Nitrogen and Heavy Metal Fluxes from Cesspits in Palestine:

Beit Dajan and Beit Fourik as a Case Study

By
Belal Amous

Supervised by
Dr. Nidal Mahmoud

This Thesis was Submitted in Partial Fulfillment of the Requirements
for the Master Degree in Water and Environmental Engineering from
the Faculty of Graduate Studies at Birzeit University-Palestine

Birzeit University

February, 2014

Nitrogen and Heavy Metal Fluxes from Cesspits in Palestine: Beit Dajan and Beit Fourik as a Case Study

تدفق النيتروجين والمعادن الثقيلة من حفر الامتصاص في فلسطين: حالة دراسية قرى بيت دجن وبيت فوريك

By

Belal Amous

1085317

Thesis was prepared under the supervision of Dr. Nidal Mahmoud and has been approved by all members of the Examination Committee

Dr. Nidal Mahmoud

Chairman of Committee

Dr. Rashed Al-Sa'ed

Member

Prof. Dr. Marwan Haddad

Member

Marwan Haddad

Date of Defense: March, 2014

DEDICATION

I dedicate my dissertation work to my family. A special feeling of gratitude to my wife Iftitah and my daughters Zaina, Yasmeen and Leen and to my brothers and sisters and all my friends

ACKNOWLEDGEMENTS

It would not have been possible to write this master thesis without the help and support of the kind people around me, to only some of whom it is possible to give particular mention here.

I would like to express my deepest gratitude to my advisor, Dr. Nidal Mahmoud, for his excellent guidance, caring, patience, and providing me with an excellent atmosphere for doing research.

I would like to acknowledge the financial, academic and technical support of the Institute of Environmental and Water Studies and its staff.

My sincere thanks also goes to Dr. Ramzi Sansur for his encouragement and continuous support. I am most grateful to Shadi Kiabni and Tareq Thaher for their support in sampling and performing the lab.analysis.

This study was carried out as a part of the project “Impact of untreated wastewater on natural water bodies: Integrated risk assessment (UWIRA)”. This project is financially supported by the Dutch Government (DGIS) through UNESCO-IHE Partnership Research Fund (UPaRF), which is highly appreciated. We highly appreciate the continuous support of the project partners from UNESCO-IHE, namely Jochen Wenninger, Piet Lens, Peter van der Steen and Stefan Uhlenbrook.

Finally I would also like to thank my family for their support and encouragement. Special thanks to my wife, Iftitah Amous for her personal support and great patience at all times.

Abstract

Proper Wastewater management in Palestine is still very limited. About 59.8 % of the West Bank households have cesspit sanitation system where almost 3% are left without any sanitation systems (PCBS, 2011). Cesspits are known to be one of the major sources of soil and groundwater pollution.

The main goal of the research was to assess the pollution load in terms of total nitrogen and heavy metals from cesspits in Beit Dajan and Beit Fourik villages in Nablus East. This was achieved through meeting the following specific objectives:

- Characterizing septage in terms of TN and HM from various cesspits of different desludging frequencies
- Determining the pollution load fluxes from cesspits both in infiltrated and desludged septage in terms of TN and HM.

This research was accomplished by integrating a comprehensive data collection and analysis with a technical field work. 150 household were surveyed to obtain data about drinking water consumption and wastewater generation and disposal. In addition, 50 different random septage samples were collected from different cesspits. 5 samples were collected from infiltrated septage accumulated in a monitoring well installed for this study at around 1.0 m distance from a cesspit , and 5 drinking water samples were also collected from the water supply network and water supply wells.

The data collection survey revealed that the average daily consumption of drinking water in Beit Dajan and Beit Fourik is 58 l/cap.day, while the average daily wastewater generated per capita is 49 l/cap.day and the daily average septage infiltrated from cesspits per capita is 19

l/cap.day. 70% of the drinking water needs is covered from the public water network, while 25% from the rain water harvesting, and 5% purchased through truck tanks.

Cesspits are the only final wastewater disposal method in the study area where 22% of the surveyed houses empty their cesspits once in a month or less, 20% every two or three months, 15% every 4-7 months, 14% every 8-11 months, 8% every 12-24 months, 6% every 25-36 months and 15% never emptied their cesspits.

The technical study revealed that the average TN concentration in septage cesspits in Beit Dajan and Beit Fourik is 297 mg/l, where the lowest concentration was found to be 171 mg/l and the highest value was found to be 516 mg/l. The specific TN in cesspit septage was 8.53 g/cap.day.

On the other hand, the average TN concentration in the infiltrated septage was 159 mg/l, where the lowest concentration was found to be 91 mg/l and the highest value was found to be 277 mg/l and the specific TN in infiltrated septage was 3.27 g/cap.day. Accordingly, it was found that 46.4% of the total nitrogen concentration in the septage was removed during the movement of infiltrates from the cesspit to the sampling and monitoring well.

The average heavy metals (Cu, Ni, Pb, Mn, Fe, Cr, Zn) concentration in the cesspit septage are Cu (0.24 mg/l), Ni (0.03 mg/l), Pb (0.01 mg/l), Mn (0.47 mg/l), Fe (12.56 mg/l), Cr (0.04 mg/l), and Zn (1.23 mg/l). Iron (Fe) and Zinc (Zn) have the highest concentration.

Heavy metals concentrations in the infiltrated septage have been reduced after being moved through soil particles. Copper, nickel and chromium that was detected in the septage have not been detected in the infiltrates, while other metals such as manganese, iron and zinc have been reduced dramatically where Mn was detected at 0.008 mg/l, Fe (0.32 mg/l) and Zn (0.02 mg/l). The heavy metal concentration have witnessed a vast reduction during the infiltration process though soil.

The total infiltrated septage calculated as recharge to groundwater was 134,835 m^3/year (13.9 m^3/dunum.yr), while the total annual recharge from rainfall was calculated as 910,061m^3/yr (63.1 m^3/dunum.yr). Therefore, septage infiltrated from cesspits contributes to as much as 15% of total recharge from precipitation, making cesspits a significant source of recharge. On the same context, TN that is infiltrated from cesspits from both villages was 27,694 kg per year, which is equal to 2.87 kg TN/dunum.yr.

الملخص

لا تحظى إدارة المياه العادمة في فلسطين ما تستحقه من اهتمام ومتابعة. إذ يعتمد ما يقارب الـ 59.8 ٪ من الأسر في الضفة الغربية على نظام الحفر الامتصاصية كوسيلة للتخلص النهائي من المياه العادمة بينما يترك ما يقرب من 3 ٪ من دون أي أنظمة الصرف الصحي (الجهاز المركزي للإحصاء، 2011). وتشير العديد من الدراسات والأبحاث إلى أن الحفر الامتصاصية تعد أحد المصادر الرئيسية الملوثة للتربة وللمياه الجوفية.

يهدف هذا البحث إلى دراسة التلوث الناجم عن الحفر الامتصاصية من حيث النتروجين الكلي والمعادن الثقيلة في قرى بيت دجن وبيت فوريك الواقعة شرق نابلس كمنطقة دراسة. وقد تم انجاز هذا البحث من خلال تحقيق الاهداف التالية:

- دراسة خصائص المياه العادمة من حيث النيتروجين الكلي والمعادن الثقيلة لمجموعة من الحفر الامتصاصية ذات فترات نضح مختلفة.
- تحديد التلوث الناجم عن الحفر الامتصاصية من حيث النتروجين الكلي والمعادن الثقيلة في كل من المياه العادمة في الحفر الامتصاصية والمياه العادمة المتسربة من الحفر إلى التربة المحيطة.

لقد تم تحقيق هذه الاهداف أولا من خلال تأسيس قاعدة بيانات جديدة تعتمد على مسح ميداني لمنطقة الدراسة والتي شملت 150 عائلة ومنزل. يتضمن المسح معلومات عن السكان بما في ذلك عدد افراد الاسرة والتوزيع العمري للافراد بالإضافة على معلومات حول مصادر مياه الشرب ومعدل استهلاكها وعن المياه العادمة من حيث كمياتها وطرق التخلص منها. بالإضافة على ذلك تم الاستعانة بسجل البيانات الخاص بسيارة النضح للحصول على معلومات بخصوص المعدل الزمني لنضح الحفر الامتصاصية والكميات المستخرجة من عملية النضح.

ثانيا، تم تنفيذ دراسة فنية تقوم على جمع عينات من مياه عادمة من 50 حفرة امتصاصية ذات فترات نضح مختلفة، وجمع خمس عينات من المياه العادمة المتسربة من الحفر على التربة عن طريق انشاء بئر مراقبة بجانب احد الحفر الامتصاصية بهدف جمع المياه المتسربة إلى التربة المحيطة، بالإضافة إلى جمع عينات مياه شرب من المنازل والآبار الارتوازية في المنطقة البحث. وقد تم تحليل جميع هذه العينات مخبريا لفحص النتروجين الكلي والمعادن الثقيلة.

وقد أظهرت قاعدة البيانات أن 70 ٪ من احتياجات مياه الشرب في منطقة الدراسة مصدرها شبكة المياه العامة، و25 ٪ مصدرة آبار جمع مياه الامطار في حين أن 5 ٪ يتم شراؤها من خلال من صهاريج نقل المياه. كما تبين أن متوسط الاستهلاك اليومي للفرد من مياه الشرب في كل من بيت دجن وبيت فوريك هو 58.04 لتر/فرد.يوم، في حين بلغ متوسط انتاج الفرد اليومي من المياه العادمة 49.2 لتر/فرد.يوم يتسرب منها الى التربة ما معدلة 19 لتر/فرد.يوم.

كما تبين أن الحفر الامتصاصية هي النظام الوحيد للتخلص النهائي من المياه العادمة في منطقة الدراسة حيث يقوم 22٪ من المنازل التي شملتها الدراسة بتفريغ الحفر الامتصاصية الخاصة بهم مرة واحدة في الشهر، في حين أن 20٪ من الحفر يتم تفريغها في فترة زمنية ما بين شهرين أو ثلاثة أشهر، و15٪ في الفترة الزمنية من 4-7 أشهر، و 14 ٪ كل 8-11 شهرا، و8٪ كل 12-24 شهرا، 6٪ كل 25-36 شهرا في حين ان 15 ٪ من الحفر لا يتم تفريغها مطلقا.

وبالنظر إلى نتائج الدراسة الفنية، فقد تبين أن متوسط تركيز النتروجين الكلي في الحفر الامتصاصية يبلغ 297 ملغ/لتر، حيث بلغ ادنى تركيز 171 ملغم/لتر في حين أن اعلى تركيز تم قياسه كان 516 ملغم/لتر. وبلغت مساهمة الفرد في النيتروجين الكلي في الحفر الامتصاصية 8.53 غم/فرد.يوم. من ناحية أخرى، كان متوسط تركيز النيروجين الكلي في بئر المراقبة 159 ملغ/لتر، وكانت مساهمة الفرد 3.27 غم/فرد.يوم. وهذا يعني أن 46.4٪ من النيتروجين الكلي قد تم ازالته في التربة خلال فترة تسرب المياه من الحفرة الامتصاصية إلى بئر المراقبة.

كما أنه وجد أن متوسط نسبة المعادن الثقيلة في الحفر الامتصاصية كانت النحاس (0.24 ملغ/لتر)، نيكل (0.03 ملغ/لتر)، الرصاص (0.01 ملغ/لتر)، المنغنيز (0.47 ملغ/لتر)، الحديد (12.56 ملغ/لتر)، الكروم (0.04 ملغ/لتر) والزنك (1.23 ملغ/لتر). ويمثل الحديد والزنك اعلى نسبة تركيز. اما في بئر المراقبة، فقد انخفضت هذه النسب بشكل كبير بعد مرورها خلال التربة إلى المنغنيز (0.008 ملغ/ لتر)، الحديد (0.32 ملغ/لتر) والزنك (0.02 ملغ/لتر) بينما لم يظهر وجود لكل من النحاس، النيكل، الكروم والرصاص.

أما بالنسبة لتأثير الحفر الامتصاصية على المياه الجوفية، فقد تبين أن المياه العادمة المتسربة من الحفر الامتصاصية في منطقة الدراسة تغذي المياه الجوفية بما معدلة 134,835 م^3/سنه، بينما يبلغ معدل التغذية الطبيعية لمنطقة الدراسة من الامطار 910,061 م^3/سنه حسب البيانات التي تم الحصول عليها من سلطة المياه الفلسطينية. وبالتالي، فإن التسرب من الحفر الامتصاصية يساهم بـــ 15٪ من إجمالي التغذية للمياه الجوفية، مما يجعل الحفر الامتصاصية مصدرا هاما للتغذية وبالتالي للتلوث. وفي نفس السياق، تبين أن النيتروجين الكلي المتسرب سنويا من الحفر الامتصاصية في منطقة الدراسة يبلغ 27،694 كغم سنويا، أي ما يعادل 2.87 كغم/دنم.سنه.

Table of Contents

List of Figures

List of Tables

Abbreviations

BOD	Biochemical Oxygen demand
BZUTL	Birzeit University testing Laboratories
Cr	Chromium
EPA	U.S. Environmental Protection Agency
FAO	Food and Agriculture Organization
Fe	Iron
GS	Gaza Strip
HM	Heavy Metals
L	Liter
L/cap.d	Liter per capita per day
MCM	Million Cubic Meter
Mn	Mangenese
Ni	Nickel
NO_2-N	Nitrite-nitrogen
NO_3-N	Nitrate-nitrogen
Pb	Lead
PCBS	Palestinian Central Bureau of Statistics
PS	Palestinian Standards
PWA	Palestinian Water Authority
Q septg	Amount of cesspits septage
QC	Quality Control Sample
QInf	Amount of infiltrated septage
STD	Standard Deviation
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TN inf	Total Nitrogen in infiltrated septage
TN septg	Total Nitrogen in cesspits septage
WB	West Bank
Zn	Zinc

Chapter One

Introduction

1.1 **Introduction**

According to the Annual Water Status Report of 2011 published by the Palestinian Water Authority, the available amount of ground water, the main source of drinking water, in the West Bank is estimated at 633-874 MCM of which the Palestinians have access to only about 15-20%. In addition to water scarcity and access limitation for the Palestinians, in recent years, a‘red line‘ has been crossed, as untreated or partly treated septage has begun to seep into these water sources. Alarming signals have been reported in some places of ground water pollution with high concentrations of chloride, sodium, potassium and nitrate, e.g. up to 250 mg/l, in both West Bank and Gaza Strip (Arij, 2007).

Wastewater management in Palestine has not been given the attention it deserves. Many populated areas are still unsewered, untreated domestic wastewater has been discharged in the nearby wadis. In Palestine about 59.8 % of the West Bank households have cesspit sanitation system where almost 3% are left without any sanitation systems (PCBS, 2011). The cesspits are left without lining, so septage seeps into the soil layers and eventually reach groundwater. Consequently, cesspits themselves pose increasing environmental pollution problems.

In many areas, ground and surface water are now contaminated with an assortment of pollutants like heavy metals, POPs (persistent organic pollutants), nutrients and microorganisms that have an adverse affect on health. The effects of water pollution are not only devastating to people but also to natural resources and biodiversity (Strategic Environmental Research and Development Program-SERDP 2012).

In order to avoid an extraordinary burden on the drinking water sources it is important to prevent this vulnerable system at the source of pollution. Apart from leakages of the septage system, the free flow and direct use of raw wastewater from domestic centers into the natural environment, diffuse pollution from cesspits plays an important role regarding groundwater and drinking water quality. The interactions between the surface and subsurface pollutants and groundwater are quite complex and depend on many influencing factors and vary significantly in space and time (Sophocleous, 2002). Although, soil can filter some suspended pollutants, whereas soluble pollutants (e.g. nutrients and heavy metals) and very small particles, e.g. viruses, travel with the infiltrated water to the groundwater aquifer (Palmquist*et al.*, 2004).

Most of the assessments studies on the quality of waste inputs into cesspit have mainly focused on the addition of human excreta. The quantity and the content of excreta produced by humans varies by age, food habits, climate and the presence of diseases associated with infection by pathogenic bacteria, viruses and protozoa (Jackson *et al*., 1997). This research focus is on identifying of pollution in term of total nitrogen and heavy metals from cesspits in Nablus East where the study took place in Beit Dajan and Beit Fourik villages, where the largest chemical concerns from on-site sanitation systems are considered to be nitrogen and heavy metals (Pedley*et al.*, 2006). This research will contribute to indentifies and quantifies the pollution load in the study area.

1.2 **Problem Statement**

The presence of improperly treated sewage is a threat to public health as well as to the surrounding environment and natural resources since it may contains sediments, nutrients, and chemicals.

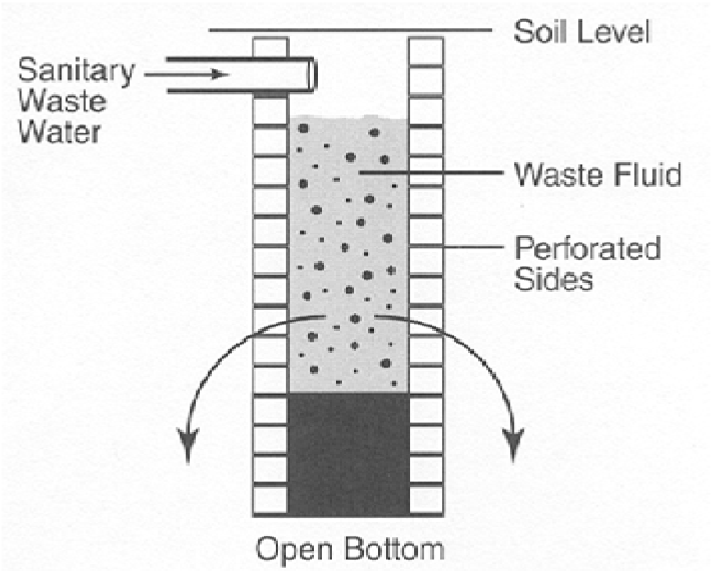

FIGURE 1.1 TYPICAL PROFILE OF A CESSPIT SYSTEM (EPA, 1996)

Infiltration of wastewater from cesspit systems is known to be one of the major sources of soil and groundwater pollution. Moreover, this type of pollution is somehow difficult to be monitored and/or corrected. It is suspected to be a hidden source of pollution, since it often occur sub-surface, and move usually in slow rate. Therefore, it can cause serious problems before it could be detected. Accordingly, on-site sewage disposal systems have been identified as local source of groundwater pollution (Hoover *et al.*, 1996).

At the beginning of this study, a preliminary field study was carried out to investigate the degree of pollution in the fresh water sources in the study area and the surroundings. Three different water samples were collected from different water wells in Al-Bathan, Al Fa’ra and from the study area itself. Samples were analyzed at BZUTL labs for nitrate, heavy metals and fecal coliforms. It was found that nitrate and heavy metals do not exceed the acceptable limits set at the Palestinian drinking water standard, and fecal coliforms were not detected. This does not mean that groundwater is safe from cesspits threats or that cesspit disposal method are safe. The reason behind that could be ascribed to the depth of groundwater level in the area, where the contaminants are still on their way to reach the groundwater in mid or long term.

Away from direct threat of infiltrated septage into groundwater, the emptied septage is either disposed in open areas, or will eventually be disposed in the municipal wastewater treatment plants to be further treated. In both cases, adequate septage characterization is essential.

1.3 Goal and Objectives

The main goal of the research is to assess the pollution load in term of total nitrogen (TKN and NO_3) and heavy metals (HM), namely Cu, Ni, Pb, Fe, Mn, Cr and Zn from cesspits in Beit Dajan and Beit Fourik villages in Nablus East. This research aimed at identifying pollution from cesspits in the rural environment and assessed its impacts on groundwater on quantitative aspects. The results provided a basis for the characterization of the water and contaminant transport in the infiltrated septage and its linkage to groundwater pollution.

The proposed methodology linked fresh water resources and wastewater fluxes in an integrated way through conducting data collection survey on water and generated wastewater management on household level, followed by technical study that characterized the pollution loads of cesspits in terms of total nitrogen and heavy metals.

Therefore, this study will hopefully be a very valuable tool for sustainable management of water and natural resources, as well as improving public health through providing more insight in the cesspits potential impact on groundwater and septage characterization, that might lay the basis for better environmental policies and interventions in such conditions of scare water resources and poor wastewater management.

1.4 Specific objectives

The specific objectives of the study are:

1. To Characterize septage in terms of TN and HM from various cesspits of different desludging frequencies
2. To determine the pollution load fluxes from cesspits both in infiltrated and desludged septage in terms of TN and HM.

Chapter Two

Literature Review

2.1 Background

An estimated 2.6 billion people lack access to improved sanitation– defined as facilities that hygienically separate human excreta from human contact (WHO/UNICEF 2010). Improved sanitation includes toilets connected to sewers, septic systems, water-based toilets that flush into pits, simple pit latrines, and ventilated improved pit latrines.

Nearly half of the population in developing countries are lacking access to improved sanitation (Scott *et al.*, 2004). Built-up areas in developing countries are either unsewered, partially sewered or have sewage network unable to handle the growing volume of the generated wastewater. Recent studies showed that raw sewage can contribute to significant portion to groundwater recharge (Ellis *et al.*, 2004). Corcoran *et al*. (2010) reported that nearly 90% of the generated sewage worldwide is disposed into the surrounding environment without any treatment.

Although 59.8% of the West Bank household are served by cesspits (PCBS, 2011), there are no regulations govern cesspit septage. Also, in spite that five treatment plants were established in West Bank since 1970, none are still functioning. The only functioning treatment plants serving around 6% of the West Bank population are Al Bireh WWTP that was established in the year 2000, and a newly established one serving Nablus West that have started functioning in 2013. Therefore, even in sewered areas, sewage is still mostly discharged into wadeis without any treatment (UNDP 2013).

The unsewered areas relying on cesspits or septic tanks are considered a major source of groundwater pollution (Foppen *et al.*, 2002). The onsite sanitation systems, when properly sited, designed, constructed, they pose a minimal threat to public health and natural resources but when improperly sited or designed, they can pose a significant threat (Eriksson *et al.*, 2002).

The role of households as wastewater polluters has become more significant. Wastewater collection and disposal is considered a crucial issue that should be adequately addressed to ensure that the generated wastewater does not pose significant threat to public health, surrounding environment and natural resources. The qualitative and quantitative characteristics of wastewater are considered the baseline data for any environmental and wastewater management studies, such as risk assessment, selection of treatment process, impact assessment studies (Jefferson *et al.*, 1999).

Urban groundwater resources are of considerable importance to the long-term viability of many cities world-wide, yet prediction of the quantity and quality of recharge is only rarely attempted at anything other than a very basic level (Thomas *et al.*, 2005). Despite the importance of recharge in urban development, research is still at a relatively early stage, and there are no generally accepted methods for assessing the rates and quality of urban recharge (Thomas *et al.*, 2005). Whereas, the major issue is the sustainability of supplies of sufficient quantities of sufficient quality groundwater.

Groundwater is considered vulnerable to nitrogen pollution from various human activities. Jin *et al.*, (2004) demonstrated by using isotopic techniques that the major source of nitrate in groundwater under Hangzhou City in China was domestic sewage from septic tanks. A growing number of case studies have documented a trend of nitrate contamination in urban groundwater across the world, many of which have identified residential sewage from on-site sanitation facilities as the pollution source.

The limited confining layers, shallow water tables, and numerous cesspits and caves can rapidly transport N and other contaminants to groundwater (Meeroff *et al.*, 2008). An elevated nitrate level ranging from 1-3 mmol/L (62-186 mg/l) was reported in groundwater of Sana'a in Yemen, which was attributed high strength wastewater infiltrates from cesspits (Foppen *et al.*, 2002). High nitrate levels (20-30 mg/l) can be related to more densely settled areas, with a higher density of pit latrines in Zimbabwe (Zingoni *et al.*, 2005). A quantity as little as 1 mg/l of total nitrogen has been shown to lead to algae growth in Florida's springs (Hazen *et al.*, 2009). If concentrations are greater than 45 mg/l NO_3, then nitrate is a drinking water concern because it can interfere with the ability of our red blood cells to carry oxygen which lead to methaemoglobinaemia (blue-baby syndrome) (WHO, 2003).

Nitrate is colorless, odorless and highly soluble in water, under aerobic conditions, ammonium (NH_4-N) from sewage is oxidized and converted to NO_3, and ammonia volatilization considered relatively insignificant in most studies where an aerobic unsaturated zone is present (Foppen, 2002). Walker (1973) concluded that the only significant active mechanism for reducing NO_3 concentrations resulting from septic tanks was via dilution with uncontaminated groundwater.

In the West Bank, where the on-site sanitation systems using cesspits are dominant, domestic wastewater is highly accused to a pose critical threat to groundwater. Local studies revealed that groundwater nitrate levels in the West Bank frequently exceed safe level and will potentially increase overtime (Anaya *et al.*, 2009). Studies have suggested human sewage to be a significant source of nitrate in groundwater (Khayat *et al.*, 2006), however few if any studies have attempted to quantify contaminant loads from wastewaters in the region.

2.2 On-site Sanitation

On-site sanitation is a term to describe the processes related to collection, storage, treatment, and disposal of domestic waste water that cannot be carried away, i.e at household level (Figure 2.1).

On-site disposal systems allow solids in wastewater to settle and whereas some of these solids will be digested by microorganisms depending on the retention time. Most of the solids will remain in the tank while the liquid (effluent) will drain into the surrounding soil (Moe *et al.*, 1991).

FIGURE 2-1 FUNCTIONS OF CESSPIT SYSTEMS

Onsite disposal and treatment system is an alternative for treating wastewater in rural and unsewered areas in many countries. In the United States, septic tanks have been used to treat domestic wastewater since the late 1800s, and by the mid- 1900s, septic tanks combined with subsurface gravel drains have become a main application of on-site wastewater treatment (USEPA, 2002).

Worldwide, onsite sanitation systems are being promoted widely as they can play a key role in increasing access to improved sanitation. Particularly in rural and peri-urban areas where space availability and population density are not constraining factors on its adoption and where onsite sanitation can be substantially cheaper and easier to promote than sewerage networks (Schaub-Jones *et al.,* 2006).

In contrast to septic tanks which are usually made of concrete, cesspits are a cylindrical hole in deep soil, few meters in diameter with a porous inner wall of stone to shore up the soil, and a concrete lid on top. Cesspit system can easily clog, allowing waste to accumulate and run off into streams and ditches. In some cases, effluent may seep through cracks in the weathered rock deep into the ground, potentially contaminating groundwater aquifers (Hoover*et al*., 1996).

Leakage from cesspits is difficult to be monitored and/or corrected. It is suspected to be a hidden source of pollution, since it often occur sub- surface, and move usually in slow rate. Therefore, it can cause serious problems before it could be detected. Accordingly, on-site sewage disposal systems have been identified as local source of groundwater pollution (Hoover*et al*., 1996).

2.2.1 Biochemical Processes in Cesspit

Domestic wastewater quality could strongly vary from one place to another and even vary between houses in the same area as many factors influence the chemical, physical and biological characteristics. These factors could be from the generation point itself such as living standards, water consumption patterns, in-house daily activities, or could be from the final disposal such as storage duration, temperature, leaking properties or others.

Septic tanks and so as cesspits direct wastewater into the soil, and as septage flows through the soil pores, it becomes treated by means of filtration, sedimentation, chemical absorption, and biological reactions. The treatment process can be considered as a sand filter, where the removal of effluent contaminants occurs mainly in the upper few centimeters of the bed where a biologically active layer is formed (Beal*et al.,* 2005). On the contrary to other on-site disposal systems, such as constructed wetlands and overland flow systems, treatment by soil takes place underground, which protects humans and animals from physical exposure to wastewater and has no odor problem. A disadvantage of such system is the potential contamination of groundwater (USEPA 2002).

The treatment mechanisms in the soil and its hydraulic performance are complex and are highly influenced by the biological zone (biomat) or clogging layer, which is formed on the soil surface within the disposal tank system (Siegrist*et al.,* 1987). As the contaminants increase overtime, the hydraulic conductivity of the biomat decrease and consequently increase the resistant, therefore less flow through the biomat. Sometimes the flow is reduced to an extent that effluent can build up above the biomat while the underlying soil remains unsaturated (Kristiansen, 1981).

According to the U.S. Onsite Wastewater Treatment Systems Manual, 10–20% of on-site disposal and treatment systems fail in the United States (USEPA 2002). The majority of the failures attributed to that the system was not as effective in removing nitrogen substances (USEPA 1993).

The majority of solids and grease in wastewater are digested by bacterial communities present in the cesspit system. Bacteria digest large amount of the biodegradable matter under anaerobic conditions, thereby reducing the volume of the solids retained in the tank. During this, considerable amount of solids are broken down, liquified and therefore leave the tank with the effluent that seeps through the stones into the surrounding. This decomposition process usually occur in anaerobic conditions and produces gases like carbon dioxide, methane and hydrogen sulphide that escapes through the system led or through the vent that is located on the top of the house (Pohland *et al*., 1997)

Anaerobic digestion involves the degradation and stabilization of organic materials under anaerobic conditions by microorganisms. The outcome of this process is a formation of biogas, mixture of carbon dioxide and methane, and microbial biomass (Mouneimne *et al*., 2003).

In the anaerobic process, the conversion of organic matter to methane gas provides relatively little energy to the microorganisms, resulting in a slow growth rate and consequently a small portion of the waste is converted to new biomass. In contrast, microorganisms in aerobic process use oxygen in the air to metabolise a portion of the organic waste to carbon dioxide and water. This oxidation process supply microorganisms with energy, thus their growth is rapid and a large proportion of the organic waste is converted to new cells, which are not actually stabilized but simply bio-transformed (O' Flaherty *et al*., 1998).

There are four key biological and chemical stages of anaerobic digestion namely:

1. Hydrolysis
2. Acidogenesis
3. Acetogenesis
4. Methanogenesis

In the hydrolysis stage, complex long chain macromolecules like lipids, carbohydrates and proteins are hydrolyzed to short chain compounds like fatty acids and glycerol, sugars, and amino acids, respectively. This process is catalyzed by enzymes from hydrolytic bacteria.

In the acidogenesis stage, fermentative acidogenic bacteria degrade the soluble substrates produced in the hydrolysis stage to form organic acids, alcohols, ketones volatile fatty acids, carbon dioxide and hydrogen.

In the acetogenesis stage, further digestion of the simple molecules produced in the acidogenesis stage by acetogens organisms occur to produce largely acetic acid as well as carbon dioxide and hydrogen.

The final stage of anaerobic digestion is methanogenesis. In this stage methanogens organisms utilize the intermediate products of the previous stages and convert them into methane, carbon dioxide and water. Methanogenesis is sensitive to both high and low pH and occurs between pH 6.5 and pH 8.

Other pollutants in form of solid and grease reduce soil permeability with time by forming a clogging layer between disposal system and the soil around. Therefore slowing down the rate at which effluent and its constituents leave cesspits. Bacteria growing under these conditions form also a slime layer that covers the soil particles causing a reduction in soil permeability (Hoover *et al.,* 1996). Therefore, soil can filter some suspended pollutants, whereas soluble pollutants, e.g. nutrients and heavy metals and very small particles, e.g. viruses, travel with the infiltrated water to the groundwater aquifer (Palmquist *et al.,* 2004). In spite that the clogging layer has been found to be beneficial by filtering solids from the effluent, but in long term, these will lead to hydraulic failure of the disposal system. The holding capacity of the system can vary dramatically depending on (Palmquist *et al.,* 2004):

1. The quantity and quality of the generated wastewater,

2. The type and permeability of the soil and bedrock.

The side walls and bottom of the system will allow wastewater to seep into the surrounding soil. During seepage, wastewater will be subjected to further bacteriological decomposition of the organic matter by soil bacteria resulting in lowering BOD of the wastewater (Hu*et al.*, 2007).

The natural treatment process that occur in the system, followed by the absorption and purification processes that take place in the soil, is not enough to ensure that potential pollution of groundwater does not exists(Hu *et al.*, 2007).

2.3 Potential Impact of Cesspits on Groundwater Quality

The impact of cesspits on groundwater quality is influenced by two main factors, first the domestic wastewater quality and quantity and the other is the characteristics of the surrounding soil.

2.3.1 Domestic Wastewater Quality

The major organic pollutants in domestic wastewater are human excreta. The quantity and the content of excreta produced by humans varies by age, food habits, climate and the presence of diseases associated with infection by pathogenic bacteria, viruses and protozoa (Jackson*et al.*, 1997).

A review of human excreta estimated that urban adults in developing countries produce an average of 250 grams of feces (80% wet weight), while rural adults produce 350 grams of feces (85% wet weight) (Feachem *et al.*, 1983). The review estimated that 1.2 liters per person per day, was the average amount of urine produced for both rural and urban individuals in developing countries (Feachem *et al.*, 1983). An analysis of cesspit contents found the solids content range to be 2.0 – 4.2 percent solids (Pescod *et al.*, 1971).

The chemical composition of urine and feces is highly variable and controlled by different factor including food habits, drinking water composition, climate, occupation, age, and health. The organic matter makes up the largest component of feces (Cotton *et al.*, 1995), though this does not immediately cause a chemical risk to groundwater. The major chemical content of human excreta is presented in Table 2.1 (Graham *et al.*, 2003).

Table 2-1:Major chemical content of human excreta (Graham *et al.*, 2003)

Parameter	Urine (g/cap.day)[a]	Feces (g/cap.day)[b]	Yearlt Loading to Latrine (kg)[c]
N[d]	7.2 – 16.0	2.6 – 7.4	14.3– 28.7
P[d]	1.2– 4.2	1.6 – 2.8	4.1 – 10.3
Cl[e]	3.6– 3.8	0.1 – 0.2	5.5– 6.0
K[d]	1.4– 3.8	0.5 – 1.3	2.9– 7.4
Organic matter[d]	31.2– 71.4	46.2 – 50.9	113– 179
BOD_5[f,g]	10.3	20.3	44.7

[a] *For N, P, K, and organic matter: assuming moisture content of 93-96% (Polpraset, 2007) and 1200 g urine/person/d in a rural developing country setting (Feacham et al., 1983).*
[b] *For N, P, K, and organic matter: assuming moisture content of 85% and 350 g wet feces/person/d in a rural developing country setting (Feacham et al., 1983).*
[c] *Based on 4 people per latrine.*
[d] *Composition data from Polpraset (2007), based on Gotaas (1956) and Feacham et al. (1983).*
[e] *BGS (2002).*
[f] *Feacham et al. (1983).*
[g] BOD_5 *– Biochemical Oxygen Demand-5: The amount of dissolved oxygen consumed in during wastewater decomposition in five days. This represents a measure of organic matter that can be broken down by biological processes.*

The largest chemical concerns from on-site sanitation systems are considered to be nitrogen and heavy metals (Pedley *et al.*, 2006). Most nitrogen is excreted as urea, which will, under aerobic conditions, and through nitrification process, be converted to ammonium and finally to nitrate, which is suspected to cause methemoglobinemia when consumed in high quantities (Pedley *et al.*, 2006).

The majority of nitrogen in excreta is found in urine (Table 2.1), and large quantities of nitrogen may be deposited to cesspits each year, which constitute a threat to groundwater quality. This threat might be substantially minimized by urine diversion by separation of human urine from feces at the point source (Jack *et al.*,1999).

Characterizing the behavior and transport of nitrogen (N) in cesspit systems is important because nitrogen is considered a potential contaminant in groundwater. Septic systems are recognized as one source of nitrogen pollution (Oakley *et al.*, 2010). The evidence to support the argument that infiltrates from on-site disposal systems cause widespread and serious pollution to surface and more commonly groundwaters, is by no means conclusive (Beal *et al.*, 2005).

Table 2-2: Comparison of nitrogen from domestic wastewater and septic tank effluent (Lowe *et al.*, 2009)

Parameter	Description	Median Value, mg N/L		Range of Values mg/l	
		Raw WW	Septic Tank Effluent	Raw WW	Septic Tank Effluent
TKN	Total kjeldahl Nitrogen (TKN) is organic N plus ammonium-N	57	57	16-189	33-171
NH_4-N	May be present as Ammonium (NH_4) ion or ammonia gas (NH_3), with NH_4 dominating when pH is below 9.3	13.7	53	1.6-94	25-112
Organic N	Organic N is the difference between TKN and ammonium-N	43.3	4.0	14.4-187.4	8-146
Nitrate-N	Very Little nitrate-N is found in raw wastewater	1.9	0.5	0.2-8.5	0.1-7.1

* Raw wastewater: wastewater that has not yet entered a septic tank.

** Septic tank effluent: wastewater that has passed through the septic tank but has not entered the drain field.

Water quality surveys in the United States have identified local and regional contamination of groundwater and surface water by nitrate derived from septic systems. In some cases, these studies have detected nitrate-N concentrations exceeding the allowable groundwater level of 10 mg/l at considerable distances from septic systems' drain fields (Beal *et al.,* 2005).

Hazen *et al*. (2009) found that approximately 10% – 50% percent of the total nitrogen in the septic tank effluent be adsorbed or otherwise removed during infiltration through the unsaturated zone in the soil before the effluent reaches groundwater (Hazen *et al.,* 2009). During this process, nitrogen from septic systems is converted to nitrate by the process of nitrification. Unless denitrification takes place, the most likely fate of this nitrate is leaching to groundwater. Moreover, as nitrate leaches through the soil, it does not interact with soil components under aerobic conditions. It can travel through the unsaturated soil zone to groundwater (Beal *et al*., 2005).

Lee (2011) reported that the subsurface infiltration of septage from cesspits has proved to be a good alternative for on-site wastewater treatment in consideration of efficiency and cost. Walker (1973) concluded that the only significant active mechanism for reducing Nitrate-N resulting from on-site sanitation was through dilution with fresh groundwater.

A study conducted in 2008 in Israel by Dror Avesar to detect the progressive improvement to original water quality levels when central sewage disposal system is set to replace individual cesspits. The study was conducted in two large neighboring agricultural villages (Kefar Kassem and Kefar Bara) that are relying upon cesspits/cesspools for waste disposal where a long-term deterioration of the ground water supply in these villages was traced. The study revealed that a rapid improvement in water quality was witnessed and is attributed to the replacement of the cesspits by a central sewage disposal network (Avisar *et al.,* 2008). The nitrate level in groundwater before the replacement was increasing over time reaching to as high as 67 mg/l NO_3. But within several years after the cesspit disposal was terminated, the nitrate values declined to concentrations that were reported (approximately 25 mg/l NO_3) decades prior, when the water quality monitoring had just started. This study demonstrates not only how water quality can degrade but also how it can be restored once the problem is identified and countered.

Chloride and phosphorus are also excreted through urine. Chloride is fairly mobile in groundwater and can impact the acceptability of drinking water. Phosphorus, as phosphate, is not a direct health threat from drinking water and is relatively immobile, but high concentrations may promote algal blooms and it is therefore a concern as a contaminant of surface water (Schouw*et al.,* 2002).

In addition to major chemical components of excreta, there are a number of potential organic and inorganic contaminants found in highly variable concentrations within excreta (Fourie*et al.*, 1995). There is a growing concern of pharmaceuticals, household chemicals and personal care products in water supplies. Heavy metals, such as lead and cadmium, are predominantly excreted in feces and may provide a residual source of contaminants in cesspits (Schouw*et al.*, 2002).

2.3.2 Characteristics of the surrounding soil

Geological characteristics of the surrounding soil where the cesspits are placed can have an important influence in the processes happening inside the pool(Bhagwan *et al.,* 2008). These include:

- Type of soil or rock : The porosity of the soil will determine the leaching and draining process that will occur in the cesspit. This will affect the liquid water level and moisture contents, as well as potentially pH. It will also influence diffusion of soluble components in or out of the cesspit.

- Water table: Height of the water table will also influence levels of soluble components in the cesspit. Flooding of cesspit is a common phenomenon in situations of high water table conditions and during the rainy season. This is a major problem that has been described in different settings. Flooding could also change microbial composition either directly through losses or indirectly through altering the pit environment.

Soil type may also affect decomposition through the alteration of the ecosystem in the cesspit. Soil microflora and microfauna (higher organisms such as protozoa, metazoa and worms) may move into the pit from the surrounding soil and contribute to decomposition of organic material

2.4 Characteristics of Domestic Wastewater

Wastewater is mostly water by weight, but the small portion of contaminants are considered large enough to endanger public health and the environment. In general, domestic wastewater generates from:

1. Wastewater from the toilet *(blackwater)*, which is characterized by high content of solids, and contributes to a significant amount of nutrients (nitrogen, N and phosphorus, P) and contains bacteria and pathogens.

2. Wastewater from laundry, bathing/showering and from the kitchen *(Greywater)*, which is characterized by high content of solids and grease, and may contains bacteria and pathogens.

Wastewater contains organic and inorganic materials as will be described in the following sections.

2.4.1 Inorganic Matter

The major inorganic contaminants found in wastewater are salts, minerals, metals and heavy metals like sodium, potassium, calcium, magnesium, cadmium, copper, lead, nickel, zinc and others. Such substances are relatively stable and cannot be broken down easily by organisms in wastewater, therefore, an extra treatment steps are necessary to remove them from wastewater (Sternbeck *et al*., 1999)

Land application of industrial or domestic sludge, mining, manufacturing, and the use of synthetic products can result in heavy metals contamination of urban and agricultural soils. Heavy metals also occur naturally, but rarely at toxic levels (Brady *et al*.,1999). Excess heavy metal accumulation in soils is toxic to humans and other animals. Exposure to heavy metals is normally chronic (exposure over a longer period of time), due to food chain transfer. Acute (immediate) poisoning from heavy metals is rare through ingestion or dermal contact, but is possible (Wenzel *et al*., 1999). Chronic problems associated with long-term heavy metal exposures are:

- Lead – mental lapse.
- Cadmium – affects kidney, liver, and gastrointestinal tract.
- Arsenic – skin poisoning, affects kidneys and central nervous system

Wastewater contains several constituents that are of concern to human health and natural resources. Heavy metals such as Cu , Ni, Pb, Cr and Zn are of great concern since they are considered hazardous to human health and natural resources.

Heavy metals infiltrated from cesspits and present in the aqueous phase of soils are subject to movement with soil water, and consequently may reach the ground water through the vadose zone. Even metals are considered stable, i.e cannot be degraded, they can be transformed to other oxidation states in soil, reducing their mobility and toxicity. The mobility is reduced by mechanism of adsorption and precipitation. Metal transport within the soil may be enhances if the retention capacity of the soil is overloaded, or metal interaction with the associated waste matrix enhances mobility (Amacher*et al.*, 1986).

The variation in the concentration of some heavy metals in different waste streams is presented in Table 2.3. It is obvious that domestic wastewater contains less heavy metals than commercial wastewater since the sources of heavy metals in house applications are limited compared to industrial and commercial wastewater..

Table 2-3: Concentrations of HM in domestic and commercial wastewater in Munich, Germany (Wilderer and Kolb, 1997)

Element	Domestic Wastewater mg/l	Commercial Wastewater mg/l
Pb	0.1	< 13
Cu	0.2	0.04-26
Zn	0.1-1.0	0.03-133
Cd	< 0.03	0.003-1.3
Cr	0.03	< 20
Ni	0.04	< 7.3

Heavy metals enter domestic sewage from different sources such as cleaning agents, paints, pesticides and other household chemicals. Heavy metals associated with septage infiltration are present as free ions. As soil consists of mixtures of different solid organic and inorganic substances, as well as of a variety of soluble substances. Thus, when these metals reach the surrounding soil mass, they will have the opportunity be adsorbed to soil colloidal particles at various levels depending on the type of metal, soil composition and the soil reaction and redox conditions (De Matos *et al.*, 1996).

2.4.2 Organic Matter

Organic matter are the carbon based chemicals, and considered the building block for living things, therefore they are found everywhere in the environment. They enter the domestic wastewater as human waste, paper products, detergent, cosmetics, foods, synthetic organic compounds and many others.

Organic matter could be classified into biodegradable and non-biodegradable. Organic matter in form of proteins, carbohydrates or fats are considered biodegradable, that they can be consumed and easily broken down by microorganisms. Organic compounds that are more stable and cannot be easily or quickly broken down by organisms are considered non-biodegradable. Many synthetic organic compounds that inter in the manufacturing process of some household chemicals like volatile organic compound, benzene, toluene are not only considered non-biodegradable, but they are also considered toxic and may inhibit the microorganisms activities in the biological treatment process (Sauer *et al.*, 1995).

2.4.3 Nutrients

Nutrients are always present in domestic wastewater and could not be removed during conventional treatment processes. Nitrogen and phosphorus are the major source of nutrients in wastewater. Under aerobic conditions, they are found in the form of nitrate and phosphate, respectively. The presence of nutrients in wastewater is important in enhancing the microbiological activities required in treatment process. Since organisms in septic tanks or in biological treatment unit require only small amount of this nutrient, therefore, there would be an excess of nutrients available in wastewater (Garcia*et al.*, 2006).

Nitrogen could present in wastewater in the form or organic and inorganic like nitrate (NO_3), nitrite (NO_2), ammonia (NH_4), and nitrogen gas (N_2). All of these forms are biochemically interconvertible depending on the physical and chemical characteristic of wastewater (Berg *et al.*, 2002).

Organic Nitrogen is nitrogen that is bound to carbon. The main source of organic nitrogen in domestic wastewater are feces and urine. Organic nitrogen goes through nitrification process and is converted to nitrate.

Nitrate is the most stable form of nitrogen compounds. It is formed by the nitrification process that convert organic nitrogen to nitrate by the activity of nitrifying bacteria in an aerobic conditions. Since nitrate has negative ion in a solution, so it will not bind to soil particles which are also negatively charged. Therefore, nitrate can move through soil and reach groundwater (Berman *et al.,* 2003).

Nitrite is the least stable form of nitrogen compounds. It is an intermediate compound in the nitrogen cycle and is converted to nitrate by the Nitrobacter bacteria, therefore it is not usually detected in water sources (Berman *et al.,* 2003).

Ammonia presents in water as either the ammonium ion (NH_4^+) or ammonia gas (NH_3), depending on the pH value of water. The chemical equation that drives the relationship between ammonia and ammonium is

$$NH_3 + H_2O \leftrightarrow NH_4^+ + OH^-$$

When the pH is low, the reaction is driven to the right and the ammonium ion is the predominant form, and when the pH is high, the reaction is driven to the left and the ammonia gas is the predominant form (Berman *et al.*, 2003).

Since ammonia has positive ion in a solution, it binds to soil which is negatively charged. Therefore, ammonia will not be easily leached from the soil. Plants can readily use the ammonia form of nitrogen.

2.5 Study Area

The study took place in Beit Dajan and Beit Fouriq villages with a total population of about 15699 (PCBS, 2013). Both villages are adjacent and located 10 km east of Nablus city.

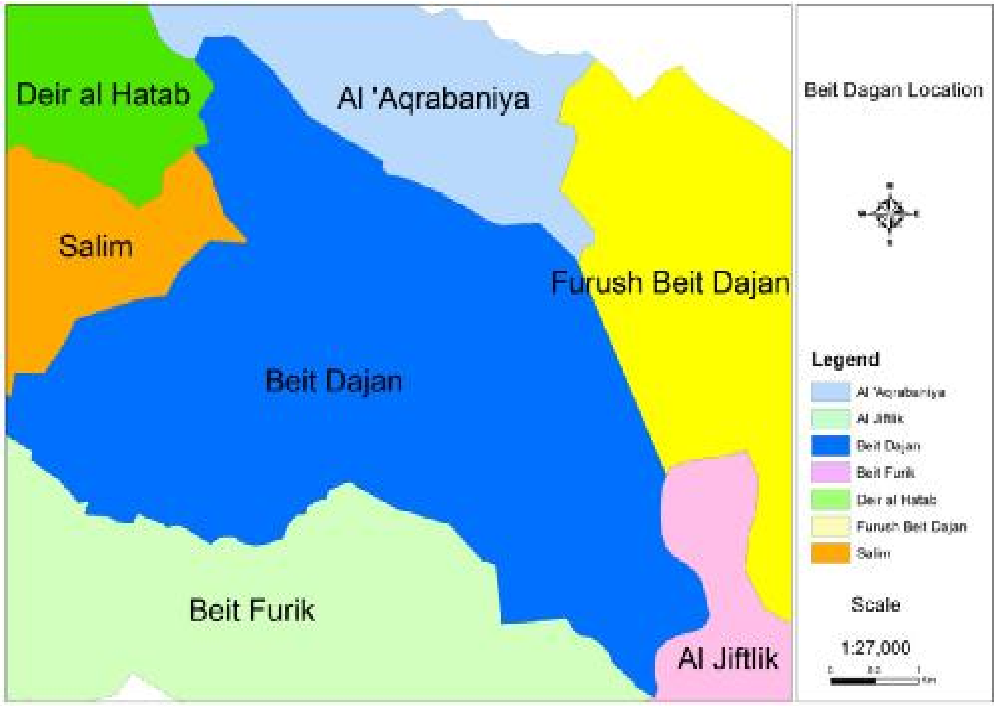

Figure 2-2: Location of Beit Dajan and Beit Fourik villages/Nablus Governorate, Palest
(ARIJ, 2009)

Both villages share the same geological and hydrological and environmental conditions and almost have similar economical situation. The majority of people in the study area are living in single unsewered separate houses, scattered over mountainous and plain area where intensive buildings were observed in the mountainous part. There are 2599 households in 1819 buildings (PCBS, 2011).

FIGURE 2-3: AERIAL PHOTO FOR BEIT DAJAN AND BEIT FOURIK VILLAGES/NABLUS GOVERNORATE, PALESTINE

The main human activities in the study area are almost limited to animal husbandry and rain fed agriculture that take place in the plain area, while mountainous area is planted mainly with olive, almond and some fruit trees in small scale. Except for one olive mill and small scale workshops, there are no industrial activities in the area. Therefore, cesspits are considered the main source of pollution in the area.

The area is neither classified as an environmental sensitive area, nor being used as a habitat for rare or endangered species. Moreover, there are no official records for any natural and cultural heritages present in or within the surrounding area*(*ARIJ, 2007*)*.

2.5.1 Geology and Hydrology

Nablus district expand over parts of three main groundwater basins of the West Bank (Western, Eastern, and Northeastern basin). The study area is located within the Eastern Catchment in the Cinomanian Yatta Formation (Beit Meir and Moza formations in Israeli literature). This formation overlies the Upper Beit Kahil Formation. Beit Meir, 50-110 m thick, is composed of limestone, chalky limestone, dolomite, marl and greenish clay at the bottom. Moza, 10-20 m thick, is composed of yellowish marly limestone with traces of greenish marl at the bottom. Yatta Formation in general act as an aquiclude and separate the Cenomanian aquifer from the Albian aquifer underlying it. The dolomite of the upper part of Beit Meir shows some water bearing nature (Guttman and Gotlieb 1996). Sometimes the limestone near the top, officiates as a local perched aquifer, which explains why a few springs emerge 20 m below the contact of the Yatta Formation with the Hebron Formation (Rofe and Raffety 1963).

Yatta formation have low infiltration capacities; at least where these rocks are not extensively fractured or karstified (PWA, 2012) . The dominating soils in the study area are "Terra Rossa, Brown Rendzinas and Pale Rendzinas (ARIJ, 2009)

This formation has a small outcrop area because of its steep dips. It has a thickness of about 120-250 m. The formation is marked by joints and includes Carvenous limestone, thus forming a good aquifer*(*Rofe *et al.*, 1965*)*.

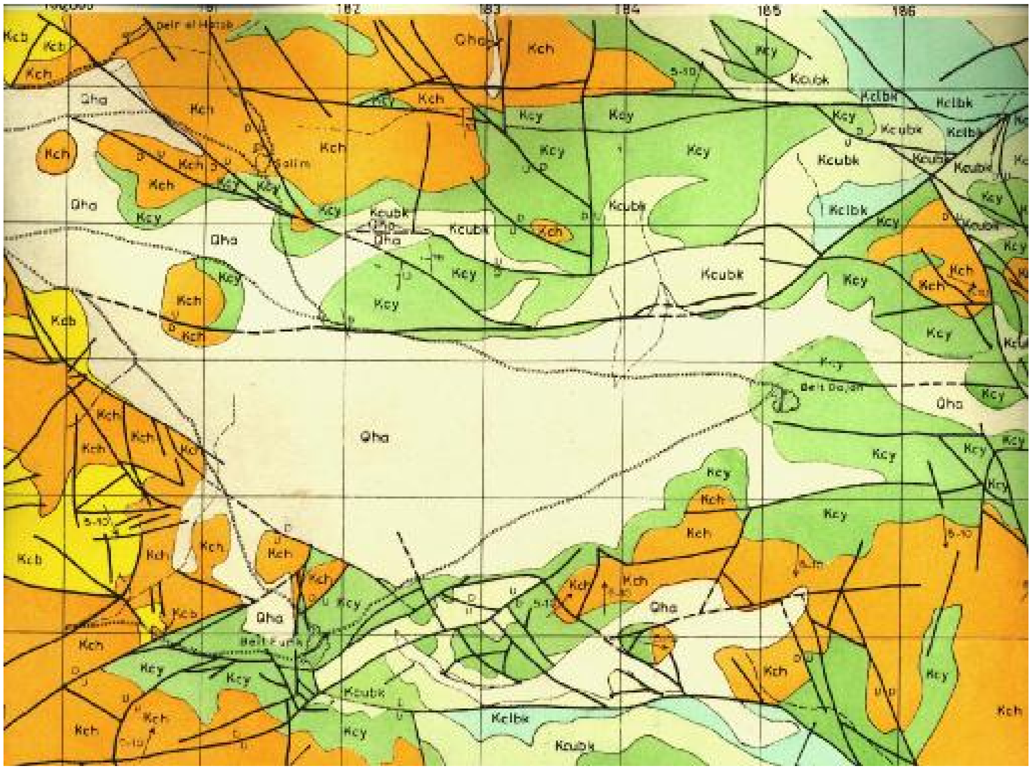

FIGURE 2-4 GEOLOGICAL STRUCTURE OF THE STUDY AREA (PWA 2012)

In Nablus district, the main depressed areas, like Far'a, Tubas and Tayasir Grabens are boarded by complex fault systems. Majdal Bani Fadil fault and Beit Furik fault also form major structures in the district. Most of faults trend north west and south east. Towards the west, the faults become more hummock and their impact therefore, becomes less visible(ARIJ, 1996).

2.5.2 Climate and Precipitation

The study area follows the Nablus district climate conditions. The district is located at the northern latitude earth grid 3213`, it has hot, dry summers and moderate, rainy winters. Rainfall in the district is limited to the winter and spring months, from October to May. The annual mean rainfall is 377 mm (Palestinian National Information Center, 2012). Nearly 81% of the annual rainfall occurs between December and March, while July is totally dry. Some showers, however, were registered at Nablus Meteorological Station in June and August. No data is available on hail or snow in Nablus district. It does periodically snow and hail, but these events are rare.

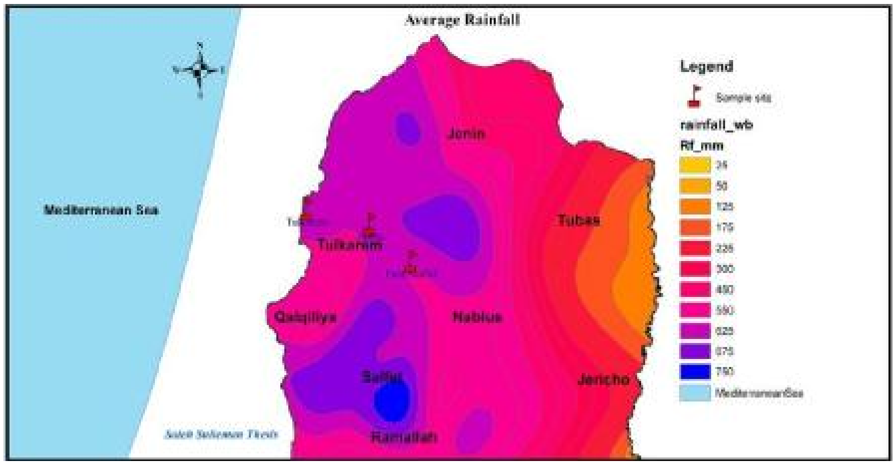

FIGURE 2-5: AVERAGE RAINFALL DISTRIBUTION IN NABLUS GOVERNORATE, (ARIJ, 1996)

2.5.3 Humidity

The mean annual relative humidity of Nablus district is 62%. The relative humidity decreases to reach its minimum value of 50.72% (in May). Maximum humidity of 67% is usually registered in December, January and February. This value increases gradually at night (ARIJ 2009).

2.5.4 Temperature

The geographical position of the district in the northern part of the West Bank gives it a comparatively lower temperature range than the other districts. During January, the coldest month, the average maximum temperature reaches 13.1°C, and average minimum temperature reaches 6.2°C. During August, the hottest month, the average maximum temperature is 29.4 and the average minimum temperature is 19.5 (ARIJ 2009).

2.5.5 Wind

The southwest and northwest winds are the prevailing winds in this area with an annual average wind speed of 237 km per day. During the summer, wind moves with relatively cooler air from the Mediterranean towards the north, with an average wind speed of 298.71 km per day in June. At night, the land areas become cooler, causing diurnal fluctuations in wind speeds due to the reduction of the pressure gradient. In winter, the wind moves from west to east over the Mediterranean, bringing westerly rain bearing winds of average wind speed 209.19 km per day in January. The desert storm, may occur during the period from April to June. During which the temperature increases, the humidity decreases, and the atmosphere becomes hazy with dust of desert origin (ARIJ 2009).

2.5.6 Topography

The topography of Nablus district can be divided into four parts: Jordan Valley, the eastern slopes, mountain crests and western slopes. The Jordan Valley is located between Jordan river and the eastern slopes with elevation ranges between 349m below sea level to 100m above sea level. The eastern slopes are located between the Jordan Valley and the Mountains. They are characterized

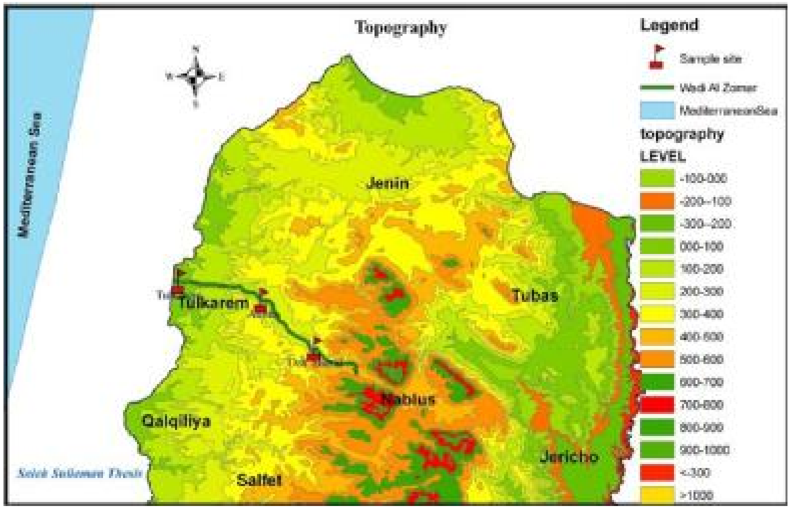

FIGURE 2-6:TOPOGRAPHY OF NABLUS GOVERNORATE. (ARIJ, 1996)

by steep slope which contribute to forming young wadis such wadi El Badan. mountain crests form the watershed line and separate the eastern and western slopes (ARIJ 2009).

Elevation ranges on average between 750 and 800 meters above sea level. Western slopes, characterized by gentle slopes, with elevation ranges between 250-500 meters above sea level. Two main drainage systems are distinguished in Nablus district. The first system is run to the west such as wadi Qana, wadi Rabah, wadi Khalifa and wadi Mas-ha. While the second system is run to the east or south east, such as wadi el Maleh, wadi Dura, wadi el Far'a and wadi el Ahmar (ARIJ, 2009).

Chapter Three

Materials and Methods

3.1 Background

In order to achieve the envisaged objectives, the study was carried out firstly by establishing an updated database through data collection survey. Then it was followed by technical field study in term of sampling and performing lab analysis to estimate the quality of septage, and measuring also the quality of infiltrated septage through installing a monitoring and sampling well that receives infiltrates from a cesspit. These data were used to characterize the quality of septage and infiltrated septage and also to assess the pollution load to the groundwater and natural resources.

The objectives of data collection survey was to obtain an updated and realistic data for demographical and environmental factors. The sampling and lab analysis was to characterize septage in terms of total nitrogen (TKN and NO_3) and heavy metals: copper, nickel, lead, iron, manganese, chromium and zinc. This was achieved through collecting septage samples from cesspits with various emptying frequencies and also from infiltrated wastewater.

3.2 Data Collection Survey

In order to get in-depth, comprehensive, reliable and updated data on drinking water sources and consumption patterns, wastewater generation and disposal methods in the study area, a questionnaire was performed and survey was conducted through direct meeting with household owners, people from the municipalities and emptying truck owners. 200 questionnaires were filled out in Beit Dajan and Beit Fourik villages during the period from 16/09/2011 until 02/02/2012.

The questionnaire was designed to answer the following questions:

- Family size
- Age distribution of the family
- Water consumption
- Sources of water supply and percentage distribution if more than one source
- Percentage distribution of water use patterns within houses
- Wastewater disposal methods and the existence and use of cesspits in houses

In addition, the data about the desludging frequencies of cesspits and the emptied septage volume per round (L/round) were obtained from the records of the driver of the cesspit emptier truck servicing the towns

3.2.1 Calculations

From this questionnaire, the following data were obtained or calculated:

1. Family size: from the questionnaire
2. Daily water consumption per household (L/day): calculated from monthly water bills and water storage tank refilling frequency from rain wells.
3. The daily water consumption per capita (L/cap.day): calculated as:

$$Water\ consumption\ per\ capita = \frac{Daily\ Water\ consumption\ per\ household}{Family\ size} \text{.............. Eq 3.1}$$

4. The daily generated wastewater per household (L/day): calculated as

$$\text{WW}_{\text{Daily Generated}} = \text{Water}_{\text{ Daily consumed}} - \text{Water}_{\text{ daily used outdoor}} \text{..Eq. 3.2}$$

where water daily used outdoor was obtained from the *water use pattern* item in the questionnaire. Large emphasis were put to obtain a reliable data from the interviewees to verify the quantities of water used outdoor like how many water buckets or how much time water hose is being used outdoor, while the impact of other uses like drinking and cooking is considered minimal and therefore negligible.

5. The daily generated wastewater per capita (L/cap.day): calculated as

$$Daily\ genarated\ wastewater\ per\ capita = \frac{Daily\ Generated\ wastewater}{Family\ size} \quad \text{Eq. 3.3}$$

6. Daily emptied septage volume (day): calculated as

$$daily\ emptied\ septage\ volume = \frac{emptued\ septage\ volume\ per\ round}{emptying\ frequency} \quad \text{Eq. 3.4}$$

7. Daily emptied septage volume per capita (L/cap.day)

$$Daily\ emptied\ septage\ volume\ per\ capita = \frac{Septage\ daily\ emptied\ volume}{family\ size} \quad \text{Eq. 3.5}$$

8. Daily infiltrated septage (L/day) calculated as

$$Daily\ infiltrated\ septage = daily\ generated\ wastewater - daily\ emptied\ septage\ volume \quad \text{Eq. 3.6}$$

9. Daily infiltrated septage per capita (L/cap.day): calculated as

$$Daily\ infiltrated\ septage\ per\ capita = \frac{Daily\ infiltrated\ septage}{family\ size} \quad \text{Eq. 3.7}$$

The TN and HM values for all collected septage and infiltrated septage samples were obtained directly from the lab analytical reports. These data is presented in Annex B and C.

3.3 Quality of Cesspits Septage and Infiltrates

The pollution load estimation was done through sampling from septage and infiltrated septage, followed by lab analysis for the determination of the quality of septage and water in the study area. Three different sources were assigned for performing the sampling processes.

1. Sampling from cesspits: Fifty septage samples were collected from fifty different cesspits based on desludging frequencies. Each sample was drawn from a unique cesspit representing a one household or cluster of households sharing the same cesspit (usually 2-4 houses).

   As the cesspit contents are not homogeneous where heavier particles settle and scum floats. Therefore, sampling program was coordinated with the truck driver in order to collect samples during cesspit emptying time by taking samples from truck itself through sampling tap attached to the emptying truck tank to ensure complete mixing in the truck tank and getting a representative sample. Indeed, direct manual sampling from cesspits was hindered by the location and shape of the cesspit itself.
2. Sampling from the infiltrated septage: Five samples were collected from the monitoring and sampling well that was installed for the sake of this study near a cesspit to collect the infiltrated septage.
3. Sampling fresh water: Three different fresh water samples were collected from:
   a. One sample from the main water well supplying fresh water to the study area
   b. Two samples from Al Bathan and Al Far'a wells in the vicinity of the study area

All collected samples were analyzed at Birzeit University Testing Labs according to Standard Methods APHA 21st edition. QC samples were run in parallel for quality assurance purposes. Sample were analyzed for the following parameters:

1. Total Nitrogen: TKN and Nitrate

2. Heavy Metals: Copper (Cu) , Nickle (Ni), Lead (pb), Manganese (Mn), Iron (Fe), Chromium (Cr) and Zinc (Zn) were analyzed using Inductively Coupled Plasma (ICP)

3.3.1 Cesspits Septage

Fifty septage samples were collected from cesspits of different desludging frequencies. Each sample was drawn from a unique cesspit representing one household or cluster of household sharing the same cesspit.

All samples were collected over five months period between October 2012 to February 2013. (Table 3.1) shows The number of septage samples collected with reference to emptying frequencies are presented in Table 3.1:

Table 3-1: Number of collected septage samples as per emptying frequencies in Beit Dajan and Beit Fourik, Palestine

Emptying Frequency (Days)	Number of Samples	Emptying Frequency (Days)	Number of Samples
10	6	120	3
15	5	180	3
20	5	210	3
30	6	360	3
45	4	510	1
60	4	720	3
90	5		

3.3.2 Infiltrated Septage

A monitoring and sampling well that was installed near a preselected cesspit to collect the infiltrated septage (Fig 3.1). This system was installed at the beginning of the research in order to in order to monitor the occurance of septage infiltration. The monitoring well was made by installing a three inches PVC pipe that is 6 meter long in a hole dug out near a cesspit. The hole was made by drilling truck using three inches core drill. The pipe was installed 0.5 -1.0 meter away from the cesspits while it went down almost 1.5-2.0 meters below its bottom since the depth of the cesspit was around four meter (source: household owner) . The bottom end of the pipe was sealed, whereas the sides were perforated 15 cm above the bottom end to enable infiltrates to enter and accumulate.

The system was monitored twice a week after being installed. Septage infiltrates started to accumulate four months after installation. Five samples were collected manually from the monitoring well during the period between February to April 2013 and analyzed (Fig. 3.1). Samples are drawn manually using a small bottle attached to a rope, where the bottle was perforated at 3 cm above the bottom to collect infiltrated septage (Fig. 3.2). After each sampling process, the remaining infiltrated septage in the well that could not be removed by the bottle is removed using a sponge attached to a metal wire to ensure that new infiltrate is collected each time. In addition, septage samples were also collected from the cesspit itself to study the change in quality of raw wastewater and after infiltrated through the soil

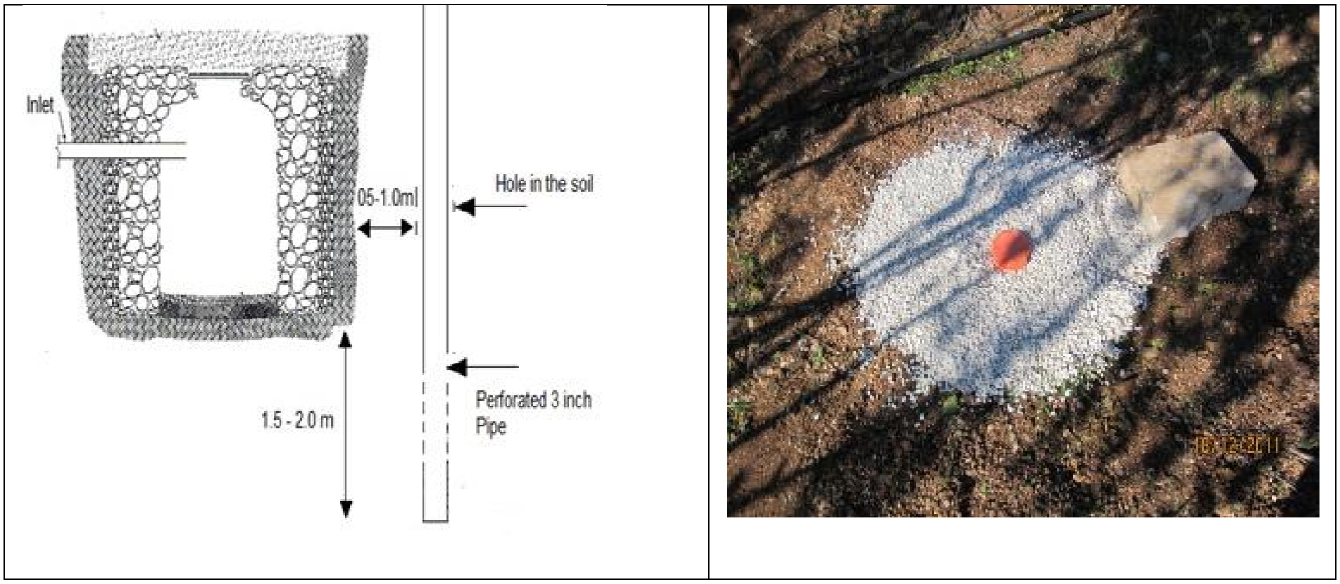

FIGURE 3-1:SETUP OF MONITORING AND COLLECTION WELL OF INFILTRATED SEPTAGE FROM A CESSPIT IN BEIT DAJAN

FIGURE 3-2 : SAMPLING OF INFILTRATED SEPTAGE FROM A CESSPIT IN BEIT DAJAN

3.3.3 Drinking Water Quality

Three drinking water samples were collected during the study to investigate the degree of pollution in the fresh water sources in the study area and its vicinity. Samples were collected from different water wells in Al-Bathan, Al Far’a and from water well in the study area itself. Samples were analyzed at BZUTL labs for TN and heavy metals.

Chapter Four

Results and Discussion

4.1 Background

The main objective of the study was to assess the pollution loads on the environment in terms of total nitrogen (TKN and NO_3) and heavy metals (HM) from cesspits in Nablus East. This was done through identification of pollutants from cesspits in the rural environment and assessed its impacts on groundwater on qualitative aspects. Detailed information about the sampling program and survey and analytical results are presented in separate attached annexes as following:

- Results of Data Collection Survey (Annex A) including:
    - Family Size
    - Water consumption
    - Emptying Frequency and volume
    - WW Generated
    - Volume of Infiltrated wastewater
- Total nitrogen measured in septage pumped out from cesspits (Annex B)
- Mass balance and total nitrogen for the drinking water, infiltrated and pumped out septage (Annex C)
- Heavy Metals measured in infiltrated septage (Annex D), and in the infiltrated septage (Table 4-13)

As mentioned in the previous chapter, the field study was performed in two consecutive parts, data collection survey and pollution load estimation. This chapter will discuss the outcome of these studies.

4.2 Data Collection Survey

This survey was based on a household sample survey. It provides basic statistics on various aspects such as desludging frequencies, water sources and consumption, and wastewater generation and disposal. The obtained data was then processed according to calculation methodology mentioned in section 3.2.1, and summarized in Table 4.1. The whole data is available in Table A-1, annex 1.

Table 4-1: Water consumption and fate of generated wastewater collected in cesspits in Beit Dajan and Beit Fourik villages.

	Unit	Average (STD)	Range
Family Size[1]	Person	10 (4.9)	2-23
Water consumption	L/cap.day	58 (11.5)	40-90
Emptying Freq. (Day)[2]	Day	134 (200)	10-720
WW Generated	L/cap.day	49 (9.5)	35-75
Emptied septage volume[3]	L/cap.day	30 (11.6)	4-48
Infiltrated septage	L/cap.day	19 (12.5)	2-53

*Standard deviations are presented between brackets

The results present in Table 4.1 show that the average daily consumption of drinking water per capita is 58.04 L/cap.day, while the average daily wastewater generated per capita is 49.2 L/cap.day and the daily average septage infiltrated from cesspits per capita is 19 L/cap.day.

The majority of the surveyed houses empty their cesspits in a short time interval. About 22% of the surveyed houses empty their cesspits once in a month or less, while 20% every two or three months, 15% in time interval of 4-7 months, 14% every 8-11 months, 8% every 12-24 months, 6% every 25-36 months and 15% have never emptied their cesspits (Figure 4.1).

---

[1] Family term represents household or cluster of households sharing the same cesspit

[2] From the records of the emptying truck diver

[3] Calculated from the records of the emptying truck driver and survey results

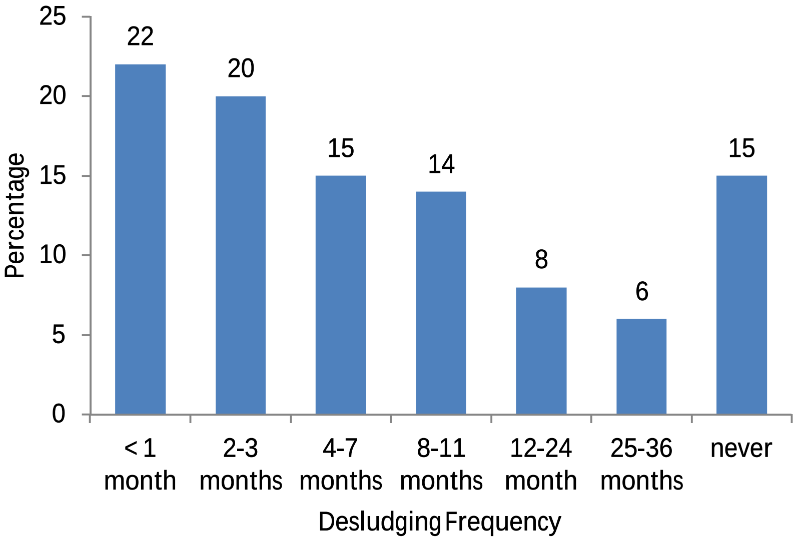

FIGURE 4-1: PERCENTAGE OF SEPTAGE DESLUDGING FREQUENCIES OF CESSPITS IN BEIT DAJAN AND BEIT FOURIK VILLAGES

4.2.2 Water Sources and Use

All the houses covered by the survey are serviced by public water supply network. The survey showed that 70% of their water needs are covered from the water network, 25% from the rain water harvesting system and 5% of water needs are purchased and delivered by truck tank when there is a failure in the water supply network (Figure 4.2).

In addition, it was found out during the direct interviews with household owners in Beit Dajan that drinking water consumption, before installing water supply network couple of years ago, was much more lower than of today. Majority of people are claiming that their water consumption have been almost doubled since then. Consequently, the quantity of the generated wastewater have witnessed also a significant increase over the past years.

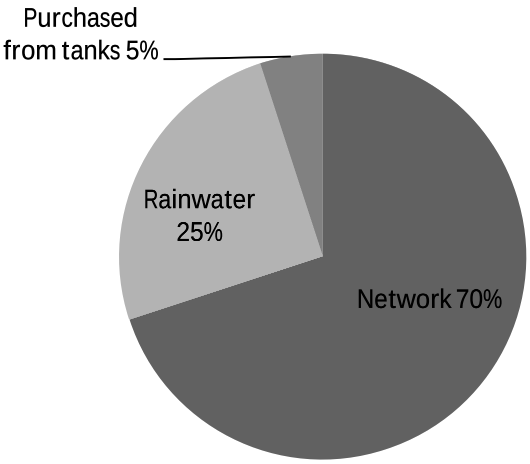

FIGURE 4-2: PERCENT DISTRIBUTION OF DRINKING WATER SOURCES IN BEIT DAJAN AND BEIT FOURIK VILLAGES

4.2.3 Wastewater Generation and Disposal

The survey results revealed that cesspit system is the only final wastewater disposal method in the study area. Moreover, it was found that cesspit receives an average of 85% of the consumed fresh water within household, whereas the other 15% is used for outdoor cleaning, irrigation, livestock and other uses outside the house. These percentages were obtained by taking the average of all household for water consumption and wastewater generation.

4.3 Pollution Load Estimation

The following sections presents the analytical results obtained from lab analysis of septage and infiltrated septage samples collected from Beit Dajan and Beit Fourik villages. This will help is in understanding the variation of TN values from the accumulation point until infiltration.

4.3.1 Total Nitrogen

Total Nitrogen was determined for cesspits septage, infiltrated septage and also for fresh water samples.All collected samples were analyzed at the day of collection for total nitrogen in term of TKN and Nitrate

4.3.1.1 Total Nitrogen in Cesspits Septage

Total Nitrogen (TN) was analyzed as the sum of nitrate-nitrogen (NO_3-N) plus total kjeldahl nitrogen which is the sum of ammonia-nitrogen plus organically bound nitrogen.

The Total nitrogen values measured in pumped out septage are presented in (Table B-2, Annex-B), and the total nitrogen values measured and calculated for the infiltrated septage and pumped out septage are presented in (Table C-1, Annex C). The TN values of septage are presented as minimum, maximum, average and standard deviation in Table 4.2.

Table 4-2: Total nitrogen concentration in the pumped out septage.

	Average (STD)	**Min.**	**Max.**
TKN	297 (88.63)	171	516
NO_3-N	0.17 (0.18)	0.0	0.66
TN	297 (88.69)	171	516

*Standard deviations are presented between brackets; all units are in mg/l

The average TN in cesspits is found to be 297 mg/l where the lowest concentration was found to be 171 mg/l and the highest value was found to be 516 mg/l. The variation in TN values in cesspits could be attributed to variation in water consumption, economic situation and diet habits. The results of the study presented in Table B.1 Annex B do not show strong relation between family size, water consumption, and desludging frequencies with the concentration of TN in cesspit septage.

The high value of nitrogen concentration in septage is due to accumulation and mineralization. This was also found by Al Atawneh (2013), where the raw sewage and the septage of one household in Beit Dajan was monitored over a six months period. The average TN value in raw sewage was 199 mg/L, while the average TN value in septage in the cesspit was 337.67 mg/L. Therefore, infiltration from cesspits results in higher TN value in septage than raw sewage since content high in solid and organic matters remain in the cesspit.

Al shayyah (2008) used Upflow Anaerobic Sludge Blanket (UASB) septic tanks of two different hydraulic retention times, 2, 4 days, for domestic sewage from Al-Bireh city to study the removal efficiency of nitrogen among other pollutants. The average TKN of the influent was 76 mg/l while the average effluent wa 65 mg/l, therefore 15% of TKN was removed in the reactor. Al-shayyah reported that TKN nitrogen was partly removed in the reactors due to particulate N removal with no significant difference between both reactors. He also reported that the removed organic N might had been accumulated in the sludge bed and was not completely converted, hydrolyzed or acidified. Therefore nutrients, as expected, were not removed in both reactors and only a change in the chemical forms of nitrogen and phosphorus took place. Therefore this explains why cesspit septage is higher in TN than septic effluent.

The analytical results revealed that the septage of Beit Dajan and Beit Fourik is classified of high TN content compared with TN of raw wastewater of urban areas in Palestine , but on the other hand, it falls within the range of TN of septage characteristics in the USA, (Table 4.3). Detailed discussion of the measured sepatge characteristics is presented hereafter.

Table 4-3: Comparison of TN values of septage and raw wastewater between Beit Dajan and Beit Fourik cesspits and other Palestinian cities and USA

	Beit Dajan and Beit Fourik villages/ septage	Al Bireh City /Palestine Raw wastewater	Ramallah city/ Palestine Raw wastewater	USA septage
TN (mg/l)	297	104	99.4	66-1060
		Mahmoud *et al.* (2003)	Mahmoud *et al.* (2003)	EPA (1994)

Figure 4.3 shows that TN tend to decrease slightly as family size increases. This could be attributed to the fact that large families include more young members who consume more water for bathing and more frequent than old members. While it is the opposite when considering

emptying frequencies where TN slightly increases as the emptying frequency decrease due to continuous infiltration of septage leaving solids and organic matters trapped in cesspit. Therefore, the long storage period will accumulate more solids that will decompose producing NH$_4$.

Atawneh (2013) found that for one cesspit in Beit Dajan, there was no significant variation was noticed in the average TN values of septage during the filling period of six months. Therefore septage characteristics in term of TN can be generalized regardless the age of septage.

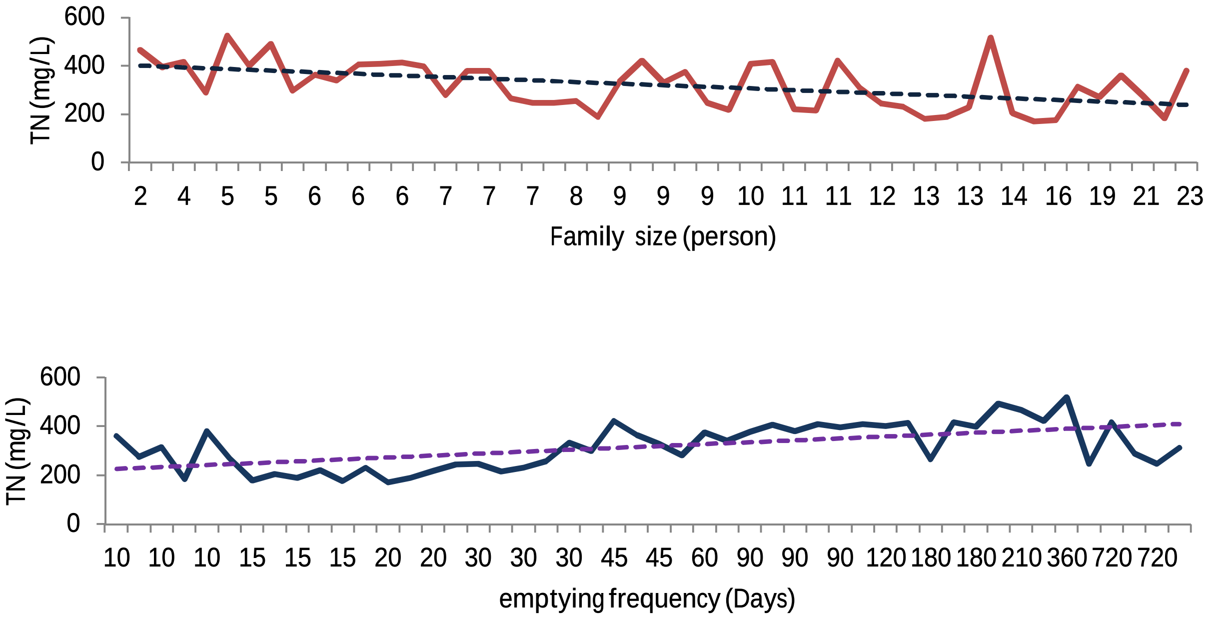

Figure 4-3: Impact of family size and emptying frequencies on TN values

4.3.1.2 Total Nitrogen in Infiltrates

The removal of nitrogen in the soil is influenced by many factors, the soil microbial composition are the key factor which determine the degree of removal. Al-Atawneh (2013) reported that the vast majority of N removed will most likely travel out of the cesspit into the surrounding soil, but hard to predict that the amount that might reach the groundwater or adsorbed onto soil.

In order to find the TN values in infiltrated septage, samples from the installed sampling and monitoring well were collected and analyzed for nitrate and TKN, at the same time septage samples were also collected from the cesspit itself. Table (4.4) represents TN values for the septage samples and infiltrated septage.

Table 4-4: Average TN values of the septage from cesspit connected to monitoring well and of the infiltrated septage collected in the monitoring well

Septage Type	TKN Avg. (STD)	NO_3-N Avg. (STD)	TN Avg. (STD)
Cesspit Septage	233 (23.6)	0	233 (23.6)
Infiltrated Septage	103 (11.7)	22 (11.3)	125 (0.6)

* Standard deviations are presented between brackets; all values are in mg/l

The removal efficiency of the surrounding soil is demonstrated in dry season. Where,

TN removed in soil = (TN septage – TN infiltrated)/TN septage

Therefore, removed $TN = \frac{233-125}{233} \times 100 = 46.4\%$

and TN infiltrated = 100-46.4 =53.6%

Accordingly, it was found that 46.4% of the total nitrogen concentration was removed during the movement of infiltrates from the cesspit to the sampling well. This indicates that further treatment of the septage is effected by the soil mass, but no conclusive evidence exists to emphasize any further degradation of the effluent by the soil at greater depths. Moreover, even anaerobic conditions existed within the cesspit system, presence of nitrates (Concentration range from 14-35 mg/l as NO_3-N) in the infiltrates indicated that aerobic conditions existed in the soil mass surrounding the cesspit.

If a cesspit system and surrounding soil mass function properly, effective treatment of septage in term of total nitrogen could be achieved and consequently help recharge groundwater. However, it can also be a source of pollution to ground waters depending on type and thickness of soil and rocks beneath the system (Avisar *et al.*, 2008). Nitrogen that reach the soil may be removed and broken down through denitrification, absorption before the effluent reaches groundwater. But still, portion of it is likely to travel with effluent to the groundwater. Therefore, cesspits could also act as a potential sources of pollution, whereas, filtration in the soil is the main way to reduce the pollution load dramatically.

Gerritse (1995) reported that around 80% of nitrogen was lost within 10 m of travel in sandy soil in Peth, Western Australia. He concluded that nitrogen additions to catchment waterways were originating to a much greater extent from agricultural areas compared to non-sewered areas (Gerritse *et al.*, 1995). Dawes and Goonetilleke (2003) reported that the greatest removal of nitrogen occurred within 1m of the surrounding soil, with negligible further removal between 1-3m from cesspit.

Nitrate is very stable and soluble, that if does not interact with soil components. Therefore nitrate can travel through the soil easily. Once nitrate reaches groundwater, it will not undergo further transformation, unless conditions for denitrification exist (Avisar *et al.*, 2008).

Elevated nitrate concentrations in groundwater associated with cesspits have been well-documented (EPRI, 2000). Tracer experiments have revealed that nitrate can travel in aquifers underlying cesspits in relatively well-defined, narrow plumes which have been recorded to be up to 130 m in length (Robertson *et al.*, 1991) but may extend up to 200m (Valiela *et al.*, 1997).

When water table is too high and the mass soil surrounding the cesspit system is too permeable, septage reaches the ground water too quickly and is not adequately treated from pollutants load. The densely built up area in both Beit Dajan and Beit Fouriq is a mountainous area characterized by thin soil layer at the top and limestone bedrock. Around 15% of houses do not pump out their cesspits at all while 14% are pumped out at long time intervals (more than a year per round), while other do not even have cesspits at all, where generated raw wastewater is being discharged into rock vaults or caves and never been pumped out. This formation allow septage to infiltrate more easily into the subsurface layers. When the soil mass or bedrock vaults become too saturated, the dissolved organics, heavy metals and even pathogens can easily transport without being removed (De Matos *et al.*, 2000).

The high nitrate level in the water supply well of Beit Dajan and Beit Fourik compared to that of that of other water supply wells in Nablus East (Far'a and Bathan) indicates that there is a source of nitrate pollution. Nitrate level is expected to be higher in Nablus East since these wells are located in an area witnessing an extensive irrigated agricultural activities where large quantities of fertilizers are applied. Therefore, the elevated nitrate level in the study area could be attributed to infiltrates of the cesspits systems in the absence of any other major source of nitrogen in the area.

Assuming the same removal efficiency (46.4%) is valid for all cesspits since all are located in the same geographical area and sharing the same soil type, then the quality of infiltrates in term of TN can be calculated as:

$TN_{infiltrate} = TN_{septage} \times 53.6\%$

Using this equation and assuming that the same removal efficiency is valid for all cesspits in the study area, then the TN values of the infiltrated septage of all the cesspits are calculated as shown in (Table C-1, Annex C) and are summarized in Table (4.5).

Table 4-5: Amount of emptied and infiltrated septage and TN content (range, average and standard deviation) for septage and infiltrated septage in Beit Dajan and Beit Fourik.

		Average (STD)	**Range**
Q septg	L/day	312 (228)	44 - 800
Q *inf*	L/day	176 (126)	22 - 582
TN septg	mg/l	297 (89)	171 - 517
TN *inf*	mg/l	159 (47.7)	92 - 277
TN *inf*	g/cap.day	3.27 (2.61)	0.21 - 11.92
TN septage	g/cap.day	8.53 (3.75)	1.26 – 17.78

*Standard deviations are presented between brackets

Water use and generated wastewater for the study area were calculated according to equations 4.4; 4.5 and 4.6. The results of calculations are presented in Table (4.6).

Water use (m^3/day) = Water use L/cap.day x population x m^3/ 1000L Eq.4.4
= (58.04 L/cap.day x 15,699) / 1000
= 911 m^3/day

$WW_{infiltrated}$ (m^3/day) = WW infiltrated L/cap.day x population x m^3/ 1000L .... Eq. 4.5
= (19 L/cap.day x 15,699) / 1000
= 298 m^3/day

$WW_{pumped\ out}$ (m^3/day) = WW pumped out L/cap.day x population x m^3/ 1000L .... Eq. 4.6
= (30 L/cap.day x 15,699) / 1000
= 471 m^3/day

Table 4-6: Daily amount of drinking water consumption and emptied and infiltrated septage in Beit Dajan and Beit Fourik

Water Use (m^3/day)	**Wastewater** (m^3/day)		
Total	Total	Infiltrated	Pumped out
911	769	298 (38.8%)	471 (61.2%)

*Percent fraction from total generated wastewater is presented between brackets

From Table (4.5), the average daily nitrogen infiltrated per capita was found to be 3.27 g/cap.d (= 1.2 kg/cap/yr), while the average TN per capita in the cesspit was found to be 8.53 g/cap.day.

Brost (2013) have calculated the annual nitrogen load per capita from wastewater in Nablus East using three different methods (Table 4.7). The difference in TN load figure between the two studies can be attributed to the fact that Brost, in her study, assumed that all the generated wastewater will eventually be infiltrated and ends up in groundwater, while in this study, the TN load represents the TN infiltrated directly from cesspits. (Table 4.7) presents a comparison of the annual nitrogen load per capita calculated by this study with the results calculated by various method by Brost (2013):

Table 4-7: Comparison of (A) per capita nitrogen load from septage infiltrated directly from cesspits calculated by this study (B) per capita nitrogen load Calculated using the primary method based on wastewater characteristics and water use, (C) per capita nitrogen load Calculated based on local diet using the method by Jonsson et al.,2014, (D) average per capita nitrogen load from literature

	A Calculated (Kg/cap.yr)	B Primary Method (kg/cap.yr)	C Local Deit method (kg/cap.yr)	D By Literature (kg/cap.yr)
TN	1.2	3.5	2.6	4-5
Reference	This study	Brost *et al* (2013)	Brost *et al* (2013)	Brost *et al* (2013)

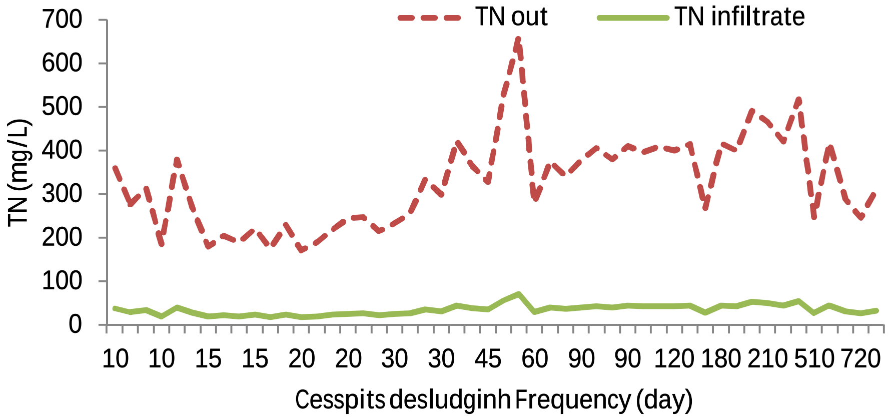

FIGURE 4-4: VARIATION OF THE TOTAL NITROGEN IN DIFFERENT WASTE STREAMS (CESSPIT SEPTAGE AND INFILTRATED SEPTAGE) WITH RESPECT TO DESLUDGING FREQUENCIES IN BEIT DAJAN AND BEIT FOURIK

4.3.2 Heavy Metals

Heavy metal values for septage and infiltrated septage samples were analyzed using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) according to the Standard Method (ICP multi element stander solution 4 certiPUR lot- No. HC957274).

The analytical method is as follows:

1. Put 50 ml of sample in crucible, heat gently on hotplate. During heating, add concentrated nitric acid till the color of the sample becomes clear.
2. Cool the sample and filter with filter paper.
3. In step one, volume reduction in ample occur (sample size becomes about 10 ml due to evaporation and digestion) therefore, during filtration, add distilled water to sample up to total volume of 50 ml (total volume of sample and distilled water).
4. Run the sample on ICP (inductively coupled plasma) instrument which measure the minerals and heavy metals.

4.3.2.1 Heavy Metals in Cesspit Septage

All septage samples have been analyzed for a set of heavy metals including Copper (Cu) , Nickle (Ni), Lead (pb), Manganese (Mn), Iron (Fe), Chromium (Cr) and Zinc (Zn).

The heavy metals concentration in the septage from the cesspit in Beit Dajan and Beit Fourik including the minimum, maximum, average and the standard deviation values are presented in Table (4.8)

Table 4-8: Heavy metals concentration in cesspit septage in Beit Dajan and Beit Fourik

	Average (STD)	Min.	Max.
Cu	0.24 (0.26)	0.0	1.56
Ni	0.03 (0.048)	0.0	0.226
Pb	0.01 (0.02)	0.0	0.095
Mn	0.47 (0.39)	0.078	2.54
Fe	12.56 (8.6)	2.18	44.8
Cr	0.04 (0.03)	0.0	0.167
Zn	1.23 (1.83)	0.08	7.56

*Standard deviations are presented between brackets; all units are in mg/l

The analytical results show that septage contains metals at various concentrations Figure 4.5. The major contribution was obvious in iron, manganese, copper and zinc where the major sources are food, washing powder, cleaning agents, pest control chemicals, shampoo and hear conditioners deodorants, cosmetics, medicines and ointments, paints and others.

The most abundant one is iron with an average of 12.56 mg/l, while it was detected in values up to 44 mg/l in some samples. Other metals are found in trace quantities. Lead and Nickel were not detected in most of the analyzed samples but as an average input from all cesspits, the average concentration was 0.01 and 0.03 mg/l respectively. The average concentration of the other metals are found to be 0.48 mg/l for Copper, 0.47 mg/l for Manganese, 0.04 mg/l for Chromium and 1.23 mg/l for Zinc. The high Fe concentration in septage is most likely due to solubilisation of iron from the ferric form to ferrous under the reduced anaerobic conditions.

The variation of heavy metals values according to desludging frequencies of cesspits are presented in Figure 4-5 and Figure 4.6.

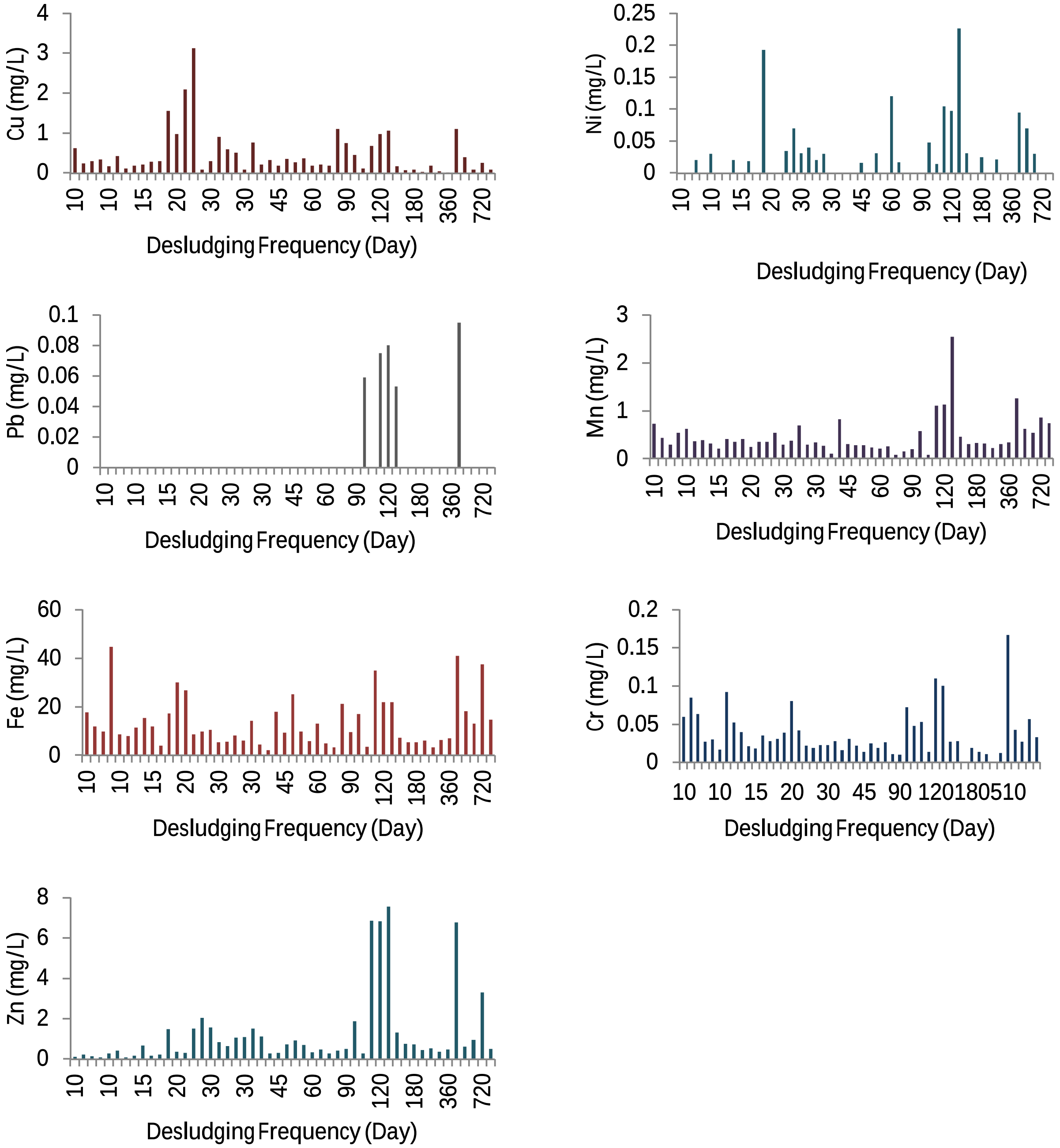

FIGURE 4-5: HEAVY METALS IN CESSPITS WITH RESPECT TO CESSPIT EMPTYING FREQUENCIES IN BEIT DAJAN AND BEIT FOURIK

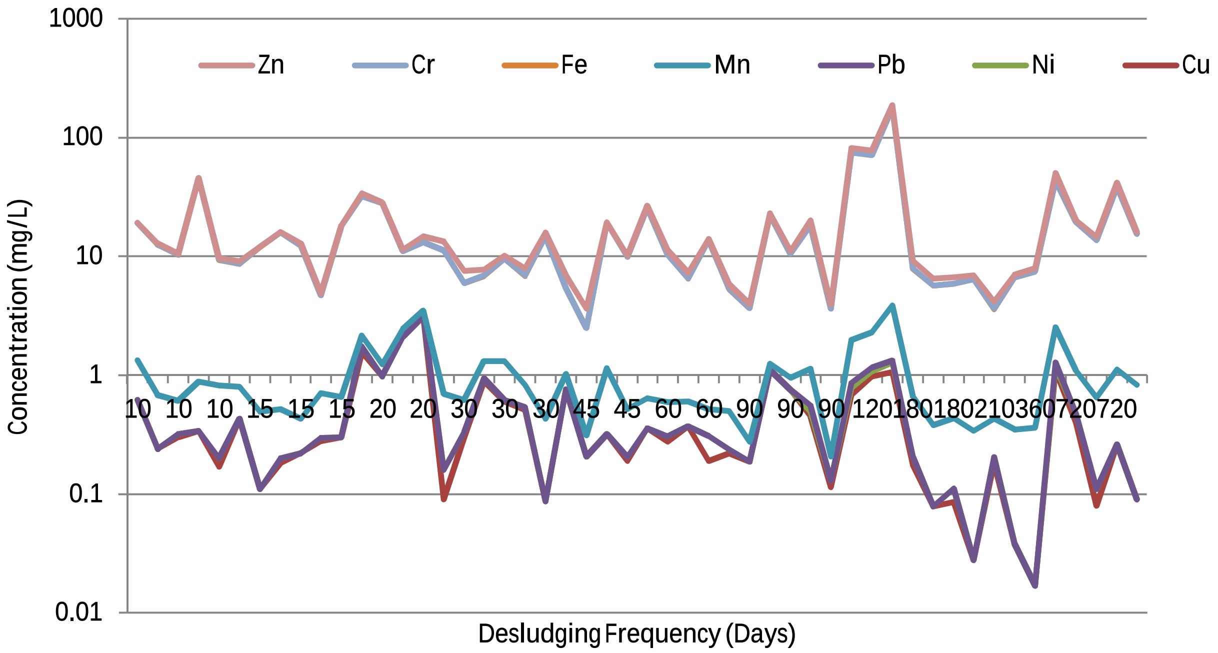

Figure 4-6: Heavy metals variation with respect to emptying frequencies

Figures 4.5 and 4.6 shows that there is no relation between heavy metal concentration and delsudging frequencies. Moreover, Figure 4.6 shows that heavy metals in cesspits are fluctuating in the same pattern for all measured metals, this may indicate that the sources of heavy metals are almost the same in the domestic wastewater.

The quality of raw wastewater entering Al-Bireh WWTP in terms of heavy metals and the maximum concentration of HM in industrial effluent to be discharges in the public sewerage system are presented in Table 4-9. The average concentration of heavy metals in cesspit septage in Beit Dajan and Beit Fourik are lower than of the raw wastewater of Al-Bireh, therefore cesspit septage regardless its age can be treated at the WWTP. The high HM concentration in raw wastewater in Al-Bireh could be attributed to the fact that wastewater is generated from different sources including industry, healthcare and commercial centers and others.

The sewerage by-law of Al-Bireh municipality (for the year 2000) has specified an obligatory guidelines for industrial effluent quality to be discharged to public sewerage system, where the maximum allowable concentration of HM were identified. According to specified maximum levels, septage heavy metals concentrations allow the disposal of septage in Al-Bireh wastewater treatment plant septage receiving unit to be further treated in the aerobic system.

Table 4-9: HM contents of the influent raw wastewater entering Al-Bireh WWTP (Samara, 2009) and The maximum concentration of heavy metals in industrial effluent to be discharged in the public sewerage system (the sewerage by law of Al Bireh municipality, 2000)

	HM contents of the influent raw wastewater entering Al-Bireh WWTP (Samara, 2009)				The maximum concentration industrial effluent (the sewerage by law of Al Bireh municipality, 2000)		
Parameter	**Min**	**Max**	**Average**	**SD**	Discharge < 15 ^{3}/day	Discharge 15-50m ^{3}/day	Discharge > 50 ^{3}/day
Zn (mg/l)	0.448	3.496	1.364	1.244	15.00	10.00	5.00
Cu (mg/l)	0.059	0.720	0.221	0.217	4.50	2.00	1.00
Ni (mg/l)	0.044	0.117	0.075	0.027	4.00	2.50	1.00
Cr (mg/l)	0.108	0.227	0.163	0.047	5.00	2.00	0.50
Pb (mg/l)	N/A	N/A	N/A	N/A	0.60	0.40	0.25
As (mg/l)	N/A	N/A	N/A	N/A	N/A	N/A	N/A

N/A: not available

Heavy metals concentrations in septage as compared to Al Bireh influent with the recommended maximum concentrations of heavy metals according to Palestinian Standards for wastewater agricultural reuse and discharge to wadies and with the FAO guidelines (Yassin et al., 2008) are presented in Table 4.10.

Table 4-10: Comparison of heavy metals values (Cu, Ni, Pb, Mn, Fe, Cr, Zn) in cesspit septage with other studies and with Palestinian standards for discharge and reuse of treated wastewater (PSI, 2003) and with FAO guidelines (1985)

	This Study *Cesspit septage*		Al Atawneh 2013 Beit Dajan septage		Samara 2009 *Al-Bireh WWTP Effluent*		PS *Standard values to be discharged to wadies*	PS *Standard values for agricultural reuse*	FAO *maximum recommended value*
	Avg.	Max.	Avg.	Max	Avg.	Max			
Cu	0.24	1.56	0.399	0.652	0.11	0.207	0.2	0.2	0.2
Ni	0.03	0.226	0.038	0.068	0.03	0.047	0.2	0.2	0.2
Pb	0.01	0.095	0.18	0.286	N/A	N/A	0.1	0.2	5.0
Mn	0.47	2.54	0.79	1.454	N/A	N/A	0.2	0.2	0.2
Fe	12.56	44.8	23.685	36.4	N/A	N/A	2.0	5.0	5.0
Cr	0.04	0.167	0.055	0.08	0.057	0.089	0.5	0.1	0.1
Zn	1.23	7.56	2.937	4.26	0.478	1.480	5.0	2.0	2.0

All parameters are in mg/l; N/A: not available

Table 4.10 shows that quality of cesspit septage in term of Cu, Mn and Fe do not comply neither with the specified limits for heavy metals concentration as per Palestinian Standards for wadies discharge and agricultural reuse, nor with FAO guidelines for the maximum recommended heavy metals concentration. Therefore, cesspit septage that discharged to wadies may impose a significant risk to public health, environment and natural resources. Differently, Al-Bireh effluent can be considered safe, with slight exception of Cu that is almost at the limit. Although the raw sewage of Al-Bireh contains higher heavy metal concentrations.

It is also obvious that the effluent of AWWTP complies with both standards in terms of maximum concentrations of heavy metals for effluent to be reused in agriculture; although Cu concentration is problematic and should be addressed before reuse, could be through dilution with fresh or brackish water (Samara, 2009).

Al-Atawneh (2013) found out that the average heavy metals concentration in cesspit septage of one household in Beit Dajan over six month period were even higher than this study.

4.3.2.2 Heavy Metals in the Infiltrated Septage

Ther average HM concentration in the infiltrated septage in Beit Dajan are presented in Table 4.11, while Table 4.12 presents a comparison of the HM concentration in the drinking water, cesspit septage and infiltrated septage in Beit Dajan.

Table 4-11: Average and standard deviation for HM concentration in various infiltrated samples in Beit Dajan

	Cu mg/l	Ni mg/l	Pb mg/l	Mn mg/l	Fe mg/l	Cr mg/l	Zn mg/l
Average	0	0	0	0.008	0.32	0	0.02
STD	0	0	0	0.009	0.165	0	0.01

Table 4-12: Comparison of Heavy metals concentrations in fresh water, cesspit feeding the sampling well and from infiltrated septage

	Cu mg/l	Ni mg/l	Pb mg/l	Mn mg/l	Fe mg/l	Cr mg/l	Zn mg/l
Drinking	0.04	0	0	0.011	0.095	0	0.56
Cesspit	0.2	0.03	0	0.23	4.35	0.019	0.66
Infiltrated	0	0	0	0.008	0.32	0	0.02

The results of heavy metals analysis in the septage and infiltrated septage shows that heavy metals concentrations in infiltrates have been reduced dramatically after being moved through soil particles Table 4.10. Copper, nickel and chromium have not been detected in the infiltrates, thus been removed from the septage. Other metals such as manganese, iron and zinc have been reduced dramatically. This confirms that soil can significantly improve wastewater quality in term of heavy metals by adsorbing major constituent of heavy metals from the wastewater. Figure 4.8 shows the reduction of heavy metals concentration during the transport of wastewater through the soil medium as it moves from the feeding cesspits to the installed sampling well.

Therefore, the pollution load from infiltrated septage in term of heavy metals can be considered minimal when talking about its impact on groundwater quality since the major part of it will be trapped and accumulated in the soil.

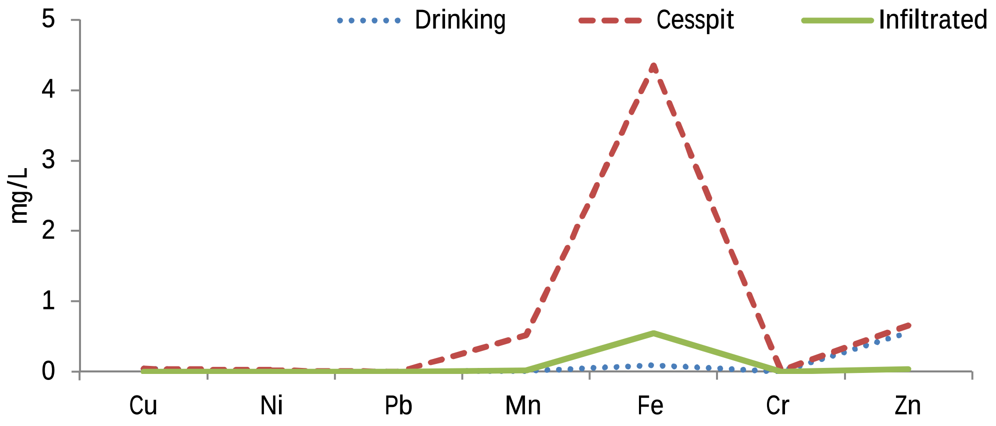

FIGURE 4-7: VARIATION OF HEAVY METALS CONCENTRATION IN THE CONSUMED WATER, SEPTAGE AND AFTER SEPTAGE HAS BEEN INFILTRATED THOUGH THE SOIL

Heavy metals concentrations in infiltrated septage as compared to Al Bireh effluent with the recommended maximum concentrations of heavy metals according to Palestinian Standards for wastewater discharge to wadies and with the FAO guidelines (Yassin et al., 2008) are presented in Table 4.13. It is obvious that the concentration of HM of the infiltrated septage in Beit Dajan and Beit Fourik are much lower than of the treated effluent from Al-Bireh WWTP, and below the maximum set by the Palestinian standards and FAO guidlines. Therefore, cesspit septage that infiltrate through the soil particles are treated in the soil to an extent that become safe to groundwater quality in term of heavy metals.

Table 4-13: Comparison of heavy metals values (Cu, Ni, Pb, Mn, Fe, Cr, Zn) in infiltrated septage with Palestinian standards for discharge and reuse of treated wastewater (PSI, 2003) and with FAO guidelines (1985)

	This Study *Cesspit septage*	Samara 2009 *Al-Bireh WWTP effluent*	PS *Standard values to be discharged to wadies*	FAO *maximum recommended value*
Cu	0.0	0.11	0.2	0.2
Ni	0.0	0.03	0.2	0.2
Pb	0.0	N/A	0.1	5.0
Mn	0.008	N/A	0.2	0.2
Fe	0.32	N/A	2.0	5.0
Cr	0.0	0.057	0.5	0.1
Zn	0.02	0.478	5.0	2.0

All parameters are in mg/l; N/A: not available

4.4 Impact of Cesspits on Groundwater

Septage infiltrated from cesspits have potential impact on groundwater quality and quantity. On one hand, they contribute to considerable volume of recharge to groundwater through non stopping infiltration, and on the other hand they are accused for deteriorate groundwater quality through continuous pollution load.

4.4.1 Contribution of Cesspits to Groundwater Recharge

Septage infiltrated from cesspits contribute to a significant part in the recharge of groundwater. In a case study in of urban areas in Sub-Saharan Africa, it was estimated that septage recharge may be as high as 10-50% of the total precipitation (Njenje *et al.*, 2010). In our case, considering all infiltrated septage reaches groundwater, it was found that infiltrated septage from cesspits makes about 6.7% of the total recharge to groundwater, whereas in Beit Fourik, the contribution of cesspits to groundwater recharges reaches up to 18.7%. Even the population of Beit Fourik is three times Beit Dajan, but the village area is smaller than of Beit Dajan and therefore receives much precipitation than Beit Fourik.

4.4.2 Calculations

The mean annual rainfall in study area is 377 mm/yr (PWA, 2011), where the area of Beit Dajan village is 5000 dunum (source Beit Dajan Village Council) whereas Beit Fourik is 4658 dunum (Beit Fourik Municipality).

Therefore, the volume of annual rainfall for Beit Dajan is:

Volume of annual rainfall = Area x annual rainfall .... Eq. 4.8

$= 5000{,}000\ m^2 \times 377\ mm/yr$

$= 1885 \times 10^6\ L$ where $1\ mm$ of rainfall $= 1\ L/m^2$

$= 1885 \times 10^3\ m^3$

The Annual Water Status Report,2011 of the Palestinian Water Authority stated that 25% of the total precipitation is recharged to groundwater, therefore the mean annual recharge in Beit Dajan from precipitation is:

Annual recharge = $= Volume_{\text{annual rainfall}} \times recharge\%_{\text{from precipitation}}$ .... Eq. 4.9

$= 1885 \times 10^3 \times 25\%$

$= 471 \times 10^3\ m^3$ water recharged to groundwater from Beit Dajan

From (Table 4.1), the average septage infiltrated from cesspits is 19 L/cap.day. and population of Beit Dajan is 3958 (PCBS, Population Estimation 2007-2016) then, the volume of the total annual infiltrated septage is calculated as:

1. Contribution from never pumped out cesspits, where all generated WW is considered to be infiltrated from cesspits:

   Infiltrated septage $= \%\ Cesspits_{\text{never pumped out}} \times$ total population x Qin (L/cap.day)

   $= 15\% \times 3958 \times 49.2$

   $= 29{,}225\ L/day$

   $= 10{,}667\ (m^3/year)$ infiltrated from cesspits that never been emptied

2. Contribution from people pumping out cesspits:

From (Table 4.1), the average daily infiltrated septage = 19 L/cap.day, then the volume of infiltrated septage is:

Infiltrated septage = % of Cesspits $_{\text{pumped out}}$ x Population x average daily infiltrated
= 85% x 3958 x 19 L/cap.day
= 63,916 L/day
= 23,329 (m^3/year) septage infiltrated from cesspits pumped out

Considering all infiltrates are recharge to groundwater, then the total recharge from cesspits is

Total volume of infiltrates from cesspits = volume infiltrated from cesspits that never been emptied + volume from cesspits that used to be emptied

Therefore,

Total infiltration from cesspits = 10,667 + 23,329 =33,996 (m^3 /year)

Total recharge from both precipitation and infiltration will be

471,000m^3+33,996 m^3 = 504,996 m^3,

therefore, the contribution of cesspits infiltrates to groundwater recharge

= (33,996 m^3 / 504,996 m^3) x100

= 6.7 % percent contribution of cesspits to total groundwater recharge in Beit Dajan

Repeating the same calculation for Beit Fourik where population is 11,741 people and land area of 4658 dunum, then

Recharge from precipitation = 439,016 (m^3/yr)

Recharge from cesspits = 100,839 (m^3/yr)

Total recharge = 439,016 m^3 + 100,839 m^3 = 539,855 m^3

Therefore, the contribution of cesspits infiltrates to groundwater recharge

$= (100{,}839\ m^3 / 539{,}855\ m^3)\ x100$

= 18.7 % percent contribution of cesspits to total groundwater recharge in Beit Fourik

Table 4-14: Contribution of Cesspits to groundwater recharge

Locality	**Area (Dunum)**	**Recharge from Precipitation (m^3/yr)**	**Recharge from Cesspits (m^3/yr)**	**Cesspits contribution to recharge (%)**
Beit Dajan	5,000	471,000	33,996	6.7
Beit Fourik	4,658	439,061	100,839	18.7
Total	9,658	910,061	134,835	13.0

From Table 4-14, the total infiltrated septage calculated as recharge in the study area was 134,835 m^3/year (13.9 m^3/dunum.yr), while the total annual rainfall recharge for the study area was calculated as 910,061m^3/yr (63.1 m^3/dunum.yr) based on recharge data obtained from the Annual Water Status Report of PWA (Table 4.14). Therefore, wastewater recharge in the study area contribute to as much as 15% of total recharge from precipitation, making cesspits a significant source of recharge bearing in mind that the study area is of low population density. This percent may increase significantly when talking about area with more population density like cities or refugee camps.

The most recent chemical analysis of groundwater samples from municipal wells in Nablus area confirm increasingly high levels of nitrate in groundwater, measuring 22 and 25 mg/l NO_3 at wells of depth 670 ft and 675 ft and 11 mg/l NO_3 at a well of depth 413 ft (Mahmoud *et al.*, 2012).

In order to have wider view at national level, the contribution of cesspits to groundwater recharge for West Bank (not including Israeli settlements) and Gaza Strip for the years 2013 and 2023 was calculated according to figures presented in (Table 4.15), where 59.8% of WB depends on cesspits as the final disposal system for wastewater while it is 16.9% in GS (PCBS 2011). Moreover, 59.8%, and 19.6% of the total population for WB and GS respectively use cesspits (PCBS 2011). Assuming this rate is assumed to remain constant till 2023.

Table 4-15: Percent distribution of wastewater disposal by cesspits and the long term average recharge to groundwater with respect to population and population projection for 2013 for West Bank and Gaza Stip, Palestine

	Population 2013	% Growth Rate (GR)*	Population 2023*	WW disposal by Cesspits (%)*	Long Term Average Recharge MCM**
West Bank	2,719,112	3.4	3,798,678	59.8 %	578
Gaza	1,701,437	4.0	2,518,542	16.9 %	55

* *Population*$_{2023}$ *= Population*$_{2013}$ *(1+GR)*^{10} *where GR*$_{WB}$ *= 3.4%, GR*$_{GS}$ *= 4.0% (*PCBS, 2011*)*
*** Source PWA 2011*

From (Table 4.15), people relying on cesspits as their on-site disposal system in West Bank and Gaza Strip was calculated for the years 2013 and 2023 as follows:

Pop $_{\text{West Bank using cesspits 2013}}$ = Population 2013 $_{\text{total}}$ x 59.8%
= 2719112 x 59.8%
= **1,626,029**

Pop $_{\text{West Bank using cesspits 2023}}$ = Population 2023 $_{\text{total}}$ x 59.8%
= 3798678 x 59.8%
= **2,271,610**

Pop $_{\text{Gaza using cesspits 2013}}$ = Population 2013 $_{\text{total}}$ x 16.9%
= 1701437 x 19.6%
= **287543**

Pop $_{\text{Gaza cesspits 2023}}$ = Population 2023 $_{\text{total}}$ x 16.9%
= 2518542 x 16.9%
= **425,633**

Applying the same factors used in previous calculations where 15% of people never pump out cesspits and all generated wastewater (49..2 L/cap.day) is considered infiltrated, while 85% pump cesspits out periodically and 19.0 L/cap/day is considered to be infiltrated from cesspits. Assuming the same WW generation rate per capita in WB and GS, Then:

WB Population $2013_{\text{never pumpout}}$ = 1626029 X15% = 243,904
WB Population 2013_{pumpout} = 1626029 X85% = 1,382,125
WB Population $2023_{\text{never pumpout}}$ = 2271610 X15% = 340,741
WB Population 2023_{pumpout} = 2271610 X15% = 1,930,869
And
GS Population $2013_{\text{never pumpout}}$ = 287543 X15% = 43,132
GS Population 2013_{pumpout} = 287543 X85% = 244,411
GS Population $2023_{\text{never pumpout}}$ = 425633 X15% = 63,845
GS Population 2023_{pumpout} = 425633 X85% = 361,788

Therefore,
The amount of infiltrated septage in 2013 in WB is:
$WW_{inf} = WW_{\text{never pumpout}} + WW_{\text{pumpout}}$ .... Eq . 4.10
= (243904 X49.2 (L/cap.day)) + (1382125 x 19 (L/cap.day))
= 12,000,076 (L/day) + 26,260,375 (L/day)
=38,260,451 (L/day)
= 13,974,629 (m^3/year) septage infiltrated to groundwater in WB in 2013

The amount of infiltrated septage in 2023 in WB is:
$WW_{inf} = WW_{\text{never pumpout}} + WW_{\text{pumpout}}$ .... Eq. 4.11
= (340741 X49.2 (L/cap.day)) + (1930869 x 19 (L/cap.day))
= 16,764,457 (L/day) + 36,686,511 (L/day)
=53,450,968 (L/day)
= 19,522,966 (m^3/year) septage infiltrated to groundwater in WB in 2023

The amount of infiltrated septage in 2013 in GS is:
$WW_{inf} = WW_{\text{never pumpout}} + WW_{\text{pumpout}}$ .... Eq. 4.12
= (43132 X49.2 (L/cap.day)) + (244411 x 19 (L/cap.day))
= 212,210 (L/day) + 4,643,809 (L/day)
=4,856,019 L/day

= 1,773,660 (m^3/yr) septage infiltrated to groundwater in GS in 2013

The amount of infiltrated septage in 2023 in GS is:

$WW_{inf} = WW_{never\ pumpout} + WW_{pumpout}$ .... Eq. 4.13

= (63845 X49.2 (L/cap.day)) + (361788 x 19 (L/cap.day))

= 3,141,174 (L/day) + 6,873,972 (L/day)

=10,015,146 (L/day)

= 3,658,032 (m^3/yr) septage infiltrated to groundwater in GS in 2023

The obtained data are summarized in (Table 4.16)

Table 4-16: Contribution of Cesspits to groundwater recharge in West Bank and Gaza strip, Palestine

	Infiltrated 2013 MCM/yr	Infiltrated 2023 MCM/yr	Long Term Average Recharge MCM	Total Recharge 2013 MCM	Total Recharge 2023 MCM	Cesspits Contribution 2013, %	Cesspits Contribution 2023, %
WB	13,97	19,52	578	591,97	597.5	2.36	3.26
GS	1,77	3,65	55	56.77	58.65	3.12	6.22

4.4.3 Contribution of Cesspits to Groundwater Nitrogen

The impact of cesspits on groundwater quality in term of TN is of great importance. The contribution of cesspits to groundwater in term of TN was calculated assuming all infiltrated septage will find its way to the groundwater. The infiltrates was calculated for cesspits that's pumped out periodically and also for those that's never been pumped out where all generated wastewater was considered to be infiltrated. Therefore, the TN infiltrated ($TN_{inf)}$) from Beit Dajan area was calculated as:

$TN_{infiltrated} = TN_{inf\ from\ pumped\ out\ cesspits} + TN_{inf\ from\ never\ pumped\ out\ cesspits}$ .... Eq. 4.14

where:

$TN_{inf\ –pumped\ out\ cesspits}$ = TN_{inf} g/cap.d x pop x 365.25 day/yr x 85%
= 3.27 x 3958 x 365.25 x 0.85
= 40.17 x 10^5 g/yr
= 4017 kg/yr

$TN_{inf-never\ pumped\ out}$ = TN_{in} g/cap.d x pop x 365.25 day/yr x 15%
= 11.81 x 3958 x365.25 x 0.15
= 2560986 g/yr
= 2561 kg/yr

Therefore, total infiltrated nitrogen from Beit Dajan area is:

$TN_{inf-Beit\ Dajan}$ = 4017 + 2561
= 6,578 kg /yr

Repeating the same calculation for Beit Fourik, then

$TN_{inf\ –pumped\ out\ cesspits}$ = TN_{inf} g/cap.d x pop x 365.25 day/yr x 85%
= 3.27 x 11741 x 365.25 x 0.85
= 135.6 x 10^5 g/yr
= 13,556 kg/yr

$TN_{inf-never\ pumped\ out}$ = TN_{in} g/cap.d x pop x 365.25 day/yr x 15%
= 11.81 x 11741 x365.25 x 0.15
= 75.9 x 10^5 g/yr
= 7,590 kg/yr

Therefore, total infiltrated nitrogen from Beit Fourik area is:

$TN_{inf-Beit\ Fourik}$ = 13556 + 7590
= 21,116 kg /yr

A projection for TN was estimated for the year 2023 using the same calculation methods taking into consideration a population growth of 3.4% (Table 4.17).

Table 4-17: Population and population projection for 2023 for Beit Dajan and Beit Fourik

	Population 2013	% Growth Rate (GR)*	Population 2023*
Beit Dajan	3958	3.4	5,529
Beit Fourik	11741	4.0	16,402

The quantity of TN that is infiltrated from cesspits in 2013 and the expected quantity to be infiltrated in 2023 are presented in (Table 4.18).

Table 4-18: TN load by cesspits infiltrates from Beit Dajan and Beit Fourik in 2013 and 2023

Locality	Population 2013	Population 2023*	TN(kg/yr) Inf. 2013	TN (kg/yr) Inf. 2023
Beit Dajan	3,958	5,529	6,578	9,189
Beit Fourik	11,741	16,402	21,116	29,541
Total	15,699	21,931	27,694	38,730

* *Population*$_{2023}$ *= Population*$_{2013}$ *(1+GR)*^{10} *where GR = 3.4%, (PCBS, 2011)*

These figures show that the quantity of TN that is infiltrated from cesspits from both villages was 27,694 kg per year. Dividing this value by the total area of 9,658 dunum, then the total nitrogen load will be 2.87 kg /dunum.yr. This value is subjected to a 40% increase in 10 years.Brost (2013) reported that the total loading nitrogen from septage in Nablus East was estimated to be 1.8 kg N/dunum. month (21.6 kg N/dunum.yr). The large variation in results was due to the fact that Brost considered in her estimation that all generated wastewater will be infiltrated. Furthermore, the study area of Brost contains high population densities refugee camps where N loading from the refugee camp wastewater was estimated to vary from 4 to 5 (kg N/ ha.day).

The impact of cesspits in term of nitrate on the quality of the recharge to groundwater as a contribution from the built up area of both of the villages was calculated assuming that contribution of the agricultural activities to groundwater nitrate is insignificant since only rainfed crops are raised and fertilizers are almost not being used (source Beit Dajan village council).

The total recharge to groundwater in the study area from precipitation and cesspits is 1,044,896 m^3/yr (Table 4.15) while the total nitrogen infiltrated is 27,694 kg/yr N (=122,645 kg NO_3) (Table 4.19), therefore, according to this assumption, nitrate concentration in the recharge from precipitation and infiltration from both villages will be:

$$\text{Nitrate} = 122{,}645 \text{ kg} / 1{,}044{,}896 \text{ m}^3 = 0.117 \text{ (kg/m}^3\text{)} = (117 \text{ mg/l})$$

Therefore, this high nitrate level (117mg/l) in the recharge from both villages as contribution to the catchment of the water supply well will have significant impact on groundwater quality. This explains the high nitrate level (30 mg/l) in the shallow water supply well in Beit Dajan plain.

4.4.4 Total Nitrogen in Fresh Water

In addition, fresh water samples collected from the water well feeding the study area, and from two other wells nearby the study area have also been analyzed for nitrate and heavy metals.

Three fresh water samples were collected and analysed for the sake of this study from three water wells in the study area (Figure 4.8). One well is located in the in the study area and supply the two villages with fresh water. The other two wells are located downstream in Al Bathan and Al Far'a areas.

FIGURE 4-8 AERIAL PHOTO FOR WATER WELL IN BEIT DAJAN AND BEIT FOURIK AREA

These samples were analyzed for nitrate and heavy metals. The nitrate level was found to be higher in well # 1 than of it in the other two well (Table 4.19). The results were contrary to expectation since the other two well are located in an irrigated agricultural area where natural and chemical fertilizers are used intensively, while well# 1 is located in a rain fed agricultural area where fertilizers are used in small scale.

The determination of the relation between groundwater nitrate contaminations to a particular source is complicated by (1) the occurrence of multiple possible sources of nitrate in many regions, (2) the presence of overlapping point and non-point sources, and (3) the co-existence of several biogeochemical processes that alter nitrate concentrations.

Table 04-19: Nitrate levels in fresh water in the study area and surrounding wells

Location	NO_3 mg/l	NO_3-N mg/l
Beit Dajan	30	6.8
Bathan	10.6	2.4
Far’a	15.6	3.5

Chapter Five

Conclusions and Recommendations

5.1 Conclusions

The main objective of this study was to characterize septage in terms of TN and HM from various cesspits of different desludging frequencies in Beit Dajan and Beit Fourik villages, and to determine the TN and HM pollution load fluxes from these cesspits. This was achieved through data collection survey and technical field study. Based on the results of the study, the following conclusions were drawn:

- ⇒ Drinking water supply in the study area was 70% covered from water supply network, while 25% from rain water harvesting systems and 5% purchased through tank hauler.
- ⇒ The average daily consumption of drinking water per capita was 58 L/cap.day, while the average daily wastewater generated per capita was 49 L/cap.day. The daily average sewage infiltrated from cesspits per capita was 19 L/cap.day.
- ⇒ 22% of the houses empty their cesspits once in a month or less, while 20% every two or three months, 15% in time interval of 4-7 months, 14% every 8-11 months, 8% every 12-24 months, 6% every 25-36 months and 15% never emptied their cesspits.
- ⇒ An average of 85% of the consumed fresh water within household goes to cesspits, while 15% is being used for outdoor cleaning, irrigation, livestock.
- ⇒ The average TN of septage was 297 mg/l where the lowest concentration was 171 mg/l and the highest value was 516 mg/l.

⇒ 46% of the total nitrogen in septage was removed while infiltrated through surrounding soil of around 1.0 m thick.

⇒ The average daily nitrogen passed through surrounding soil of around 1.0 m thick was 3.27 g/cap.d (= 1.2 kg/cap/yr).

⇒ There is no strong relation between desludging frequencies, family size and water consumption with the concentration of TN in cesspit septage.

⇒ The high value of nitrogen concentration in septage (297 mg/l) compared to TN of raw wastewater (199 mg/l) is due to accumulation and mineralization.

⇒ The most abundant HM element was iron with an average of 12.56 mg/l, with a maximum value of 44 mg/l. Lead and nickel were not detected in most of the analyzed samples but the average concentration was 0.01 and 0.03 mg/l respectively. The average concentration of copper, manganese, chromium and zinc were 0.48 mg/l, 0.47 mg/l, 0.04 mg/l and 1.23 mg/l respectively.

⇒ HM concentration in the infiltrated septage had been reduced dramatically after being moved through the surrounding soil of around 1.0 m thick. Copper, nickel and chromium had not been detected in the infiltrates, while other metals such as manganese, iron and zinc had been reduced dramatically where the average concentration of Mn, Fe and Zn were 0.008 mg/l, 0.32 mg/l and 0.02 mg/l respectively.

⇒ The volume of the total infiltrated septage into subsoil in the study area was 134,835 m^3/year (13.9 m^3/dunum.yr), representing 13% of the total annual rainfall recharge of the same area which was calculated as 910,061m3/yr(63.1 m^3/dunum.yr).

⇒ The amount of TN infiltrated from cesspits from both villages was 27,694 kg per year, which is equal to 2.87 kg /dunum.year.

5.2 Recommendations

The following recommendations are made to mitigate the impact of cesspits on the environment and are also considered as a potential source of support for future studies. These recommendations address the following issues regarding the wastewater management:

- Construction of a central wastewater treatment plants, each covers a cluster of communities using cesspits where septage hauler tanks empties their load in the treatment plant instead of wadies.
- Implement a national groundwater quality management system that includes a periodic monitoring program for groundwater quality in term of TN, HM and microbiological contaminants.
- Developing new laws and regulations to control the movement and unloading points of the septage hauler tanks.
- Raise public awareness targeting the public and decision makers on groundwater and natural resources issues.

References

Beal, C. D., Gardner, E. A, and Menzies, N.W.2005. “Process, performanceand pollution potential: A review of septic tank–soil absorption systems.” *Austral. J. Soil Res.*, 43, 781–802.

Kristiansen, R. 1981. “Sand-filter trenches for purification of septic tank effluent: I. The clogging mechanism and soil physical environment.” *J. Environ. Qual*, 10, 353–357.

Siegrist, R, and Boyle,W. C. 1987. “Wastewater-induced soil clogging development.” *J. Environ. Eng.*, 1133, 550–566.

U.S. Environmental Protection Agency USEPA. 1993. “Guidance specifying management measures for sources of nonpoint pollution incoastal waters.” *EPA840-B-92-002*, Office of Water, Washington, D.C.

U.S. Environmental Protection Agency USEPA. 2002. *Onsite wastewater treatment systems manual*, Chaps. 1 and 4, U.S. EPA, Office of Water, Office of Research and Development, Washington, D.C., 6–34.

Beal, C.D., Gardner, E.A., Menzies, N.W., Rassam, D.W. and Vieritz, A.M. (2004) Prediction of steady-state flux through variably saturated zones within a septic absorption trench. Proceedings of the International Soil Science Conference 2004, 5 - 9 December 2004, Sydney, Australia.

Jefferson B, Laine A, Parsons S, Stephenson T, Judd S.Technologies for domestic wastewater recycling. Urban Water 1999;1(4);285– 92.

Moe, C. L., M. D. Sobsey,,(1991). “Bacterial indicators of risk of diarrhoeal disease from drinking-water in the Philippines.

Hoover, M.T., Disy, T.M, Pfeiffer, M.A., Dudley, N., Mayer, R.B., and Buffington, B., 1996. North Carolina Subsurface System Operators Training School Manual.

Mouneimne, A.H., Carre`re, H., Bernet, N., Delgene`s, J.P., 2003. Effect ofsaponification on the anaerobic digestion of solid fatty residues. Bioresour. Technol. 90, 89–94.

O’Flaherty, V., Lens, P., Leaky, B., Colleran, E., 1998b. Long term competition between sulphate reducing and methane-producing bacteria during full-scale anaerobic treatment of citric acid production wastewater. Water Res. 32 (3), 815–825.

Palmquist H, Hanæus J. A Swedish overview of selecting hazardous substances as pollution indicators in wastewater. Management of Environmental Quality 2004;

Jackson, B. J. (1997). Are we exaggerating the dangers of groundwater pollution from on-site santation systems such as pit-latrines

Feachem, R.G., Bradley, D.J., Garelick, H. and Mara, D.D. (1983) Sanitation and disease: health aspects of excreta and wastewater management. World Bank Studies in Water Supply and Sanitation 3, Wiley, Chichester, UK

Pescod M. B. (1971). Sludge handling and disposal in tropical developing countries. Water Pollution Control Federation. Vol. 43, No. 4, pp. 555-570

Cotton, A., Franceys, R., Pickford, J. and Saywell, D.F. (1995) On-Plot Sanitation in Low-Income Urban Communities – a Review of the Literature. Water, Engineering and Development Centre (WEDC), Loughborough, UK.

Pedley S, Yates M, Schijven JF, West J, Howard G, Barrett M. 2006. Pathogens: Health

Jack, R., M. de Zamaroczy and M. Merrick, 1999 The signal transduction protein GlnK is required for NifL-dependent nitrogen control of nif gene expression in Klebsiella pneumoniae. J. Bacteriol.181: 1156–1162.

Schouw, N.L., Danteravanich, S., Mosbaek, H., Tjell, J.C. 2002. Composition of human excreta – a case study from Southern Thailand. Science of the Total Environment Journal 286(1-3), 155-166.

Sternbeck J, O¨ stlund P. New metals and metalloids in the society [Nya metaller och metalloider i samh7llet]. Stockholm7 Swedish Environmental Research Institute; 1999. IVL.

Sauer, P. A., and E. J. Tyler. 1995. "Heavy Metal and Volatile Organic Chemical Removal and Treatment in Onsite Wastewater Infiltration Systems." *Water, Air, and Soil Pollution* 89:221-32.

García, J., Green, B.F., Lundquist, T., Mujeriego, R., Hernández-Mariné, M., Oswald, W.J., 2006. Long term diurnal variations in contaminant removal in high rate ponds treating urban wastewater. Bioresource Technology 97, 1709–1715.

Powell, N., Shilton, A., Chisti, Y., Pratt, S., 2009. Towards a luxury uptake process via microalgae – defining the polyphosphate dynamics. Water Research 43, 4207– 4213

Berman, T., and D. A. Bronk. 2003. Dissolved organic nitrogen: a dynamic participant in aquatic ecosystems. Aquatic Microbial Ecology 31: 279-305.

Berg, G., D. Repeta, and J. LaRoche. 2002. Dissolved organic nitrogen hydrolysis rates in axenic cultures of Aureococcus anophagefferens (Pelagophyceae): comparison with heterotrophic bacteria. Applied and Environmental Microbiology 68: 401-404.

Hallberg, G. R., Nitrate in Ground Water in the United States, in Nitrogen Management and Groundwater Protection, (Edited by R. F. Follett) Elsevier Sci. Publ., Amsterdam, 1989.

Hantzsche, N. and Finnemore, E., Predicting Ground-Water Nitrate-Nitrogen Impacts, Ground Water, Vol. 30, No. 4, pp. 490-499, 1992.

Ferguson CM, Coote BG, Ashbolt NJ, Stevenson IM (1996). Relationships between indicators, pathogens and water quality in an estuarine system. Water. Res. 30: 2045-2054

Godfree, A. F., Kay, D. & Wyer, M. D., 1997. Faecal streptococci as indicators of faecal contamination in water. Journalof Applied Microbiology, Volume 83, pp. 110-119.

Bhagwan JN, Still D, Buckley C, Foxon K. Challenges with up-scaling dry sanitation technologies. Water Sci Technol. 2008;58(1):21-27

Pohland, F.G. and Ghosh, S. (1971) 'Developments in anaerobic treatment processes', in Canale, R.P. (Ed.): Biological Waste Treatment, Interscience, New York, pp.85–106.

Rofe and Raffety Consulting Engineer 1965, Nablus District Water resources Survey, Geological and Hydrological Report

Hazen and Sawyer Environmental Engineers and Scientists. "Literature Review of Nitrogen Reduction Technologies for Onsite Sewage Treatment Systems." Task A.2 Final Report prepared for the Florida Department of Health (2009)

Beal, C.D., E.A. Gardner, and N.W. Menzies. "Process Performance and Pollution Potential: A Review of Septic Tank-soil Absorption Systems." Australian Journal of Soil Research 43 (2005):781–802.

Oakley, S.M., A.J. Gold, and A.J. Oczkowski. "Nitrogen Control through Decentralized Wastewater Treatment: Process Performance and Alternative Management Strategies." Ecological Engineering 36 (2010):1520-31.

Meeroff, D.E., F. Bloetscher, T. Bocca, and F. Morin. "Evaluation of Water Quality Impacts of On-site Treatment and Disposal Systems on Urban Coastal Waters." Water Air Soil Pollution 192 (2008): 11-24.

Ying-Hua Li, Hai-Bo Li , Tie-Heng Sun, Xin Wang. Effects of hydraulic loading rate on pollutants removal by a deep subsurface wastewater infiltration system,2011

Dror Avisar Æ Joel Kronfeld Æ A. Siep Talma Amelioration of groundwater nitrate contamination following installation of a central sewage system in two Israeli villages 2008

Siegrist, R.L., Anderson, D.L., and Converse, J.C. 1984. Onsite Treatment and Disposal of Restaurant

Wastewater. Small Scale Waste Management Project, University of Wisconsin. Madison, WI. pp 38.

Annex A

Table A-1 Results of Data Collection Survey

	Family Size*	Water consumption per capita (L/cap.d)	Water consumption per household (L/day)	Emptying Freq. (Day)	Emptied volume per round (L/Round)	WW Generated per capita (L/cap/d)	WW generated per household (L/ day)	Emptied volume per day (L/day)	Emptied volume per capita per day (L/cap.d)	Daily Infiltrated (L/day)	Infiltrated Per capita (L/cap day)
1	20	60	1200	10	8000	50	1000	800	40	200	10
2	21	55	1155	10	8000	45	945	800	38	145	7
3	19	65	1235	10	8000	55	1045	800	42	245	13
4	22	45	990	10	8000	40	880	800	36	80	4
5	23	45	1035	10	8000	40	920	800	35	120	5
6	19	60	1140	10	8000	50	950	800	42	150	8
7	13	50	650	15	8000	45	585	533	41	52	4
8	14	45	630	15	8000	40	560	533	38	27	2
9	13	60	780	15	8000	50	650	533	41	117	9
10	11	70	770	15	8000	60	660	533	48	127	12
11	16	55	880	15	8000	45	720	533	33	187	12
12	13	60	780	20	8000	50	650	400	31	250	19
13	15	40	600	20	8000	35	525	400	27	125	8
14	9	90	810	20	8000	75	675	400	44	275	31
15	10	65	650	20	8000	55	550	400	40	150	15
16	12	55	660	20	8000	45	540	400	33	140	12
17	8	60	480	30	8000	50	400	267	33	133	17

	Family Size*	Water consumption per capita (L/cap.d)	Water consumption per household (L/day)	Emptying Freq. (Day)	Emptied volume per round (L/Round)	WW Generated per capita (L/cap/d)	WW generated per household (L/ day)	Emptied volume per day (L/day)	Emptied volume per capita per day (L/cap.d)	Daily Infiltrated (L/day)	Infiltrated Per capita (L/cap day)
18	11	60	660	30	8000	50	550	267	24	283	26
19	12	40	480	30	8000	35	420	267	22	153	13
20	8	60	480	30	8000	50	400	267	33	133	17
21	9	45	405	30	8000	40	360	267	30	93	10
22	6	60	360	30	8000	50	300	267	44	33	6
23	9	70	630	45	16000	60	540	356	40	184	20
24	6	65	390	45	8000	55	330	178	30	152	25
25	9	45	405	45	8000	40	360	178	20	182	20
26	5	50	250	45	8000	40	200	178	36	22	4
27	9	65	585	60	16000	55	495	267	30	228	25
28	7	55	385	60	16000	45	315	267	38	48	7
29	9	60	540	60	16000	50	450	267	30	183	20
30	6	70	420	60	16000	60	360	267	44	93	16
31	7	60	420	90	24000	50	350	267	38	83	12
32	6	50	300	90	16000	45	270	178	30	92	15
33	7	60	420	90	16000	51	357	178	25	179	26
34	10	80	800	90	24000	70	700	267	27	433	43
35	4	90	360	90	16000	75	300	178	44	122	31
36	6	70	420	120	24000	60	360	200	33	160	27
37	5	40	200	120	16000	35	175	133	27	42	8
38	6	40	240	120	16000	35	210	133	22	77	13

	Family Size*	Water consumption per capita (L/cap.d)	Water consumption per household (L/day)	Emptying Freq. (Day)	Emptied volume per round (L/Round)	WW Generated per capita (L/cap/d)	WW generated per household (L/ day)	Emptied volume per day (L/day)	Emptied volume per capita per day (L/cap.d)	Daily Infiltrated (L/day)	Infiltrated Per capita (L/cap day)
39	7	55	385	180	16000	45	315	89	13	226	32
40	4	45	180	180	16000	40	160	89	22	71	18
41	6	55	330	180	24000	45	270	133	22	137	23
42	5	60	300	210	24000	50	250	114	23	136	27
43	2	65	130	210	16000	55	110	76	38	34	17
44	11	75	825	360	48000	65	715	133	12	582	53
45	13	60	780	360	48000	50	650	133	10	517	40
46	9	55	495	510	40000	45	405	78	9	327	36
47	10	55	550	720	40000	45	450	56	6	394	39
48	4	45	180	720	32000	40	160	44	11	116	29
49	7	65	455	720	32000	55	385	44	6	341	49
50	11	52	572	720	32000	44	484	44	4	440	40
Avg		58.04				49.2	488	312	30	176	19

**Family term here represents either one single house or cluster of houses sharing the same cesspit*

Annex B

Table B-1 Total nitrogen measured in septage pumped out from cesspits

Family Size	Desludging Fequency	Water Use (L/cap.d)	WW Generated (L/cap/d)	TKN mg/l	NO3-N mg/l	TN mg/l
20	10	60	50	360	0.00	360
21	10	55	45	276	0.00	276
19	10	65	55	314	0.00	314
22	10	45	40	185	0.00	185
23	10	45	40	380	0.00	380
19	10	60	50	270	0.00	270
13	15	50	45	180	0.00	180
14	15	45	40	205	0.00	205
13	15	60	50	190	0.00	190
11	15	70	60	220	0.10	220
16	15	55	45	175	0.20	175
13	20	60	50	230	0.00	230
15	20	40	35	171	0.00	171
9	20	90	75	190	0.00	190
10	20	65	55	218	0.00	218
12	20	55	45	244	0.00	244
8	30	60	50	247	0.00	247
11	30	60	50	214	0.36	214
12	30	40	35	230	0.51	231
8	30	60	50	256	0.10	256
9	30	45	40	332	0.31	332
6	30	60	50	298	0.15	298
9	45	70	60	421	0.20	421
6	45	65	55	365	0.00	365
9	45	45	40	328	0.00	328
5	45	50	40	290	0.15	290
9	60	65	55	316	0.00	316
7	60	55	45	280	0.00	280
9	60	60	50	375	0.00	375
6	60	70	60	340	0.25	340
7	90	60	50	230	0.36	230
6	90	50	45	195	0.20	195

Family Size	Desludging Fequency	Water Use (L/cap.d)	WW Generated (L/cap/d)	TKN mg/l	NO3-N mg/l	TN mg/l
7	90	60	51	229	0.05	229
10	90	80	70	275	0.00	275
4	90	90	75	260	0.10	260
6	120	70	60	281	0.25	281
5	120	40	35	398	0.41	398
6	120	40	35	412	0.46	412
7	180	55	45	265	0.25	265
4	180	45	40	414	0.56	415
6	180	55	45	398	0.31	398
5	210	60	50	490	0.41	490
2	210	65	55	465	0.41	465
11	360	75	65	420	0.15	420
13	360	60	50	516	0.25	516
9	510	55	45	245	0.66	246
10	720	55	45	416	0.41	416
4	720	45	40	287	0.31	287
7	720	65	55	245	0.25	245
11	720	52	44	311	0.20	311
avg		58.04	49.2	297	0.17	297

Annex C

Table C-1 Total nitrogen for the infiltrated and pumped out septage

Family size	Flow			Total Nitrogen			
	Q*in* *L/day*	Q*out* *L/day*	Q*inf* *L/day*	*TN ceptage* mg/l	*TN inf mg/l*	*TN cesptage g/cap.d*	*TN inf g/cap.d*
20	1000	800	200	360	192.96	14.40	1.93
21	945	800	145	276	147.94	10.51	1.02
19	1045	800	245	314	168.30	13.22	2.17
22	880	800	80	185	99.16	6.73	0.36
23	920	800	120	380	203.68	13.22	1.06
19	950	800	150	270	144.72	11.37	1.14
13	585	533	52	180	96.48	7.38	0.38
14	560	533	27	205	109.88	7.81	0.21
13	650	533	117	190	101.84	7.79	0.91
11	660	533	127	220	118.16	10.69	1.36
16	720	533	187	176	94.28	5.86	1.10
13	650	400	250	230	123.28	7.08	2.37
15	525	400	125	171	91.66	4.56	0.76
9	675	400	275	190	101.84	8.44	3.11
10	550	400	150	218	116.85	8.72	1.75
12	540	400	140	244	130.78	8.13	1.53
8	400	267	133	247	132.39	8.23	2.21
11	550	267	283	216	115.55	5.23	2.98
12	420	267	153	232	124.49	5.16	1.59
8	400	267	133	256	137.46	8.55	2.29
9	360	267	93	333	178.68	9.88	1.85
6	300	267	33	299	160.09	13.27	0.89
9	540	356	184	422	226.14	16.67	4.63
6	330	178	152	365	195.64	10.81	4.96
9	360	178	182	328	175.81	6.48	3.56
5	200	178	22	290	155.44	10.31	0.69
9	495	267	228	316	169.38	9.36	4.30
7	315	267	48	280	150.08	10.67	1.04
9	450	267	183	375	201.00	11.11	4.09
6	360	267	93	340	182.24	15.11	2.83
7	350	267	83	230	123.28	8.76	1.47
6	270	178	92	195	104.52	5.78	1.61
7	357	178	179	229	122.74	5.82	3.14
10	700	267	433	275	147.40	7.33	6.39

Family size	Flow			Total Nitrogen			
	Q*in* *L/day*	Q*out* *L/day*	Q*inf* *L/day*	*TN ceptage* mg/l	*TN inf mg/l*	*TN cesptage g/cap.d*	*TN inf g/cap.d*
4	300	178	122	260	139.36	11.56	4.26
6	360	200	160	281	150.62	9.37	4.02
5	175	133	42	400	214.30	10.66	1.79
6	210	133	77	414	221.92	9.20	2.84
7	315	89	226	266	142.65	3.38	4.61
4	160	89	71	416	223.24	9.26	3.97
6	270	133	137	399	214.05	8.87	4.88
5	250	114	136	492	263.61	11.24	7.16
2	110	76	34	467	250.21	17.78	4.23
11	715	133	582	421	225.48	5.10	11.92
13	650	133	517	517	277.18	5.30	11.02
9	405	78	327	248	132.89	2.16	4.82
10	450	56	394	418	223.94	2.32	8.83
4	160	44	116	288	154.56	3.20	4.47
7	385	44	341	246	131.93	1.56	6.42
11	484	44	440	312	167.18	1.26	6.68
avg	488.22	311.8226	176.3974	297.6587	159.55	8.53	3.27

Annex D

Table D1: Heavy Metals in cesspits septage and the individual contribution to heavy metals load

	Cu		Ni		Pb		Mn		Fe		Cr		Zn	
	mg/l	mg/cap.d	mg/l	mg/cap.d	mg/l	mg/cap.d	mg/l	mg/cap.d	mg/l	mg/cap.d	mg/l	mg/cap.d	mg/l	mg/cap.d
1	0	0	0	0	0	0	0.725	36.25	17.63	881.5	0.06	3	0.13	6.5
2	0.24	10.8	0	0	0	0	0.44	19.8	11.8	531	0.085	3.825	0.24	10.8
3	0.3	16.5	0.02	1.1	0	0	0.29	15.95	9.7	533.5	0.063	3.465	0.16	8.8
4	0.34	13.6	0	0	0	0	0.541	21.64	44.8	1792	0.027	1.08	0.09	3.6
5	0.17	6.8	0.03	1.2	0	0	0.62	24.8	8.54	341.6	0.03	1.2	0.28	11.2
6	0	0	0	0	0	0	0.37	18.5	7.88	394	0.017	0.85	0.42	21
7	0.11	4.95	0	0	0	0	0.386	17.37	11.48	516.6	0.092	4.14	0.08	3.6
8	0.18	7.2	0.02	0.8	0	0	0.322	12.88	15.3	612	0.052	2.08	0.18	7.2
9	0.22	11	0	0	0	0	0.21	10.5	11.8	590	0.04	2	0.67	33.5
10	0.28	16.8	0.019	1.14	0	0	0.412	24.72	3.98	238.8	0.021	1.26	0.17	10.2
11	0.3	13.5	0	0	0	0	0.356	16.02	17.27	777.15	0.018	0.81	0.22	9.9
12	1.56	78	0.193	9.65	0	0	0.408	20.4	30.07	1503.5	0.035	1.75	1.49	74.5
13	0.64	22.4	0	0	0	0	0.25	8.75	26.7	934.5	0.028	0.98	0.36	12.6
14	0.09	6.75	0	0	0	0	0.352	26.4	8.6	645	0.031	2.325	0.31	23.25
15	0.41	22.55	0.035	1.925	0	0	0.356	19.58	9.72	534.6	0.039	2.145	1.52	83.6
16	0.09	4.05	0.07	3.15	0	0	0.541	24.345	10.48	471.6	0.08	3.6	2.05	92.25
17	0.3	15	0.031	1.55	0	0	0.29	14.5	5.31	265.5	0.042	2.1	1.587	79.35
18	0.9	45	0.04	2	0	0	0.38	19	5.55	277.5	0.022	1.1	0.85	42.5
19	0.6	21	0.02	0.7	0	0	0.7	24.5	8.21	287.35	0.019	0.665	0.66	23.1
20	0.02	1	0.03	1.5	0	0	0.29	14.5	6.03	301.5	0.023	1.15	1.06	53
21	0.087	3.48	0	0	0	0	0.342	13.68	14.31	572.4	0.023	0.92	1.1	44
22	0.08	4	0	0	0	0	0.27	13.5	4.35	217.5	0.028	1.4	1.51	75.5
23	0.207	12.42	0	0	0	0	0.105	6.3	2.18	130.8	0.016	0.96	1.13	67.8
24	0.32	17.6	0	0	0	0	0.824	45.32	17.88	983.4	0.031	1.705	0.293	16.115
25	0.19	7.6	0.016	0.64	0	0	0.311	12.44	9.36	374.4	0.022	0.88	0.311	12.44
26	0.36	14.4	0	0	0	0	0.279	11.16	25.21	1008.4	0.014	0.56	0.74	29.6

	Cu		Ni		Pb		Mn		Fe		Cr		Zn	
	mg/l	mg/cap.d	mg/l	mg/cap.d	mg/l	mg/cap.d	mg/l	mg/cap.d	mg/l	mg/cap.d	mg/l	mg/cap.d	mg/l	mg/cap.d
27	0.275	15.125	0.031	1.705	0	0	0.288	15.84	9.7	533.5	0.025	1.375	0.94	51.7
28	0.37	16.65	0	0	0	0	0.236	10.62	5.91	265.95	0.019	0.855	0.72	32.4
29	0.19	9.5	0.12	6	0	0	0.211	10.55	13.14	657	0.026	1.3	0.33	16.5
30	0.22	13.2	0.017	1.02	0	0	0.263	15.78	4.86	291.6	0.011	0.66	0.47	28.2
31	0.189	9.45	0	0	0	0	0.086	4.3	3.4	170	0.01	0.5	0.296	14.8
32	0.38	17.1	0	0	0	0	0.155	6.975	21.3	958.5	0.072	3.24	0.42	18.9
33	0.08	4.08	0	0	0	0	0.205	10.455	9.6	489.6	0.048	2.448	0.52	26.52
34	0.09	6.3	0.048	3.36	0.059	4.13	0.576	40.32	17	1190	0.053	3.71	1.883	131.81
35	0.115	8.625	0.014	1.05	0	0	0.078	5.85	3.41	255.75	0.014	1.05	0.297	22.275
36	0.13	7.8	0.104	6.24	0.075	4.5	1.11	66.6	72.81	1068.6	0.11	6.6	6.86	411.6
37	0.09	3.15	0.097	3.395	0.08	2.8	1.13	39.55	68.59	790.65	0.1	3.5	6.82	238.7
38	0.24	8.4	0.226	7.91	0.053	1.855	2.54	88.9	174.83	764.05	0.027	0.945	7.56	264.6
39	0.177	7.965	0.031	1.395	0	0	0.455	20.475	7.22	324.9	0.028	1.26	1.33	59.85
40	0.079	3.16	0	0	0	0	0.302	12.08	5.32	212.8	0	0	0.77	30.8
41	0.086	3.87	0.025	1.125	0	0	0.328	14.76	5.44	244.8	0.019	0.855	0.732	32.94
42	0.028	1.4	0	0	0	0	0.314	15.7	6.073	303.65	0.014	0.7	0.457	22.85
43	0.184	10.12	0.021	1.155	0	0	0.227	12.485	3.172	174.46	0.011	0.605	0.537	29.535
44	0.038	2.47	0	0	0	0	0.312	20.28	6.292	408.98	0	0	0.357	23.205
45	0.017	0.85	0	0	0	0	0.347	17.35	7.087	354.35	0.012	0.6	0.486	24.3
46	0.23	10.35	0.095	4.275	0.095	4.275	1.255	56.475	41.04	685.8	0.167	7.515	6.786	305.37
47	0.24	10.8	0.07	3.15	0	0	0.62	27.9	18.25	821.25	0.043	1.935	0.61	27.45
48	0.08	3.2	0.03	1.2	0	0	0.54	21.6	12.96	518.4	0.027	1.08	0.96	38.4
49	0.261	14.355	0	0	0	0	0.854	46.97	37.44	1729.2	0.057	3.135	3.296	181.28
50	0.09	3.96	0	0	0	0	0.74	32.56	14.65	644.6	0.033	1.452	0.521	22.924
Average		11.36		1.36		0.35		22.14		591.5		1.8		58.2

Annex D

Table D-1 Heavy Metals in Cesspit septage

	Cu mg/l	Ni mg/l	Pb mg/l	Mn mg/l	Fe mg/l	Cr mg/l	Zn mg/l
1	0	0	0	0.725	17.63	0.06	0.13
2	0.24	0	0	0.44	11.8	0.085	0.24
3	0.3	0.02	0	0.29	9.7	0.063	0.16
4	0.34	0	0	0.541	44.8	0.027	0.09
5	0.17	0.03	0	0.62	8.54	0.03	0.28
6	0	0	0	0.37	7.88	0.017	0.42
7	0.11	0	0	0.386	11.48	0.092	0.08
8	0.18	0.02	0	0.322	15.3	0.052	0.18
9	0.22	0	0	0.21	11.8	0.04	0.67
10	0.28	0.019	0	0.412	3.98	0.021	0.17
11	0.3	0	0	0.356	17.27	0.018	0.22
12	1.56	0.193	0	0.408	30.07	0.035	1.49
13	0.64	0	0	0.25	26.7	0.028	0.36
14	0.09	0	0	0.352	8.6	0.031	0.31
15	0.41	0.035	0	0.356	9.72	0.039	1.52
16	0.09	0.07	0	0.541	10.48	0.08	2.05
17	0.3	0.031	0	0.29	5.31	0.042	1.587
18	0.9	0.04	0	0.38	5.55	0.022	0.85
19	0.6	0.02	0	0.7	8.21	0.019	0.66
20	0.02	0.03	0	0.29	6.03	0.023	1.06
21	0.087	0	0	0.342	14.31	0.023	1.1
22	0.08	0	0	0.27	4.35	0.028	1.51
23	0.207	0	0	0.105	2.18	0.016	1.13
24	0.32	0	0	0.824	17.88	0.031	0.293
25	0.19	0.016	0	0.311	9.36	0.022	0.311
26	0.36	0	0	0.279	25.21	0.014	0.74
27	0.275	0.031	0	0.288	9.7	0.025	0.94
28	0.37	0	0	0.236	5.91	0.019	0.72
29	0.19	0.12	0	0.211	13.14	0.026	0.33
30	0.22	0.017	0	0.263	4.86	0.011	0.47
31	0.189	0	0	0.086	3.4	0.01	0.296
32	0.38	0	0	0.155	21.3	0.072	0.42
33	0.08	0	0	0.205	9.6	0.048	0.52
34	0.09	0.048	0.059	0.576	17	0.053	1.883
35	0.115	0.014	0	0.078	3.41	0.014	0.297

	Cu mg/l	Ni mg/l	Pb mg/l	Mn mg/l	Fe mg/l	Cr mg/l	Zn mg/l
36	0.13	0.104	0.075	1.11	17.81	0.11	6.86
37	0.09	0.097	0.08	1.13	22.59	0.1	6.82
38	0.24	0.226	0.053	2.54	21.83	0.027	7.56
39	0.177	0.031	0	0.455	7.22	0.028	1.33
40	0.079	0	0	0.302	5.32	0	0.77
41	0.086	0.025	0	0.328	5.44	0.019	0.732
42	0.028	0	0	0.314	6.073	0.014	0.457
43	0.184	0.021	0	0.227	3.172	0.011	0.537
44	0.038	0	0	0.312	6.292	0	0.357
45	0.017	0	0	0.347	7.087	0.012	0.486
46	0.23	0.095	0.095	1.255	15.24	0.167	6.786
47	0.24	0.07	0	0.62	18.25	0.043	0.61
48	0.08	0.03	0	0.54	12.96	0.027	0.96
49	0.261	0	0	0.854	31.44	0.057	3.296
50	0.09	0	0	0.74	14.65	0.033	0.521
Avg	0.24	0.03	0.01	0.47	12.557	0.04	1.23