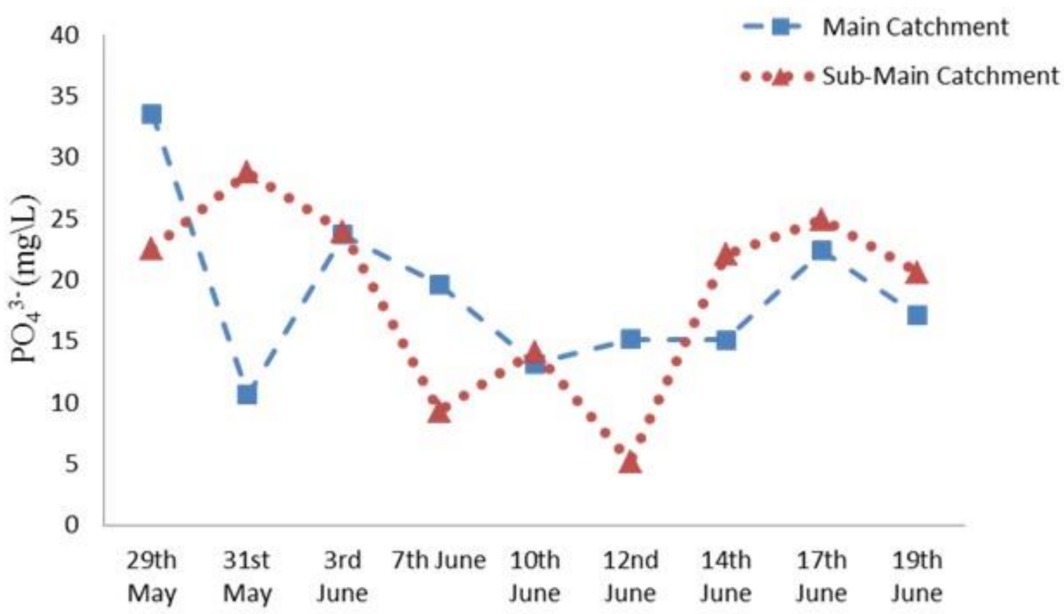

Figure 24: Temporal variability of Phosphate values for the main and sub-main catchments

- **Nitrogen Compounds**

Groundwater and natural water contamination by nitrogen compounds is an increasing problem, essentially related to intensive agriculture, industrial activity, and untreated wastewater drain to the environment. (Gain and Laborie, 2002).

- Ammonium (NH_4-N)

Ammonia is a major component of fertilizers. High concentrations can be found in waste treatment facilities, industrial effluents or fertilizer run off (WHO, 2004).

The ammonia concentration is showing a temporal variability ranging between 47.06 mg/L, and 217.21 mg/L for the Main catchment area, with higher concentration on non-working day. The average daily concentration for ammonia is 148.19 mg/L. For the sub catchment area, the average daily concentration of ammonia is 141.14 mg/L (See Figure 25).

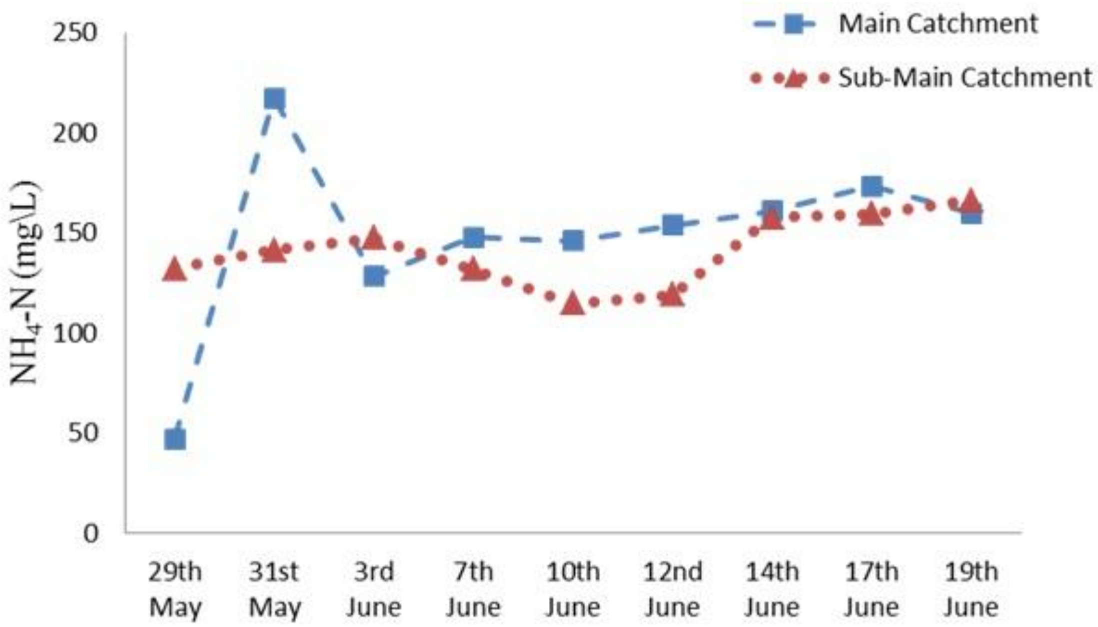

Figure 25: Temporal variability of Ammonia values for the main and sub-main catchments

- Total Nitrogen

The Total Kjeldhahl Nitrogen Method was used in order to determine the total nitrogen (TN). Since Nitrate is in a low ppm range, it can be said that the value of total nitrogen represent the TKN.

Figure 26, shows the temporal variability in TN values for the Main and the Sub-Main catchments.

The TN is showing a temporal variability ranging between 72.93 mg-N/L, and 304 mg-N/L for the Main catchment area, with higher concentration on a non-working day. The average daily concentration is 178 mg-N/L. For the sub-catchment area, the average daily concentration is 180.4 mg-N/L.

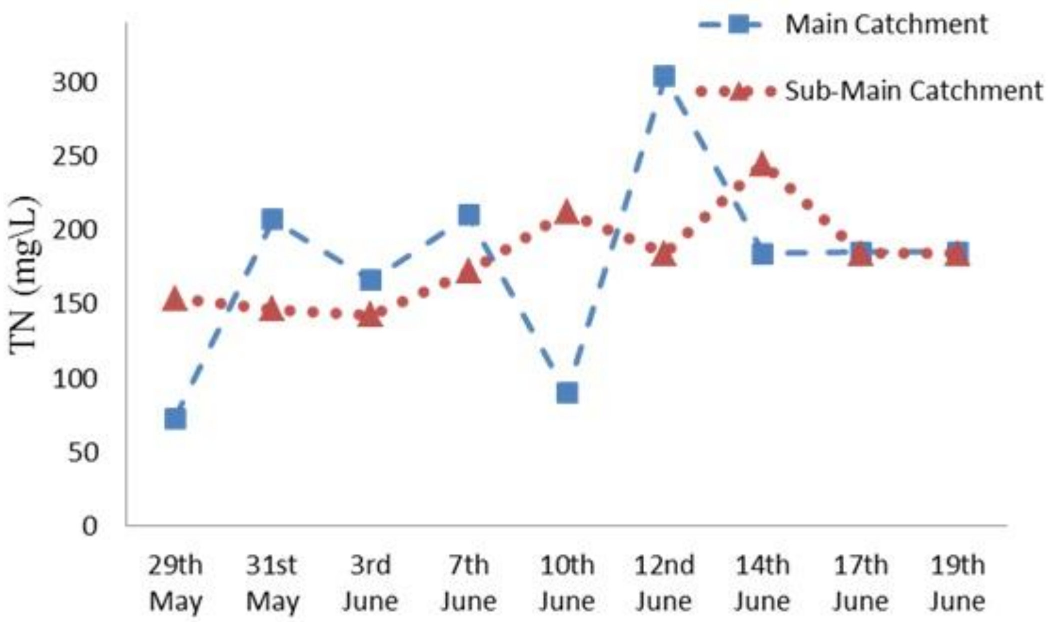

Figure 26: Temporal variability of Total Nitrogen values for the main and sub-main catchments

- **Heavy Metals**

- Nickel

The Nickel was detected on some days of the sampling days. The results show concentration of Nickel in the main catchment, due to the presence of some industrial facilities within its catchment. Figure 27 depicts the temporal variability of Nickel values for the measured samples.

The average daily concentration of Nickel for the main catchment area is 0.167mg/L, while for the sub catchment is 0.026 mg/L.

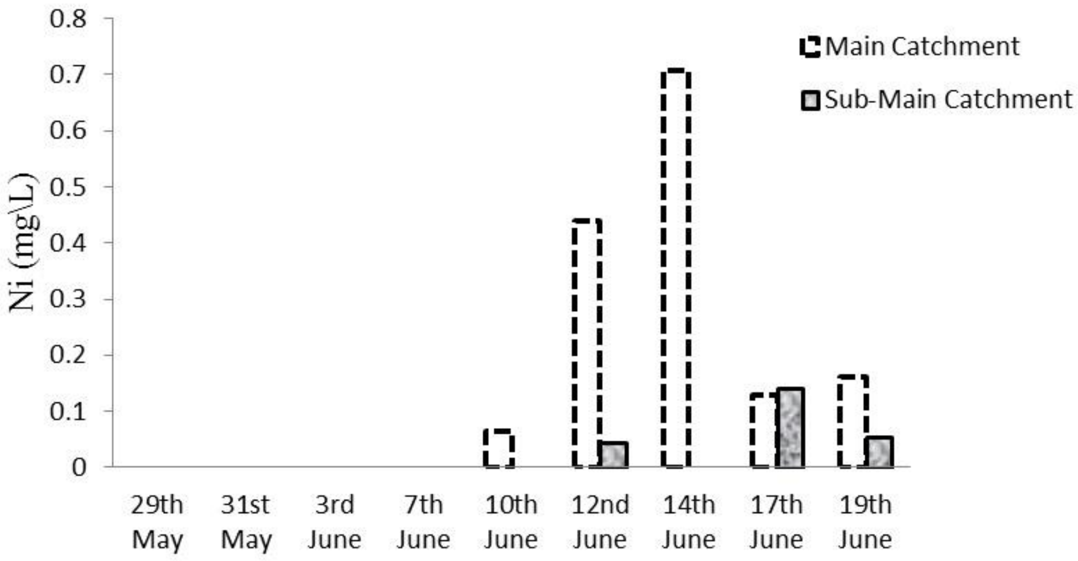

Figure 27: Temporal variability of Nickel concentration for the main and sub-main catchments

- Lead

Figure 28 depicts the concentration of Lead in the wastewater that drains from the main and the sub catchments. The lead was detected on some days of the sampling days. The results show concentration of lead in the main catchment, due to the presence of some industrial facilities within its catchment. The average daily concentration of lead for the main catchment area is 0.17mg/L. while for the sub-main is 0.024 mg/L.

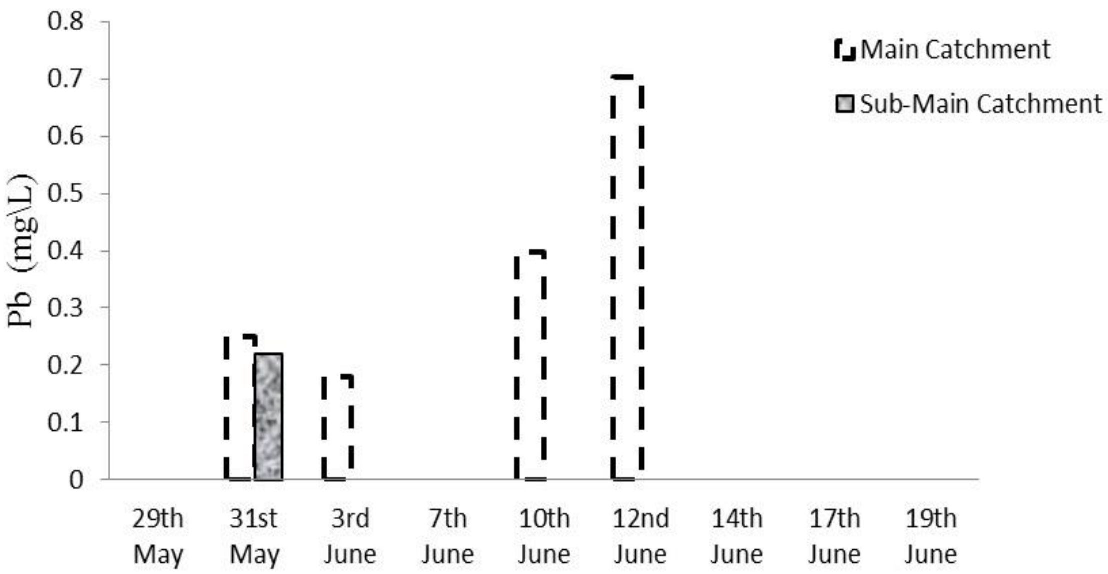

Figure 28: Temporal variability of Lead concentration for the main and sub-main catchments

- Zinc

Figure 29 shows the temporal variability in Zn values. For the main catchment, the results shows higher concentration on a non-working day other than working days with Zn concentration of 0.82 mg/L, and a daily average concentration of 0.51 mg/L.

For the sub-main catchment, Zinc was detected on some days of the sampling. The results show an average daily concentration of Zinc 0.02mg/L.

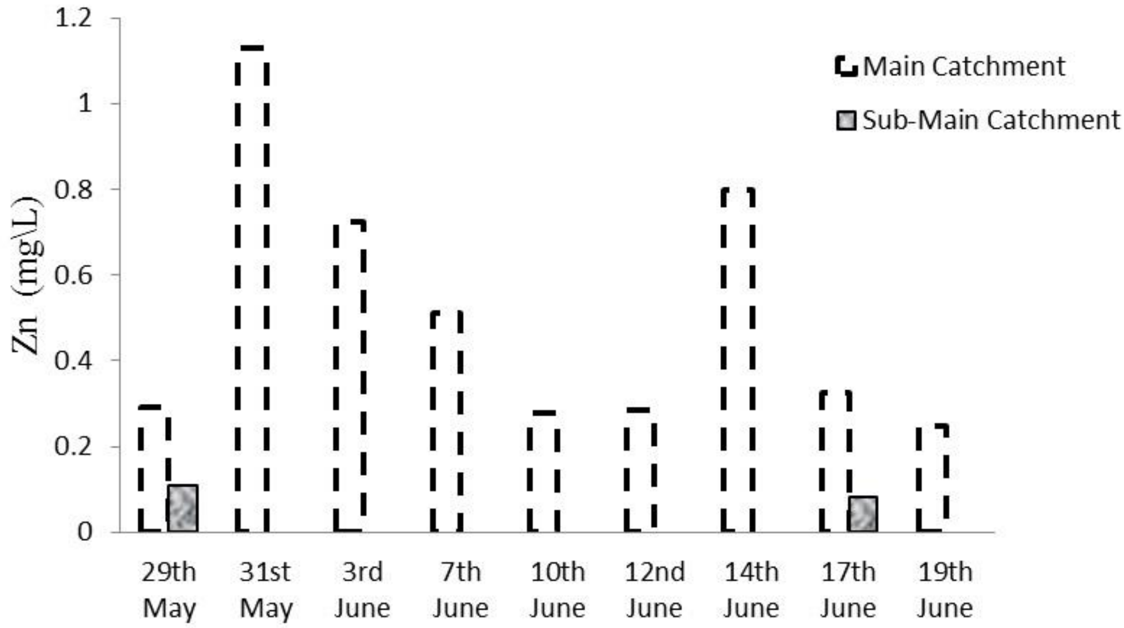

Figure 29: Temporal variability of Zinc concentration for the main and sub-main catchments

- Chromium

From the results, the concentrations of chromium in the samples show a temporal variability and higher concentration at low discharge of wastewater. Figure 30 is a graphical presentation of the chromium concentrations from the various samples from the Main and Sub-Main catchments.

For the main catchment, Chromium was detected on some days of the sampling days. The result shows a daily average concentration of 0.062 mg/L. For the sub-main catchment, Chromium was detected on all the samples. The results show an average daily concentration of Chromium 0.7 mg/L.

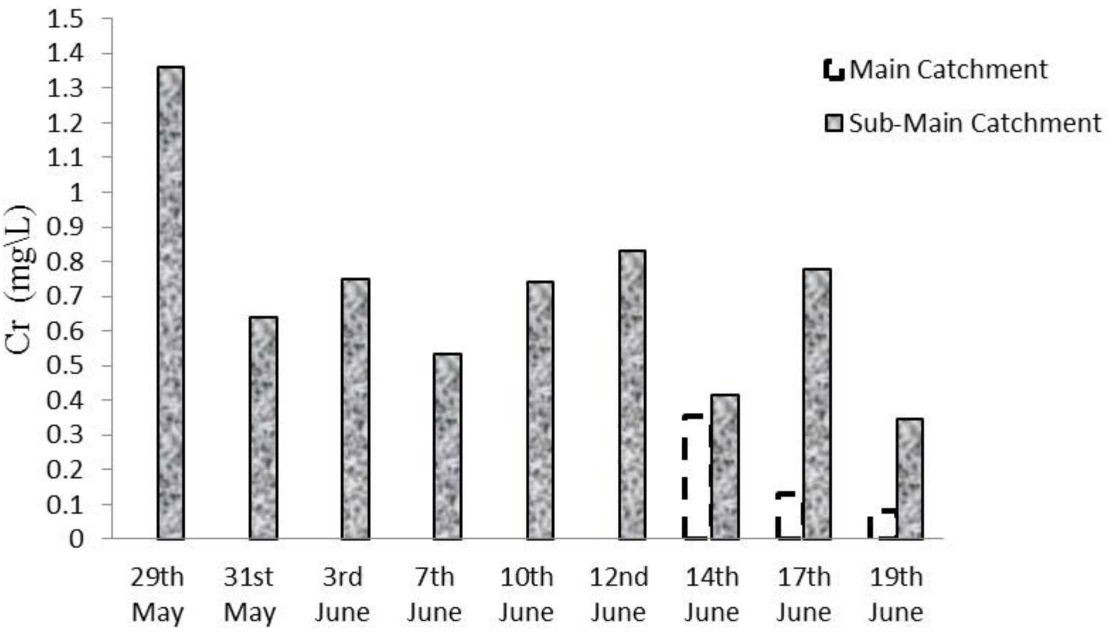

Figure 30: Temporal variability of Chromium concentration for the main and sub-main catchments

- Copper

Figure 31 depicts the concentration of Copper in the wastewater that drains from the main and the sub-main catchment. The Copper was detected on some days of the sampling days for the Main Catchment area with a average daily of 0.195.

For the sub-main catchment, Copper was detected on all the samples. The results show temporal variability with an average daily concentration of Copper 0.2 mg/L.

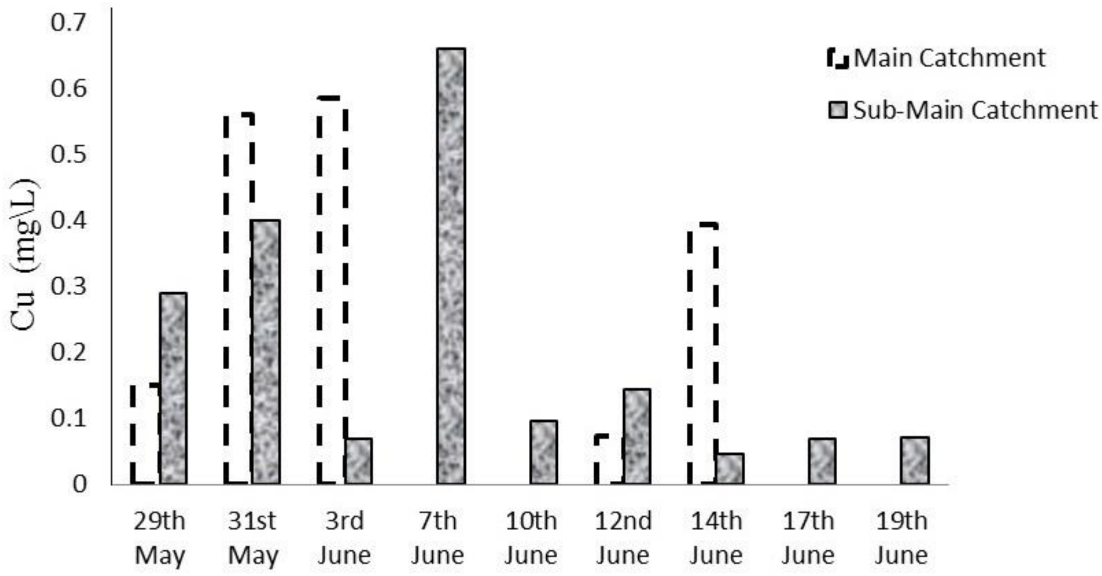

Figure 31: Temporal variability of Copper concentration for the main and sub-main catchments

- Arsenic and Cadmium

Cadmium and Arsenic in wastewater comes from industrial sources such as galvanizing. Household's 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).

Both Arsenic and Cadmium were not detected in any of the samples. Both elements will be neglected in the next chapter analysis.

4.4 Wastewater pollutant load

Wastewater quantities, exfiltration and chemical characteristics for Nablus-East wastewater were summarized in Tables 13, 14, 15, and 16. The results show high pollutants concentrations regarding the TN, TP, COD_T and BOD_5. Strong pollutant concentrations in Palestinian sewage are explained by low water usage, which is common in developing countries (Foppen, 2002; Mahmoud *et al*., 2003).

Based on the calculations, an estimated 17 % of total water consumption and associated pollutants exfiltrate from the sewer network and cesspits to the ground in Nablus-East, while the remaining 65.2% is discharged to the wadi and flow towards wadi Al Fara'a. The percentage of 12.8 is loss of wastewater from the sewer network to the ground as exfiltration and 4.2% infiltrate form cesspits.

For the other five sub-catchments, the percentages that were found from the main and sub main catchment were used in order to find the $WW_{Exfiltrate}$ for each of the different sub-catchment. Equation 6 was developed and applied for the calculation of the different parameter of the mass balance equation. The equation was used for the estimations for the other sub-catchment of the study area.

Equation 6: Other Nablus-East Catchments Findings

$$WW_{Ex\text{-}filtrate} = WC - (WC*I) - (WC*0.82) - (WC*K)$$

Where:

$WW_{Ex\text{-}filtrate}$: Wastewater that infiltrate from the sewer network

WC: Water consumption

I: 0.652

J: 0.822

K: 0.17

Outputs from the Mass balance As per Figure 15 and Figure 18

Table 13 : Total nitrogen pollutant load per day by catchments as absolute loads and loading per year as a function of area from Nablus-East wastewater; 1-5: sub-catchments as per figure 3

Catchment ID	Total nitrogen (kg/day)			Total nitrogen (kg/ha*yr)		
	Total	To Ground	To Wadi	Total	To Ground	To Wadi
Main	958	198	760	23,324	4,808	18,516
Sub-main	5.8	0	5.8	329	0	325
1	105.5	21.7	83.8	5,067	1,039.5	4,027.5
2	19.2	4	15.2	715	130	585
3	6.8	1.4	5.4	1,625	325	1,300
4	7.5	1.6	5.9	390	65	325
5	2.4	0.55	1.85	130	0	130
Total Nablus-East	1105.2	227.25	877.95	688	143	545

The total nitrogen pollutant load per day from Nablus-East wastewater is 1105.2 kg/day. It is ranged between 453 and 1887 kg/day based on the min and max TN concentrations, where the main catchment contributes with 86.7% of the total nitrogen pollutant from Nablus-East.

The total nitrogen pollutant from sewer network exfiltration and cesspits contributes with 15.4% and 5.2% respectively from Nablus-East daily total nitrogen pollutant. See Figure 32.

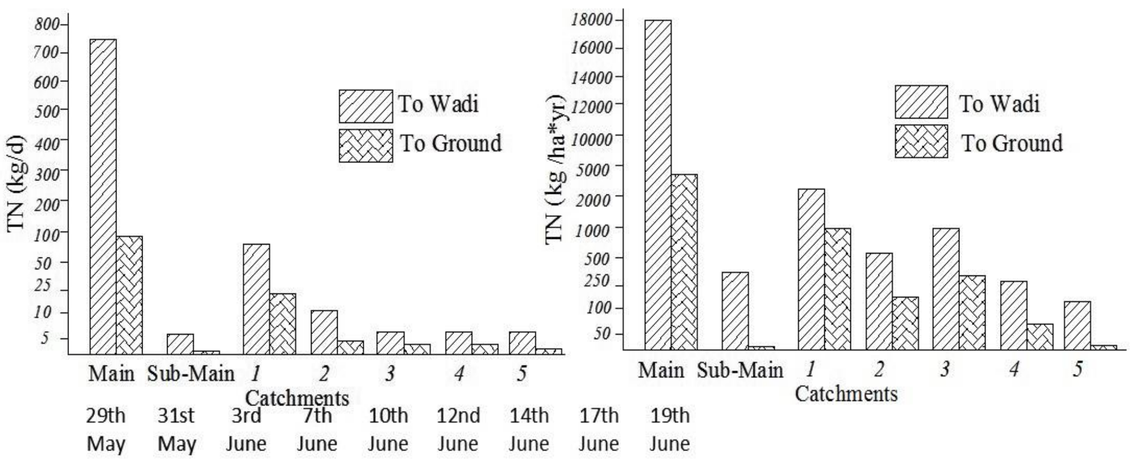

Figure 32: Nitrogen loading by catchments as absolute nitrogen loading (kg/day) and loading by area (kg/ha* yr) from Nablus-East wastewater; 1-5: sub-catchments

In term of loading per area, the results show that 688 (kg/ha*yr) is the yearly TN pollutant load per hectare from wastewater for the study area, where the daily TN pollutant load per hectare from wastewater for the study area is 227.25 (kg/day) as exfiltration.

Table 14: Total phosphorus pollutant load per day by catchments as absolute loads and loading per day as a function of area from Nablus-East wastewater; 1-5: sub-catchments as per figure 3

Catchment ID	Total phosphorus (kg/day)			Total phosphorus (kg/ha*yr)		
	Total	To Ground	To Wadi	Total	To Ground	To Wadi
Main	101.7	21.0	80.7	2476.6	510.5	1966.1
Sub-main	0.6	0.0	0.6	34.7	0.0	34.7
1	11.2	2.3	8.9	538.1	110.4	427.7
2	2.0	0.4	1.6	75.9	13.8	62.1
3	0.7	0.2	0.6	172.5	34.5	138.0
4	0.8	0.2	0.6	41.4	6.9	34.5
5	0.2	0.1	0.2	13.8	0.0	13.8
Total Nablus-East	117.3	24.1	93.2	73.1	15.2	57.9

The total phosphorus pollutant load per day from Nablus-East wastewater is 117.3 kg/day. It is ranged between 65.6 and 208.4 kg/day based on the minimum and maximum TP concentrations. In term of loading per area, the results shows that 73.1 (kg/ha*yr) is the yearly TP pollutant load per hectare for the study area.

Table 15: COD_T pollutant load per day by catchments as absolute loads and loading per day as a function of area from Nablus-East wastewater; 1-5: sub-catchments as per Figure 3

Catchment ID	COD_T (kg/day)			COD_T (kg/ha*yr)		
	Total	To Ground	To Wadi	Total	To Ground	To Wadi
Main	9,402.4	1,942.7	7,459.7	228918	47,186	18,1732
Sub-main	70.3	0.0	70.3	4010	0	4,010
1	1,036.0	213.1	822.8	49737	10,202	39,535
2	188.7	38.4	150.2	7014	1,275	5,739
3	66.4	14.0	52.4	15941	3188	12,753
4	73.4	15.7	57.7	3826	638	3,188
5	22.7	5.2	17.5	1275	0	1,275
Total Nablus-East	10,848.9	2,229.2	8,619.7	6,759	1,403	5,356

The COD_T pollutant load per day from Nablus-East wastewater is 10,849 kg/day. It is ranged between 5,640 and 16,783 kg/day based on the min and max COD_T concentrations. In term of loading per area, the results show that 6,759 (kg/ha*yr) is the yearly COD_T pollutant load per hectare for the study area.

The BOD_5 pollutant load per day from Nablus-East wastewater is 6,117 kg/day. It is ranged between 2005 and 10,225 kg/day based on the min and max BOD_5 concentrations. In term of loading per area, the results show that 3,811 (kg/ha*yr) is the yearly BOD_5 pollutant load per hectare for the study area.

Table 16: BOD_5 pollutant load per day by catchments as absolute loads and loading per day as a function of area from Nablus-East wastewater; 1-5: sub-catchments as per figure 3

Catchment ID	BOD_5 (kg/day)			BOD_5 (kg/ha*yr)		
	Total	To Ground	To Wadi	Total	To Ground	To Wadi
Main	5,301	1,095	4,206	129,069	26,605	102,465
Sub-main	32	0	32	1,798	0	1798
1	584	120	464	28,043	5,752	22,291
2	106	22	85	3,955	719	3,236
3	37	8	30	8,988	1,798	7,191
4	41	9	33	2,157	360	1,798
5	13	3	10	719	0	719
Total Nablus-East	6,117	1,257	4,860	3,811	791	3,020

4.5 Results and Literature Comparison

The results of the thesis study shows different results with (Borst *et al.*, 2012) results. Percentage wise, both studies shows that 20-22% of the total wastewater loads are exfiltration. The differences is due to the calculation of the flow where (Borst *et al.*, 2012) estimates the wastewater flow.

Table 17 shows a comparison of per capita pollutant loads results in the thesis study and (Borst *et al*., 2012) calculated chemical pollutant loads in Nablus-East as per (kg/day) and (kg/ha*yr).

Table 17: Comparison of per capita of chemical pollutant loads results in the thesis study and (Borst *et* al., 2012) calculated chemical pollutant loads in Nablus-East as per (kg/day) and (kg/ha*yr)

	This Research Results			Borst *et al*. (2012)		
Pollutant load (kg/day)	Total load	To ground	To wadi	Total load	To ground	To wadi
Total nitrogen	1105	228	878	638	138	500
Total phosphorus	117	24	93	59	13	46
BOD_5	6,117	1,257	4,860	3256	562	2694

	This Research Results			Borst *et al*. (2012)		
Pollutant load (kg/ha*yr)	Total load	To ground	To wadi	Total load	To ground	To wadi
Total nitrogen	688	143	545	216	47	169
Total phosphorus	73.1	15.2	57.9	20	4	16
BOD_5	3,811	791	3,020	1101	190	911

4.6 Discussion

The total calculated wastewater from Nablus-East that drains to wadi Al-Sajor (Fara’a catchment) is 1.8 million m^3/year. The Exfiltration form the sewer network and form cesspits are 465,740 m^3/year. The total annual rainfall recharge from Nablus-East to Fara’a catchment is between 923,954 and 1,334,600 m^3 (Najem, 2008).

Nablus East sewerage system can be considered as point source pollution to the groundwater as the wastewater drains to wadi Al-Sajor through the seven outlets. While, the exfiltration from the sewer network and cesspits as non-point source that infiltrate to the ground.

The main source of drinking water for the study area is from the municipal wells that lie along Al Farai Catchemnt. Nablus East lies on the Eocene aquifer (Qannam 2003; Najem, 2008), this means that the sewage infiltration may threaten municipal water wells. Samples from the municipal wells within the area, confirms increasingly high levels of nitrate in groundwater (Borst *et al*., 2012).

The nitrogen loading by agriculture in the region is about 1 to 3 (kg/ha*day) (Najem, 2008). This means that wastewater from Nablus-East contribute between 38-65%, with 1.88 (kg/ha*day) as much nitrogen loading by area as agriculture. In term of pollution loads, the contribution is 38.4% (1.49 kg/ha*day) as point source of nitrogen pollution. As non-point source nitrogen pollution, cesspits contribution is 2.5%, where 7.5% form exfiltration.

The urban nitrogen loading rate of 688 (kg/ha*day) calculated for Nablus-East is very high compared with other communities and areas. This can be explained by the high population density in the study area.

The annual pollution loads increase is a proportional of the normal population increase within the study area. The limited source of drinking water was reflected on the low consumption rate per capita and the wastewater high pollutant concentration.

Chapter Five: Conclusions and Recommendations

5.1 Conclusions

1. 17.8% of the water consumption is used outdoor so do not end up in the sewer network.

2. The exfiltration from the sewer network is 12.8% of the water consumption. The rests are 65.2% and 4.2% of water consumption drains to the wadi through the outlets and cesspits respectively.

3. Nablus-East wastewater contribute with 1.88 (kg/ha*day) of nitrogen pollution by area. The contribution is (1.49 kg/ha*day) as point source (through the outlets) of nitrogen pollution, and (0.39 kg/ha*day) as non-point source (exfiltration) of nitrogen pollution.

4. The yearly nitrogen loading rate for Nablus-East is 688 (kg/ha*yr). The exfiltration contributes with 15.4% (105 kg/ha*yr).

5. The yearly nitrogen loading rate per capita in Nablus East is 11.5 (g/c.d). The exfiltration contribution is 2.3(g/c.d).

5.2 Recommendations

1. Pollutions due to exfiltration form sewer networks can be significant and should be monitored.
2. A well rehabilitation plan should be developed for the sewer network, especially in the high dense populated area.
3. Additional studies are needed to model and simulate the fate and transport of wastewater that exfiltrated form the sewer network in the soil under different scenarios and boundary conditions.

ANNEXES

Annex 1: Wastewater Flow Measurements for the Sub-Main Catchment in Nablus-East

Table 18: wastewater flow measurement for the sub-main catchment

	Friday 13. April	Saturday 14. April	Monday 16. April	Thursday 19. April	Monday 23. April
Time	Total Volume (m^3) in 1 hour	Total Volume (m^3) in 1 hour	Total Volume (m^3) in 1 hour	Total Volume (m^3) in 1 hour	Total Volume (m^3) in 1 hour
9:00	2.14	1.65	1.9	1.8	1.37
10:00	2.88	1.74	1.7	1.74	1.54
11:00	3	1.11	1.7	1.6	1.3
12:00	2.06	1.01	1.2	1.46	1.43
13:00	2.09	1.19	1.4	1.36	1.3
14:00	1.92	1.24	1.2	1.32	1.6
15:00	2.05	1.21	1.4	1.28	1.8
16:00	1.28	1.12	1.6	1.3	1.7
17:00	1.13	1.34	1.4	1.32	1.6
18:00	1	1.72	1.5	1.4	1.3
19:00	0.93	1.4	1.6	1.5	1.3
20:00	1.62	1.31	0.9	0.81	0.8
21:00	1.64	0.95	-	-	-
22:00	1.25	0.74	-	-	-
23:00	0.85	0.57	-	-	-
0:00	0.78	0.37	-	-	-
1:00	0.64	0.23	-	-	-
2:00	0.55	0.47	-	-	-
3:00	0.55	0.61	-	-	-
4:00	0.6	0.91	-	-	-
5:00	0.6	1.49	1.4	1.31	1.36
6:00	1.27	1.83	2.3	2.1	1.7
7:00	2.33	1.94	3.6	3.1	2.9
8:00	2.92	1.61	2.8	3.2	2.4
Total (m^3)	36.08	27.76	33.2	32.2	31

Annex 2: Wastewater Flow Measurements for the Main Catchment in Nablus-East

Table 19: Average Daily wastewater flow for the main catchment

Time	Depth (cm)	Q (m^3/sec)	Avg. Q (m^3/sec)	Total Volume (m^3) in 30 minutes	Time	Depth (cm)	Q (m3/sec)	Avg. Q (m^3/sec)	Total Volume (m^3) for 30 minutes
5:00	3	0.018	0.0176	31.7	17:00	5	0.04	0.0366	66.0
5:30	3.5	0.0173	0.02	35.6	17:30	4.5	0.0335	0.031	55.1
6:00	3.5	0.022	0.022	40.1	18:00	4.5	0.0276	0.0276	49.8
6:30	3.5	0.022	0.031	55.8	18:30	4.5	0.0276	0.022	40.5
7:00	5	0.04	0.04	71.6	19:00	3	0.017	0.025	45.7
7:30	5	0.04	0.05	90.5	19:30	4.5	0.033	0.033	60.4
8:00	6.5	0.061	0.06	109.4	20:00	4.5	0.033	0.03	55.1
8:30	6.5	0.061	0.077	138.8	20:30	4.5	0.027	0.022	40.5
9:00	8.5	0.094	0.085	153.0	21:00	3	0.017	0.017	31.1
9:30	7.5	0.076	0.09	161.0	21:30	3	0.017	0.017	31.1
10:00	9	0.102	0.107	192.5	22:00	-	-	-	31.1
10:30	9.5	0.11	0.126	227.0	22:30	-	-	-	31.1
11:00	11	0.14	0.14	253.2	23:00	-	-	-	31.1
11:30	11	0.14	0.14	253.2	23:30	-	-	-	31.1
12:00	11	0.14	0.14	253.2	0:00	-	-	-	31.1
12:30	11	0.14	0.135	244.2	0:30	-	-	-	31.1
13:00	10.5	0.131	0.126	226.5	1:00	-	-	-	31.1
13:30	10	0.121	0.107	193.0	1:30	-	-	-	31.1
14:00	8.5	0.093	0.081	145.8	2:00	-	-	-	31.1
14:30	7	0.068	0.061	109.8	2:30	-	-	-	31.1
15:00	6	0.053	0.053	96.2	3:00	-	-	-	31.1
15:30	6	0.053	0.053	96.2	3:30	-	-	-	31.1
16:00	6	0.053	0.053	96.2	4:00	-	-	-	31.1
16:30	6	0.053	0.0466	83.9	4:30	-	-	-	31.7
								Total (m^3)	4270

Table 20: Non-working day wastewater flow measurement for the main catchment on Friday 31.may

Time	Depth (cm)	Q (m^3/sec)	Avg. Q (m^3/sec)	Total Volume (m^3) in 30 minutes	Time	Depth (cm)	Q (m3/sec)	Avg. Q (m^3/sec)	Total Volume (m^3) for 30 minutes
5:00	3	0.0179	0.0176	31.7	17:00	5	0.0398	0.0398	71.6
5:30	3	0.0173	0.0173	31.1	17:30	5	0.0398	0.0398	71.6
6:00	3	0.0173	0.0225	40.5	18:00	5	0.0398	0.0466	83.9
6:30	4	0.0277	0.0277	49.8	18:30	6	0.0534	0.0534	96.2
7:00	4	0.0277	0.0306	55.1	19:00	6	0.0534	0.0610	109.8
7:30	4.5	0.0335	0.0335	60.4	19:30	7	0.0685	0.0541	97.5
8:00	4.5	0.0335	0.0367	66.0	20:00	5	0.0398	0.0285	51.4
8:30	5	0.0398	0.0398	71.6	20:30	3	0.0173	0.0173	31.1
9:00	5	0.0398	0.0398	71.6	21:00	3	0.0173	0.0173	31.1
9:30	5	0.0398	0.0466	83.9	21:30	3	0.0173	0.0173	31.1
10:00	6	0.0534	0.0610	109.8	22:00	-	-	-	31.1
10:30	7	0.0685	0.0810	145.8	22:30	-	-	-	31.1
11:00	8.5	0.0935	0.0892	160.5	23:00	-	-	-	31.1
11:30	8	0.0848	0.1029	185.3	23:30	-	-	-	31.1
12:00	10	0.1210	0.1163	209.3	0:00	-	-	-	31.1
12:30	9.5	0.1116	0.1364	245.6	0:30	-	-	-	31.1
13:00	12	0.1613	0.1613	290.3	1:00	-	-	-	31.1
13:30	12	0.1613	0.1613	290.3	1:30	-	-	-	31.1
14:00	12	0.1613	0.1411	254.1	2:00	-	-	-	31.1
14:30	10	0.1210	0.1029	185.3	2:30	-	-	-	31.1
15:00	8	0.0848	0.0848	152.7	3:00	-	-	-	31.1
15:30	8	0.0848	0.0767	138.0	3:30	-	-	-	31.1
16:00	7	0.0685	0.0610	109.8	4:00	-	-	-	31.1
16:30	6	0.0534	0.0466	83.9	4:30	-	-	-	31.7
								Total (m^3)	4231

Table 211: wastewater flow measurement for the main catchment on Monday 03.june

Time	Depth (cm)	Q (m^3/sec)	Avg. Q (m^3/sec)	Total Volume (m^3) in 30 minutes	Time	Depth (cm)	Q (m3/sec)	Avg. Q (m^3/sec)	Total Volume (m^3) for 30 minutes
5:00	3	0.0179	0.0176	31.7	17:00	6	0.0534	0.0534	96.2
5:30	3	0.0173	0.0198	35.6	17:30	6	0.0534	0.0466	83.9
6:00	3.5	0.0223	0.0250	44.9	18:00	5	0.0398	0.0431	77.6
6:30	4	0.0277	0.0337	60.7	18:30	5.5	0.0464	0.0431	77.6
7:00	5	0.0398	0.0398	71.6	19:00	5	0.0398	0.0367	66.0
7:30	5	0.0398	0.0623	112.2	19:30	4.5	0.0335	0.0335	60.4
8:00	8	0.0848	0.0848	152.7	20:00	4.5	0.0335	0.0367	66.0
8:30	8	0.0848	0.1029	185.3	20:30	5	0.0398	0.0285	51.4
9:00	10	0.1210	0.0988	177.8	21:00	-	-	-	31.1
9:30	7.5	0.0765	0.0988	177.8	21:30	-	-	-	31.1
10:00	10	0.1210	0.1308	235.5	22:00	-	-	-	31.1
10:30	11	0.1407	0.1407	253.2	22:30	-	-	-	31.1
11:00	11	0.1407	0.1407	253.2	23:00	-	-	-	31.1
11:30	11	0.1407	0.1407	253.2	23:30	-	-	-	31.1
12:00	11	0.1407	0.1407	253.2	0:00	-	-	-	31.1
12:30	11	0.1407	0.1357	244.2	0:30	-	-	-	31.1
13:00	10.5	0.1307	0.1259	226.5	1:00	-	-	-	31.1
13:30	10	0.1210	0.1117	201.0	1:30	-	-	-	31.1
14:00	9	0.1024	0.0854	153.8	2:00	-	-	-	31.1
14:30	7	0.0685	0.0647	116.4	2:30	-	-	-	31.1
15:00	6.5	0.0608	0.0571	102.8	3:00	-	-	-	31.1
15:30	6	0.0534	0.0534	96.2	3:30	-	-	-	31.1
16:00	6	0.0534	0.0534	96.2	4:00	-	-	-	31.1
16:30	6	0.0534	0.0534	96.2	4:30	-	-	-	31.7
								Total (m^3)	4705

Table 22: wastewater flow measurement for the main catchment on Monday (10.june)

Time	Depth (cm)	Q (m^3/sec)	Avg. Q (m^3/sec)	Total Volume (m^3) in 30 minutes	Time	Depth (cm)	Q (m3/sec)	Avg. Q (m^3/sec)	Total Volume (m^3) for 30 minutes
5:00	3	0.0179	0.0176	31.7	17:00	5	0.0398	0.0398	71.6
5:30	3	0.0173	0.0173	31.1	17:30	5	0.0398	0.0337	60.7
6:00	3	0.0173	0.0198	35.6	18:00	4	0.0277	0.0337	60.7
6:30	3.5	0.0223	0.0250	44.9	18:30	5	0.0398	0.0337	60.7
7:00	4	0.0277	0.0277	49.8	19:00	4	0.0277	0.0277	49.8
7:30	4	0.0277	0.0406	73.0	19:30	4	0.0277	0.0277	49.8
8:00	6	0.0534	0.0610	109.8	20:00	4	0.0277	0.0337	60.7
8:30	7	0.0685	0.0767	138.0	20:30	5	0.0398	0.0285	51.4
9:00	8	0.0848	0.0767	138.0	21:00	-	-	-	31.1
9:30	7	0.0685	0.0767	138.0	21:30	-	-	-	31.1
10:00	8	0.0848	0.0936	168.5	22:00	-	-	-	31.1
10:30	9	0.1024	0.1024	184.3	22:30	-	-	-	31.1
11:00	9	0.1024	0.1215	218.7	23:00	-	-	-	31.1
11:30	11	0.1407	0.1407	253.2	23:30	-	-	-	31.1
12:00	11	0.1407	0.1407	253.2	0:00	-	-	-	31.1
12:30	11	0.1407	0.1308	235.5	0:30	-	-	-	31.1
13:00	10	0.1210	0.1210	217.8	1:00	-	-	-	31.1
13:30	10	0.1210	0.1029	185.3	1:30	-	-	-	31.1
14:00	8	0.0848	0.0691	124.5	2:00	-	-	-	31.1
14:30	6	0.0534	0.0534	96.2	2:30	-	-	-	31.1
15:00	6	0.0534	0.0534	96.2	3:00	-	-	-	31.1
15:30	6	0.0534	0.0534	96.2	3:30	-	-	-	31.1
16:00	6	0.0534	0.0466	83.9	4:00	-	-	-	31.1
16:30	5	0.0398	0.0398	71.6	4:30	-	-	-	31.7
								Total (m^3)	4045

Table 23: wastewater flow measurement for the main catchment on Wednesday (12.june)

Time	Depth (cm)	Q (m^3/sec)	Avg. Q (m^3/sec)	Total Volume (m^3) in 30 minutes	Time	Depth (cm)	Q (m3/sec)	Avg. Q (m^3/sec)	Total Volume (m^3) for 30 minutes
5:00	3	0.0179	0.0176	31.7	17:00	6	0.0534	0.0406	73.0
5:30	3	0.0173	0.0173	31.1	17:30	4	0.0277	0.0277	49.8
6:00	3	0.0173	0.0225	40.5	18:00	4	0.0277	0.0337	60.7
6:30	4	0.0277	0.0277	49.8	18:30	5	0.0398	0.0337	60.7
7:00	4	0.0277	0.0337	60.7	19:00	4	0.0277	0.0277	49.8
7:30	5	0.0398	0.0466	83.9	19:30	4	0.0277	0.0277	49.8
8:00	6	0.0534	0.0610	109.8	20:00	4	0.0277	0.0337	60.7
8:30	7	0.0685	0.0767	138.0	20:30	3	0.0398	0.0285	51.4
9:00	8	0.0848	0.0848	152.7	21:00	3	0.0173	0.0173	31.1
9:30	8	0.0848	0.0848	152.7	21:30	3	0.0173	0.0173	31.1
10:00	8	0.0848	0.0848	152.7	22:00	-	-	-	31.1
10:30	8	0.0848	0.0936	168.5	22:30	-	-	-	31.1
11:00	9	0.1024	0.1117	201.0	23:00	-	-	-	31.1
11:30	10	0.1210	0.1210	217.8	23:30	-	-	-	31.1
12:00	10	0.1210	0.1411	254.1	0:00	-	-	-	31.1
12:30	12	0.1613	0.1318	237.3	0:30	-	-	-	31.1
13:00	9	0.1024	0.1024	184.3	1:00	-	-	-	31.1
13:30	9	0.1024	0.1024	184.3	1:30	-	-	-	31.1
14:00	9	0.1024	0.0779	140.2	2:00	-	-	-	31.1
14:30	6	0.0534	0.0610	109.8	2:30	-	-	-	31.1
15:00	7	0.0685	0.0685	123.3	3:00	-	-	-	31.1
15:30	7	0.0685	0.0685	123.3	3:30	-	-	-	31.1
16:00	7	0.0685	0.0610	109.8	4:00	-	-	-	31.1
16:30	6	0.0534	0.0534	96.2	4:30	-	-	-	31.7
								Total (m^3)	4101

Annex 3: Laboratory Reports of the Wastewater Parameters for the Main and Sub-Main Catchment

جامعة بيرزيت
BIRZEIT UNIVERSITY
Birzeit University Testing Laboratories

Environmental Unit
PS/ISO 17025 Accredited
Phone : 02-2982010/ 02-2982102
Fax : 02-2982166

Analytical Report

Report Date : 20 June 2013
Customer : Institute of Environmental and Water Studies

Sample Code	: ES-20132683
Source Sample Code	:
Sample Name	: Waste Water
Sample Receiving Date	: 30 May 2013
Category	: Waste Water
Batch No.	:
Sample Size	: 1 L
Origin	: Osama Shaheen
Representative	:
Container Type	: Plastic
Sample Condition	: OK
Sampled By	: Tareq Aqhoush

Test	Result	Method	Comments	Test Date
Nickel	Not detected	ICP	DL= 15 ppb	04 JUN 2013
Lead	Not detected	ICP	DL= 40 ppb	04 JUN 2013
Arsenic	Not detected	ICP	DL= 50 ppb	04 JUN 2013
Chromium	Not detected	ICP	DL= 7 ppb	04 JUN 2013
Zinc	0.29 ppm	ICP		04 JUN 2013
Copper	0.15 ppm	ICP		04 JUN 2013
Cadmium	Not detected	ICP	DL=4 ppb	04 JUN 2013
Sulfates	96.8 ppm	CIA		04 JUN 2013
Nitrates	Below Detection Limit	CIA	Detection Limit = 50 ppb	11 JUN 2013
Total Kjeldahl Nitrogen	72.93 mgN/l	AOAC		20 JUN 2013

* The Center is only responsible for the results of the sample tested.

Signatures:

Belal Amous
Director of BZUTL

1034849

Senior Analyst,
Environmental Unit

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Page 1 of 1

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Birzeit University Testing Laboratories

Environmental Unit
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Analytical Report

Report Date : 20 June 2013
Customer : Institute of Environmental and Water Studies

Sample Code	: ES-20132704
Source Sample Code	: S
Sample Name	: S
Sample Receiving Date	: 03 June 2013
Category	: Waste Water
Batch No.	:
Sample Size	: 1 L
Origin	: Osama Shaheen
Representative	:
Container Type	: Plastic
Sample Condition	: OK
Sampled By	: Tareq Aqhoush

Test	Result	Method	Comments	Test Date
Nickel	Not detected	ICP	DL= 15 ppb	20 JUN 2013
Lead	Not detected	ICP	DL= 40 ppb	20 JUN 2013
Arsenic	Not detected	ICP	DL= 50 ppb	20 JUN 2013
Chromium	Not detected	ICP	DL= 7 ppb	20 JUN 2013
Zinc	0.75 ppm	ICP		20 JUN 2013
Copper	0.068 ppm	ICP		20 JUN 2013
Cadmium	Not detected	ICP	DL= 4 ppb	20 JUN 2013
Sulfates	76.9 ppm	CIA		10 JUN 2013
Nitrates	Below Detection Limit	CIA	Detection Limit = 50 ppb	11 JUN 2013
Total Kjeldahl Nitrogen	142.44 mgN/l	AOAC		20 JUN 2013

* The Center is only responsible for the results of the sample tested.

Signatures:

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Director of BZUTL

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Environmental Unit
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Analytical Report

Report Date : 20 June 2013
Customer : Institute of Environmental and Water Studies

Sample Code	: ES-20132708
Source Sample Code	: S
Sample Name	: S
Sample Receiving Date	: 08 June 2013
Category	: Waste Water
Batch No.	:
Sample Size	: 1 L
Origin	: Osama Shaheen
Representative	:
Container Type	: Plastic
Sample Condition	: OK
Sampled By	: Osama Shaheen

Test	Result	Method	Comments	Test Date
Nickel	Not detected	ICP	DL= 15 ppb	20 JUN 2013
Lead	Not detected	ICP	DL= 40 ppb	20 JUN 2013
Arsenic	Not detected	ICP	DL= 50 ppb	20 JUN 2013
Chromium	Not detected	ICP	DL= 7 ppb	20 JUN 2013
Zinc	0.532 ppm	ICP		20 JUN 2013
Copper	0.066 ppm	ICP		20 JUN 2013
Cadmium	Not detected	ICP	DL= 4 ppb	20 JUN 2013
Sulfates	104.0 ppm	CIA		11 JUN 2013
Nitrates	Below Detection Limit	CIA	Detection Limit = 50 ppb	11 JUN 2013
Total Kjeldahl Nitrogen	172.19 mgN/l	AOAC		20 JUN 2013

* The Center is only responsible for the results of the sample tested.

Signatures:

Belal Amous
Director of BZUTL

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Analytical Report

Report Date : 02 July 2013
Customer : Institute of Environmental and Water Studies

Sample Code : ES-20132713
Source Sample Code : S
Sample Name : S
Sample Receiving Date : 12 June 2013
Category : Waste Water
Batch No. :
Sample Size : 1 L
Origin : Osama Shaheen
Representative :
Container Type : Plastic
Sample Condition : OK
Sampled By : Osama Shaheen

Test	Result	Method	Comments	Test Date
Nickel	Not detected	ICP	DL= 15 ppb	25 JUN 2013
Lead	Not detected	ICP	DL = 40 ppb	25 JUN 2013
Arsenic	Not detected	ICP	DL= 50 ppb	25 JUN 2013
Chromium	Not detected	ICP	DL= 7 ppb	25 JUN 2013
Zinc	0.74 ppm	ICP		25 JUN 2013
Copper	0.096 ppm	ICP		25 JUN 2013
Cadmium	Not detected	ICP	DL = 4 ppb	25 JUN 2013
Sulfates	102.5 ppm	CIA		19 JUN 2013
Nitrates	1.58 ppm	CIA		19 JUN 2013
Total Kjeldahl Nitrogen	212 mg/L	AOAC		02 JUL 2013

* The Center is only responsible for the results of the sample tested.

Signatures:

Belal Amous

Director of BZUTL

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Senior Analyst,
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Birzeit University Testing Laboratories

Environmental Unit
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Analytical Report

Report Date : 02 July 2013
Customer : Institute of Environmental and Water Studies

Sample Code	: ES-20132716
Source Sample Code	: S
Sample Name	: S
Sample Receiving Date	: 12 June 2013
Category	: Waste Water
Batch No.	:
Sample Size	: 1 L
Origin	: Osama Shaheen
Representative	:
Container Type	: Plastic
Sample Condition	: OK
Sampled By	: Osama Shaheen

Test	Result	Method	Comments	Test Date
Nickel	0.044 ppm	ICP		25 JUN 2013
Lead	Not detected	ICP	DL= 40 ppb	25 JUN 2013
Arsenic	Not detected	ICP	DL = 50 ppb	25 JUN 2013
Chromium	Not detected	ICP	DL = 7 ppb	25 JUN 2013
Zinc	0.830 ppm	ICP		25 JUN 2013
Copper	0.144 ppm	ICP		25 JUN 2013
Cadmium	Not detected	ICP	DL= 4 ppb	25 JUN 2013
Sulfates	123.5 ppm	CIA		19 JUN 2013
Nitrates	Below Detection Limit	CIA	Detection Limit = 50 ppb	19 JUN 2013
Total Kjeldahl Nitrogen	184 mg/L	AOAC		02 JUL 2013

* The Center is only responsible for the results of the sample tested.

Signatures:

Belal Amous

Director of BZUTL

* 1 0 3 4 9 5 4 *

Hana' Ali

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BIRZEIT UNIVERSITY
Birzeit University Testing Laboratories

Environmental Unit
PS/ISO 17025 Accredited
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Analytical Report

Report Date : 02 July 2013
Customer : Institute of Environmental and Water Studies

Sample Code : ES-20132718
Source Sample Code : S
Sample Name : S
Sample Receiving Date : 17 June 2013
Category : Waste Water
Batch No. :
Sample Size : 1 L
Origin : Osama Shaheen
Representative :
Container Type : Plastic
Sample Condition : OK
Sampled By : Osama Shaheen

Test	Result	Method	Comments	Test Date
Nickel	Not detected	ICP	DL = 15 ppb	25 JUN 2013
Lead	Not detected	ICP	DL= 40 ppb	25 JUN 2013
Arsenic	Not detected	ICP	DL = 50 ppb	25 JUN 2013
Chromium	Not detected	ICP	DL =7 ppb	25 JUN 2013
Zinc	0.414 ppm	ICP		25 JUN 2013
Copper	0.046 ppm	ICP		25 JUN 2013
Cadmium	Not detected	ICP	DL =4 ppb	25 JUN 2013
Sulfates	102.4 ppm	CIA		19 JUN 2013
Nitrates	Below Detection Limit	CIA	Detection Limit = 50 ppb	19 JUN 2013
Total Kjeldahl Nitrogen	245 mg/L	AOAC		02 JUL 2013

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Analytical Report

Report Date : 02 July 2013
Customer : Institute of Environmental and Water Studies

Sample Code	: ES-20132719
Source Sample Code	: S
Sample Name	: S
Sample Receiving Date	: 17 June 2013
Category	: Waste Water
Batch No.	:
Sample Size	: 1 L
Origin	: Osama Shaheen
Representative	:
Container Type	: Plastic
Sample Condition	: OK
Sampled By	: Osama Shaheen

Test	Result	Method	Comments	Test Date
Nickel	0.142 ppm	ICP		25 JUN 2013
Lead	Not detected	ICP	DL= 40 ppb	25 JUN 2013
Arsenic	Not detected	ICP	DL= 50 ppb	25 JUN 2013
Chromium	0.082 ppm	ICP		25 JUN 2013
Zinc	0.778 ppm	ICP		25 JUN 2013
Copper	0.070 ppm	ICP		25 JUN 2013
Cadmium	Not detected	ICP	DL = 4 ppb	25 JUN 2013
Sulfates	80.7 ppm	CIA		19 JUN 2013
Nitrates	Below Detection Limit	CIA	Detection Limit = 50 ppb	19 JUN 2013
Total Kjeldahl Nitrogen	184 mg/L	AOAC		02 JUL 2013

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Analytical Report

Report Date : 02 July 2013
Customer : Institute of Environmental and Water Studies

Sample Code	: ES-20132725
Source Sample Code	: S - 19/06/2013
Sample Name	: S - 19/06/2013
Sample Receiving Date	: 19 June 2013
Category	: Waste Water
Batch No.	:
Sample Size	: 1 L
Origin	: Osama Shaheen
Representative	:
Container Type	: Plastic
Sample Condition	: OK
Sampled By	: Osama Shaheen

Test	Result	Method	Comments	Test Date
Nickel	0.054 ppm	ICP		25 JUN 2013
Lead	Not detected	ICP	DL= 40 ppb	25 JUN 2013
Arsenic	Not detected	ICP	DL = 50 ppb	25 JUN 2013
Chromium	Not detected	ICP	DL = 7 ppb	25 JUN 2013
Zinc	0.346 ppm	ICP		25 JUN 2013
Copper	0.072 ppm	ICP		25 JUN 2013
Cadmium	Not detected	ICP	DL= 4 ppb	25 JUN 2013
Sulfates	81.0 ppm	CIA		19 JUN 2013
Nitrates	Below Detection Limit	CIA	Detection Limit = 50 ppb	19 JUN 2013
Total Kjeldahl Nitrogen	184 mg/L	AOAC		02 JUL 2013

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Analytical Report

Report Date : 20 June 2013
Customer : Institute of Environmental and Water Studies

Sample Code	: ES-20132692
Source Sample Code	: Big Catchment
Sample Name	: Big Catchment
Sample Receiving Date	: 01 June 2013
Category	: Waste Water
Batch No.	:
Sample Size	: 1 L
Origin	: Osama Shaheen
Representative	:
Container Type	: Plastic
Sample Condition	: OK
Sampled By	: Tareq Aqhoush

Test	Result	Method	Comments	Test Date
Nickel	Not detected	ICP	DL= 15 ppb	04 JUN 2013
Lead	0.25 ppm	ICP		04 JUN 2013
Chromium	Not detected	ICP	DL= 7 ppb	04 JUN 2013
Zinc	1.13 ppm	ICP		04 JUN 2013
Copper	0.56 ppm	ICP		04 JUN 2013
Cadmium	Not detected	ICP	DL= 4 ppb	04 JUN 2013
Sulfates	52.2 ppm	CIA		04 JUN 2013
Nitrates	Below Detection Limit	CIA	Detection Limit = 50 ppb	11 JUN 2013
Total Kjeldahl Nitrogen	207.22 mgN/l	AOAC		20 JUN 2013

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Analytical Report

Report Date : 20 June 2013
Customer : Institute of Environmental and Water Studies

Sample Code	: ES-20132705
Source Sample Code	: B
Sample Name	: B
Sample Receiving Date	: 03 June 2013
Category	: Waste Water
Batch No.	:
Sample Size	: 1 L
Origin	: Osama Shaheen
Representative	:
Container Type	: Plastic
Sample Condition	: OK
Sampled By	: Tareq Aqhoush

Test	Result	Method	Comments	Test Date
Nickel	Not detected	ICP	DL= 15 ppb	20 JUN 2013
Lead	0.18 ppm	ICP		20 JUN 2013
Arsenic	Not detected	ICP	DL= 50 ppb	20 JUN 2013
Chromium	Not detected	ICP	DL= 7 ppb	20 JUN 2013
Zinc	0.724 ppm	ICP		20 JUN 2013
Copper	0.586 ppm	ICP		20 JUN 2013
Cadmium	Not detected	ICP	DL= 4 ppb	20 JUN 2013
Sulfates	183.6 ppm	CIA		10 JUN 2013
Nitrates	Below Detection Limit	CIA	Detection Limit = 50 ppb	11 JUN 2013
Total Kjeldahl Nitrogen	166 mgN/l	AOAC		20 JUN 2013

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Analytical Report

Report Date : 20 June 2013
Customer : Institute of Environmental and Water Studies

Sample Code	: ES-20132707
Source Sample Code	: B
Sample Name	: B
Sample Receiving Date	: 08 June 2013
Category	: Waste Water
Batch No.	:
Sample Size	: 1 L
Origin	: Osama Shaheen
Representative	:
Container Type	: Plastic
Sample Condition	: OK
Sampled By	: Osama Shaheen

Test	Result	Method	Comments	Test Date
Nickel	Not detected	ICP	DL= 15 ppb	20 JUN 2013
Lead	Not detected	ICP	DL= 40 ppb	20 JUN 2013
Arsenic	Not detected	ICP	DL= 50 ppb	20 JUN 2013
Chromium	Not detected	ICP	DL= 7 ppb	20 JUN 2013
Zinc	0.512 ppm	ICP		20 JUN 2013
Copper	Not detected	ICP	DL= 6 ppb	20 JUN 2013
Cadmium	Not detected	ICP	DL= 4 ppb	20 JUN 2013
Sulfates	76.3 ppm	CIA		11 JUN 2013
Nitrates	Below Detection Limit	CIA	Detection Limit = 50 ppb	11 JUN 2013
Total Kjeldahl Nitrogen	210.20 mgN/l	AOAC		20 JUN 2013

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Analytical Report

Report Date : 02 July 2013
Customer : Institute of Environmental and Water Studies

Sample Code	: ES-20132714
Source Sample Code	: B
Sample Name	: B
Sample Receiving Date	: 12 June 2013
Category	: Waste Water
Batch No.	:
Sample Size	: 1 L
Origin	: Osama Shaheen
Representative	:
Container Type	: Plastic
Sample Condition	: OK
Sampled By	: Osama Shaheen

Test	Result	Method	Comments	Test Date
Nickel	0.064 ppm	ICP		25 JUN 2013
Lead	0.398 ppm	ICP		25 JUN 2013
Arsenic	Not detected	ICP	DL= 50 ppb	25 JUN 2013
Chromium	Not detected	ICP	DL= 7 ppb	25 JUN 2013
Zinc	0.278 ppm	ICP		25 JUN 2013
Copper	Not detected	ICP	DL= 6 ppb	25 JUN 2013
Cadmium	Not detected	ICP	DL= 4 ppb	25 JUN 2013
Sulfates	169.4 ppm	CIA		19 JUN 2013
Nitrates	Below Detection Limit	CIA	Detection Limit = 50 ppb	19 JUN 2013
Total Kjeldahl Nitrogen	90 mg/L	AOAC		02 JUL 2013

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Analytical Report

Report Date : 02 July 2013
Customer : Institute of Environmental and Water Studies

Sample Code	: ES-20132715
Source Sample Code	: B
Sample Name	: B
Sample Receiving Date	: 12 June 2013
Category	: Waste Water
Batch No.	:
Sample Size	: 1 L
Origin	: Osama Shaheen
Representative	:
Container Type	: Plastic
Sample Condition	: OK
Sampled By	: Osama Shaheen

Test	Result	Method	Comments	Test Date
Nickel	0.044 ppm	ICP		25 JUN 2013
Lead	0.704 ppm	ICP		25 JUN 2013
Arsenic	Not detected	ICP	DL= 50 ppb	25 JUN 2013
Chromium	Not detected	ICP	DL= 7 ppb	25 JUN 2013
Zinc	0.286 ppm	ICP		25 JUN 2013
Copper	0.073 ppm	ICP		25 JUN 2013
Cadmium	Not detected	ICP	DL= 4 ppb	25 JUN 2013
Sulfates	176.8 ppm	CIA		19 JUN 2013
Nitrates	Below Detection Limit	CIA	Detection Limit = 50 ppb	19 JUN 2013
Total Kjeldahl Nitrogen	304 mg/L	AOAC		02 JUL 2013

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Analytical Report

Report Date : 02 July 2013
Customer : Institute of Environmental and Water Studies

Sample Code	: ES-20132717
Source Sample Code	: B
Sample Name	: B
Sample Receiving Date	: 15 June 2013
Category	: Waste Water
Batch No.	:
Sample Size	: 1 L
Origin	: Osama Shaheen
Representative	:
Container Type	: Plastic
Sample Condition	: OK
Sampled By	: Osama Shaheen

Test	Result	Method	Comments	Test Date
Nickel	0.706 ppm	ICP		25 JUN 2013
Lead	Not detected	ICP	DL =40 ppb	25 JUN 2013
Arsenic	Not detected	ICP	DL= 50 ppb	25 JUN 2013
Chromium	0.354 ppm	ICP		25 JUN 2013
Zinc	0.798 ppm	ICP		25 JUN 2013
Copper	0.394 ppm	ICP		25 JUN 2013
Cadmium	Not detected	ICP	DL= 4 ppb	25 JUN 2013
Sulfates	61.2 ppm	CIA		19 JUN 2013
Nitrates	Below Detection Limit	CIA	Detection Limit = 50 ppb	19 JUN 2013
Total Kjeldahl Nitrogen	184 mg/L	AOAC		02 JUL 2013

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Analytical Report

Report Date : 02 July 2013
Customer : Institute of Environmental and Water Studies

Sample Code	: ES-20132720
Source Sample Code	: B
Sample Name	: B
Sample Receiving Date	: 17 June 2013
Category	: Waste Water
Batch No.	:
Sample Size	: 1 L
Origin	: Osama Shaheen
Representative	:
Container Type	: Plastic
Sample Condition	: OK
Sampled By	: Osama Shaheen

Test	Result	Method	Comments	Test Date
Nickel	0.130 ppm	ICP		25 JUN 2013
Lead	Not detected	ICP	DL= 40 ppb	25 JUN 2013
Arsenic	Not detected	ICP	DL = 50 ppb	25 JUN 2013
Chromium	0.130 ppm	ICP		25 JUN 2013
Zinc	0.326 ppm	ICP		25 JUN 2013
Copper	Not detected	ICP	DL= 6 ppb	25 JUN 2013
Cadmium	Not detected	ICP	DL = 4 ppb	25 JUN 2013
Sulfates	156.2 ppm	CIA		19 JUN 2013
Nitrates	Below Detection Limit	CIA	Detection Limit = 50 ppm	19 JUN 2013
Total Kjeldahl Nitrogen	185 mg/L	AOAC		02 JUL 2013

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Analytical Report

Report Date : 02 July 2013
Customer : Institute of Environmental and Water Studies

Sample Code	: ES-20132724
Source Sample Code	: B
Sample Name	: B
Sample Receiving Date	: 19 June 2013
Category	: Waste Water
Batch No.	:
Sample Size	: 1 L
Origin	: Osama Shaheen
Representative	:
Container Type	: Plastic
Sample Condition	: OK
Sampled By	: Osama Shaheen

Test	Result	Method	Comments	Test Date
Nickel	0.162 ppm	ICP		25 JUN 2013
Lead	Not detected	ICP	DL= 40 ppb	25 JUN 2013
Arsenic	Not detected	ICP	DL= 50 ppb	25 JUN 2013
Chromium	0.082 ppm	ICP		25 JUN 2013
Zinc	0.246 ppm	ICP		25 JUN 2013
Copper	Not detected	ICP	DL= 6 ppb	25 JUN 2013
Cadmium	Not detected	ICP	DL= 4 ppb	25 JUN 2013
Sulfates	125.9 ppm	CIA		19 JUN 2013
Nitrates	Below Detection Limit	CIA	Detection Limit = 50 ppb	19 JUN 2013
Total Kjeldahl Nitrogen	185 mg/L	AOAC		02 JUL 2013

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Analytical Report

Report Date : 20 June 2013
Customer : Institute of Environmental and Water Studies

Sample Code	: ES-20132682
Source Sample Code	: S
Sample Name	: S
Sample Receiving Date	: 30 May 2013
Category	: Waste Water
Batch No.	:
Sample Size	: 1 L
Origin	: Osama Shaheen
Representative	:
Container Type	: Plastic
Sample Condition	: OK
Sampled By	: Tareq Aqhoush

Test	Result	Method	Comments	Test Date
Nickel	Not detected	ICP	DL= 15 ppb	04 JUN 2013
Lead	Not detected	ICP	DL=40 ppb	04 JUN 2013
Arsenic	Not detected	ICP	DL= 50 ppb	04 JUN 2013
Chromium	0.11 ppm	ICP		04 JUN 2013
Zinc	1.36 ppm	ICP		04 JUN 2013
Copper	0.29 ppm	ICP		04 JUN 2013
Cadmium	Not detected	ICP	DL= 4 ppb	04 JUN 2013
Sulfates	277.2 ppm	CIA		04 JUN 2013
Nitrates	Below Detection Limit	CIA	Detection Limit = 50 ppb	11 JUN 2013
Total Kjeldahl Nitrogen	153.76 mg N/l	AOAC		20 JUN 2013

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Analytical Report

Report Date : 20 June 2013
Customer : Institute of Environmental and Water Studies

Sample Code	: ES-20132693
Source Sample Code	: Small Catchment
Sample Name	: Small Catchment
Sample Receiving Date	: 01 June 2013
Category	: Waste Water
Batch No.	:
Sample Size	: 1 L
Origin	: Osama Shaheen
Representative	:
Container Type	: Plastic
Sample Condition	: OK
Sampled By	: Tareq Aqhoush

Test	Result	Method	Comments	Test Date
Nickel	Not detected	ICP	DL= 15 ppb	04 JUN 2013
Lead	0.22 ppm	ICP		04 JUN 2013
Arsenic	Not detected	ICP	DL= 50 ppb	04 JUN 2013
Chromium	Not detected	ICP	DL= 7 ppb	04 JUN 2013
Zinc	0.64 ppm	ICP		04 JUN 2013
Copper	0.40 ppm	ICP		04 JUN 2013
Cadmium	Not detected	ICP	DL= 4 ppb	04 JUN 2013
Sulfates	82.2 ppm	CIA		04 JUN 2013
Nitrates	Below Detection Limit	CIA	Detection Limit = 50 ppb	11 JUN 2013
Total Kjeldahl Nitrogen	146.53 mgN/l	AOAC		20 JUN 2013

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Annex 4: Summary of the wastewater parameters for the main and sub-main catchment respectively.

Table 24: Results of the Parameter Analysis for Wastewater at the Main Catchment in Nablus-East

Parameters measured	Units	29th May	31st May	3rd June	7th June	10th June	12nd June	14th June	17th June	19th June
Temperature	(°C)	25.7	23.5	26.9	26.8	27.6	27.1	25.9	26.5	27.5
pH	-	7.53	7.45	7.1	7.25	6.62	6.65	7.01	6.45	7.06
Dissolved Oxygen	$mg \cdot L^{-1}$	0.91	0.18	0.36	0.28	4.34	5.1	1.33	2.3	1.41
COD_t	mg/L	1904	2706	906	940	1160	1280	2406	2273	2150
COD_d	mg/L	1573	1673	473	440	566	677	1706	1643	1673
TSS	mg/L	771	584	720	772	1020	816	704	1356	951
Nitrates*	mg/L	BDL**	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Total Kjeldhahl Nitrogen	mgN/L	72.93	207.22	166	210.20	90	304	184	185	185
Sulfates	mg/L	96.8	52.2	183.6	76.3	169.4	176.8	61.2	156.2	125.9
Ni	mg/L	N.D**	N.D	N.D	N.D	0.064	0.44	0.706	0.130	0.162
Pb	mg/L	N.D	0.25	0.18	N.D	0.398	0.704	N.D	N.D	N.D
As	mg/L	N.D	-	N.D	N.D	N.D	N.D	N.D	N.D	N.D
Cr	mg/L	N.D	N.D	N.D	N.D	N.D	N.D	0.354	0.130	0.082
Zn	mg/L	0.29	1.13	0.724	0.512	0.278	0.286	0.798	0.326	0.246
Cu	mg/L	0.15	0.56	0.586	N.D	N.D	0.073	0.394	N.D	N.D
Cd	mg/L	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D
PO_4	mg/L	33.58	10.60	23.66	19.63	13.18	15.17	15.13	22.40	17.09
NH_4-N	mg/L	47.06	217.21	128.2	147.8	145.87	153.75	160.78	173.34	159.71

*BDL: Below Detection Limit **N.D: Not detected

Table 25: Results of the Parameter Analysis for Wastewater at the Sub-Main Catchment in Nablus-East

Parameters measured	Units	29th May	31st May	3rd June	7th June	10th June	12nd June	14th June	17th June	19th June
Temperature	(°C)	26.7	26.9	27.4	27.9	27.2	27.3	26.5	26.5	27.1
pH	-	6.89	8.06	7.64	7.73	7.57	7.88	7.43	7.14	7.22
Dissolved Oxygen	$mg \cdot L^{-1}$	0.25	0.23	0.43	0.42	0.66	0.61	0.6	0.9	0.84
COD_t	mg/L	2206	1373	2206.7	1773	2006.67	1680	2806	3073	2651
COD_d	mg/L	1606	1105	1060.7	606.7	881	741	1073	1740	1653
TSS	mg/L	836	584	812	352	392	620	364	436	451
Nitrates	mg/L	BDL*	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Total Kjeldhahl Nitrogen	mgN/L	153.76	146.53	142.44	172.19	212	184	245	184	184
Sulfates	mg/L	124	82.2	76.9	104.0	102.5	123.5	102.4	80.7	81.0
Ni	mg/L	N.D	N.D	N.D	N.D	N.D	0.044	N.D	0.142	0.054
Pb	mg/L	N.D	0.22	N.D	N.D	N.D	N.D	N.D	N.D	N.D
As	mg/L	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D
Zn	mg/L	0.11	N.D	N.D	N.D	N.D	N.D	N.D	0.082	N.D
Cr	mg/L	1.36	0.64	0.75	0.532	0.74	0.830	0.414	0.778	0.345
Cu	mg/L	0.29	0.40	0.068	0.66	0.096	0.144	0.046	0.070	0.072
Cd	mg/L	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D
PO_4	mg/L	22.56	28.78	23.93	9.27	14.12	5.20	22.09	24.91	20.61
NH_4-N	mg/L	132.24	141.4	147.6	131.8	114.78	119.04	157.58	159.50	166.31

*BDL: Below Detection Limit **N.D: Not detected

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موازنة مياه الصرف الصحي في المناطق الحضرية لدراسة مقدار التلوث من الصرف الصحي وتلوث المياه الجوفية في شرق نابلس

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الملخص

تعتبر دراسة دورة المياه أمرا ضروريا لإدارة المياه في المناطق الحضرية وللسيطرة على مصادر التلوث ضمن دورة المياه الطبيعية. حيث تزايدت في الوقت الحاضر المخاوف من تاثير مياه الصرف الصحي الغير معالجة على مصادر المياه والمياه الجوفية وخاصة في الدول النامية ضعيفة الامكانيات والبنية التحتية. في فلسطين, تبلغ نسبة السكان المستفيدين من شبكة الصرف الصحي 30%. بينما يشكل المستفيدين من محطات المعالجة ما نسبته 6 % فقط من السكان.

وقد أدى ذلك إلى إلقاء اللوم على مياه الصرف الصحي في زيادة تركيزات النترات في المياه الجوفية. كشفت العديد من الابحاث والمراجع ذات العلاقة أن المعرفة والابحاث عن تأثير ترشيح مياه الصرف الصحي من شبكات الصرف الصحي محدودة جدا. حيث أشارت هذه الدراسات أن التلوث الناتج عن ترشيح مياه الصرف الصحي من شبكات الصرف الصحي تشكل تهديدا حقيقا للمياه الجوفية. تم اختيار شرق مدينة نابلس وبعدد سكان 94,910 كمحور لدراسة وتقييم مقدار التلوث من مياه الصرف الصحي الراشحة من شبكات الصرف الصحي من شبكة المجاري بالاضافة الى مخارج الشبكة.

تم تقسييم منطقة الدراسة الى سبع مستجمعات مائية وفقا للطبوغرافية. حيث ركزت الدراسة على بشكل أساسي على مستجمع رئيسي يشكل 86% من شرق مدينة نابلس وأخر فرعي. حيث تم قياس كمية مياه الصرف الصحي لمستجمع المياه الفرعي بشكل دقيق, حيث مكنت صغر مساحة المستجمع المائي الفرعي من قياس مقدار استهلاك مياه الشرب وكذلك مقدار المياه التي تنتهي بشبكة الصرف الصحي. تم تعميم النتائج عملية الموازنة المطبقة على المستجمع المائي الفرعي على المستجمع المائي الرئيسي. بالنسبة لمستجمع المياه الرئيسي, تم قياس تدفق الصرف الصحي من المخرج لمدة أربعة أيام، وتم الحصول على المياه المستهلكة من سجلات عدادات المياه من

بلدية نابلس. تم جمع عينات مياه الصرف الصحي من مخارج المستجمع الرئيسي والفرعي وتم فحص العديد من المتغيرات.

أظهرت النتائج ان مقدار التلوث من مياه الصرف الصحي الراشحة من شبكات الصرف الصحي هي: 2.4غرام نيتروجين لكل م^3, 0.25غرام فوسفوراس لكل م^3, 23.5غرام COD لكل م^3, 2.4غرام BOD_5 لكل م^3. كذلك أظهرت نتائج الموازنة المائية أن 82.2 % من المياه المستهلكة تنتهي بشبكة الصرف الصحي. بينما تستهلك 18.7 % خارجيا. كذلك تشكل نسبة مياه الصرف الصحي الراشحة من شبكة الصرف الصحي 12.8%. كذلك أظهرت النتائج أن مقدار النايتروجين الراشح من شبكات الصرف الصحي هو 0.29 كيلو نيتروجين لكل الهكتار لكل يوم من مجموع 1.88كيلو نيتروجين لكل الهكتار لكل يوم.

لذلك، من أجل تخفيف مقدار التلوث من مياه الصرف الصحي، يجب أنشاء محطة لمعالجة الصرف الصحي بالاضافة الى إعطاء الجهود لصيانة شبكة المجاري وإعادة التأهيل لحماية المياه الجوفية.

BIRZEIT UNIVERSITY

معهد الدراسات البيئية والمائية

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قدمت هذه الأطروحة استكمالا لمتطلبات نيل درجة الماجستير في هندسة المياه والبيئة بكلية الدراسات العليا في جامعة بيرزيت-فلسطين.

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