An-Najah National University
Faculty of Graduate Studies

Septage Characterization and Fecal Sludge Treatment in Rural Nablus

By

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Dedication

Greatest dedication to our Prophet Mohammad peace be upon him.

I am proud to dedicate this Study to:

My Home, Palestine

My Mother

My Father

My Sisters

My Brothers

My dearest persons to my heart, Friends

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الإقرار

أنا الموقع أدناه مقدم الرسالة التي تحمل عنوان:

Septage Characterization and Fecal Sludge Treatment in Rural Nablus

أقر بأن ما اشتملت عليه هذه الرَسالة إنما هي نتاج جهدي الخاص باستثناء ما تمت الإشارة إليه حيثما ورد، وأن هذه الرَسالة ككل أو أي جزء منها لم يقدم من قبل لنيل أي درجة علمية أو أي بحث علمي لدى أي مؤسسة تعليمية أو بحثية أخرى.

Declaration

This work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

Student Name: **اسم الطالب:**

Signature: **التوقيع:**

Date: **التاريخ:**

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List of Abbreviations

Abbreviation	Meaning
ANU	An-Najah National University
ASP	Activated Sludge Process
BOD	Biological Oxygen Demand
CI	Confidence Interval
COD	Chemical Oxygen Demand
CoM	Council of Ministers
CW	Constructed Wetland
CWs	Constructed Wetlands
EC	Electrical Conductivity
EPA	Environmental Protection Agency
FAO	Food and Agriculture Organization
FC	Fecal Coliform
FS	Fecal Sludge
FSM	Fecal Sludge Management
MCM	Million Cubic Meter
MEDRC	Middle East Desalination Research Center
MoH	Ministry of Health
MoLG	Ministry of Local Government
NO_3	Nitrate
NWWTP	Nablus West Wastewater Treatment Plant
O&M	Operation and Maintenance
PCBS	Palestinian Central Bureau of Statistics
pH	Potential Hydrogen
PO4	Phosphorous
PWA	Palestinian Water Authority
SBR	Sequence Batch Reactor
SLR	Solid Loading Rate
SPSS	Statistical Package for Social Sciences
TC	Total Coliform
TDS	Total Dissolved Solids
TKN	Total kjeldahl Nitrogen

Abbreviation	Meaning
T-N	Total Nitrogen
TP	Treatment Plant
TS	Total Solids
TSS	Total Suspended Solids
U.S	United State
VBST	Vertical Baffled Septic Tank
VBST	Vertical Baffled Septic Tank
VDS	Volatile Dissolved Solids
VFEW	Vertical-Flow Engineered Wetland
VS	Volatile Solids
VSS	Volatile Suspended Solids
WESI	Water and Environmental Studies Institute

Septage Characterization and Fecal Sludge Treatment in Rural Nablus

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Supervised By
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Abstract

As urbanization continues to take place, the management of sanitation is becoming a major concern. Palestine is one of the countries that have major issues with sanitation, providing that most of the population relies on cesspits for disposal of wastewater. This work has characterized the septage, and quality of wastewater collected in cesspits in three villages near Nablus city (Qusin, Iraq Burin, and Tell), also proposed a pretreatment model. Samples were collected from the vacuum tankers used for emptying the cesspits in the three villages. They were then analyzed for pH, Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Turbidity, Phosphorous, Ammonia, Nitrogen, Nitrate, Alkalinity, Conductivity, Solids parameters, Total and Fecal coliform, and Heavy metals. The concentrations of the analyzed samples were compared with the EPA guidelines and municipal wastewater and septage in other countries as compared through literature, for example; in west Nablus wastewater treatment plant the average BOD concentration of row WW was 573 mg/l, Whereas the septage had an averageBOD_5 of 371 mg/l. While the average COD of municipal row wastewater and septage were 1,174 and 1,087 mg/l, respectively.

Modeling and optimization of wastewater treatment processes were applied to improve the efficiency of a wastewater treatment model. The model was applied on the Septage characterized by this study (which has a high organic loading and suspended solids concentrations) to optimize a treatment process of a two-units of Sequencing Batch Reactors SBR model using GPS-X 7.0 simulator.

Even though there were no fecal sludge disposal sites for the studied villages, the Septage was dumped untreated to open environment. This model was designed to meet the Palestinian regulations of type C of treated wastewater for agricultural reuse. The designed values for this model were (456, 1221, 386) mg/l for BOD_5, COD, and Total Suspended Solids (TSS) respectively. The results revealed that, two-units of SBR model were operated with removal efficiencies higher than 98% for BOD, 94% for COD, and 98% for TSS.

This modeling analysis was applied to define a performance measuring plan based on the most important parameters that can be reliable and applicable for any wastewater treatment plant. The produced models were feasible for construction and operation. Also, it is recommended to implement the modeled TP to examine the operation and efficiency of such TPs on the ground and to make calibration for the model if needed.

Keywords: Characteristics, Septage, Pre-Treatment, Modeling, SBR, Activated sludge.

Chapter One:

Introduction

Chapter one

Introduction

1.1: Background

In many countries water is becoming an increasingly a scarce resource and specialists are forced to consider any sources of water that might be used economically and effectively to raise further development (FAO, 2018). One example is the Palestinian territories where people are suffering from water shortage due to limited water resources, increasing demand on potable water because of the high population growth, which in turn generates a large amount of wastewater. With lack of suitable sanitation services, wastewater may lead to pollution in soil, surface water and groundwater and cause diseases related to the pollution of drinking water and agricultural land. Thus, it's a necessity to control the pollution of wastewater to save the limited water resources and face the growing demand on clean water (World Bank, 2008).

The wastewater situation in Palestine is not quite as the situation of the existing sewerage system is extremely critical. Approximately, 53.9% of the households in Palestine disposed their wastewater through the sewage network (34.2% in the West Bank), 33.6% of households in Palestine use cesspits (46.7% in the West Bank), 11% of the households use cesspits (16.6% in the West Bank), as a means of disposal of wastewater, and 1.6% of the households use other methods of disposal of wastewater (2.5% in the West Bank) (PCBS, 2019).

Roughly, 94.5% of the rural population in West Bank relies on cesspits and septic pits for temporary storage of wastewater, as they are not served by sewer networks none of which is treated (PWA, 2013), see Figure 1.1. So, there is what is called Septage (Is the liquid and solid material pumped from septic pits, cesspits, or other on-site collection and treatment system). (Dutin, 2001; EPA, 1993).

The definition of septage was conducted by the federal regulations as the liquid or solid material removed from a septic tank, cesspits portable toilet, type III marine sanitation device, or similar treatment works that receive only domestic wastewater (EPA, 1994). The majority of these pits are emptied through private-sector vacuum trucks which discharge their contents (septage) into the nearby located sewage treatment plants if any, and most likely they are overloaded, or in an irregular manner (in valleys or agricultural lands); which can couse a danger to the environment and health. As septage will mix with the non-perennial streams and wadis during winter season, while during dry season it mixes with natural springs (Al-Sa`ed, 2000).

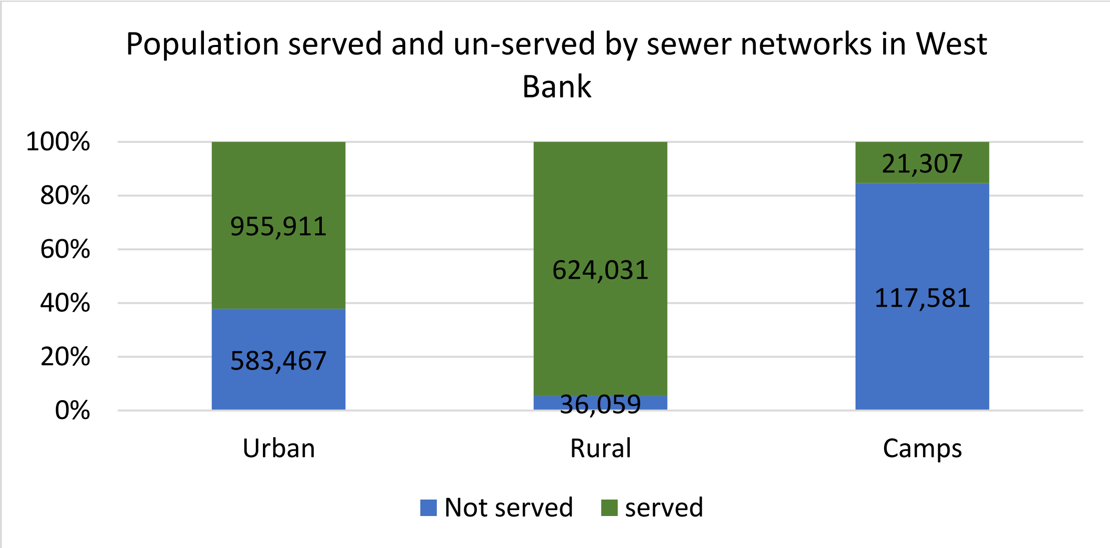


Figure 1.1: Population served and un-served by sewer networks in West Bank (Al-Sa`ed, 2000).

However, limited technical data is currently available on urban and rural wastewater characteristics (Tahboub, 1999; Mahmoud et al., 2003).

Solutions for effective and Sustainable Fecal Sludge Management (FSM) present a significant global need; FSM is a relatively new field. However, it has been rapidly developed and gained acknowledgement (Strande et al., 2014).

Knowledge of the waste that enters treatment systems is a basic prerequisite for the design and development of any wastewater treatment technology. The information is available on conventional sanitary sewage (Henze et al., 2001; Tchobanoglouset al., 2003) which has a different composition of fresh feces and urine that has not undergone any degradation processes and will have substantially less water or gray water addition. The generation rates and the chemical composition of sewage are key factors to be understood by on-site sanitation technology developers. (Henze et al., 2001; Tchobanoglous et al., 2003).

1.1.1 What is Fecal Sludge?

Fecal Sludge (FS) comes from onsite sanitation technologies, and it is not being transported through a sewer collection network. It is raw or partially digested, a slurry or semisolid, and results from the collection, storage or treatment of combination of excreta and black water, with or without grey water. FSM includes the storage, collection, transport, treatment, and safe end use or disposal of FS, see Figure 1.2 (Strande et al., 2014; Boot and Scott, 2015).

1.2: Research Questions

This research was conducted to answer the following questions:

- What are the characteristics of the septage in the study area?
- What is the model that could be prototyped to treat the septage in rural areas (as a case study)?

1.3: Research Motivation and Problem Statement

The objectives of this study are:

- To characterize the septage, fresh feces and urine in the study area that is discharged in wadis from cesspits by vacuum pumps.

- To propose an onsite pre-treatment plant model as sustainable solution for characterized septage.

1.4: Research Motivation and Problem Statement

In 2013, a decision was issued by the Council of Ministers (Decree No. 16 of the year 2013) on publishing the system for linking housing and facilities to the public sewer network (CoM, 2013). Also, the concept of “polluter-pays-principle” published by ARIJ organization put the wastewater ss one of the major pollutants and it should be controlled and monitored (ARIJ, 2015),

Moreover, in Palestine, there are a places that do not have sewage networks. So; the owners of the houses construct cesspits or septic pits to store their wastewater and then dispose it without considering the effects on health and environment. Most of the cesspits and septic pits are not constructed according to the Central Public Health and Environmental Engineering Organization (CPHEEO) standards and Ministry of Local Government standards (Raj, 2013; MoLG, 2013). Additionally, they are not well-maintained. Moreover, the practice of septage collection and disposal is neither scientific nor safe; septage which is collected from on-site systems during cleaning is invariably dumped in drains and open areas posing considerable health and environmental hazards (Baetings, 2014).

There are a lot of laws and concepts related to practice of sewage collection and disposal in Palestine. For example: Water Resources

Management Strategy Drafted in 1997. The Study of strategic planning for the water sector in 2000, and the national water policy and the water and sanitation sector strategy for 2011-2013.

Therefore, despite the existence of laws and regulations, there is a lack in technical studies that determine the mechanism of application of these laws in all regions. So, this study was conducted to characterize septage, and design a model to use for treating the characterized septage (D'Amato, 2008).

1.5: Study Area

As known, Nablus governorate has urban and rural areas. 94.5% of these rural areas are not connected to wastewater collection system, and almost all the house owners have cesspits or septic pits, figures 1.2 and 1.3 show the location of each village. Almost all these villages are suffering from this problem; as they are suffering from more than one issue related to the pits such as:

- The odor when the vacuum trucks empty their cesspits.
- The environmental risks and pollutions to crops and lands.
- The high cost of septage disposal due to lack of vacuum trucks.

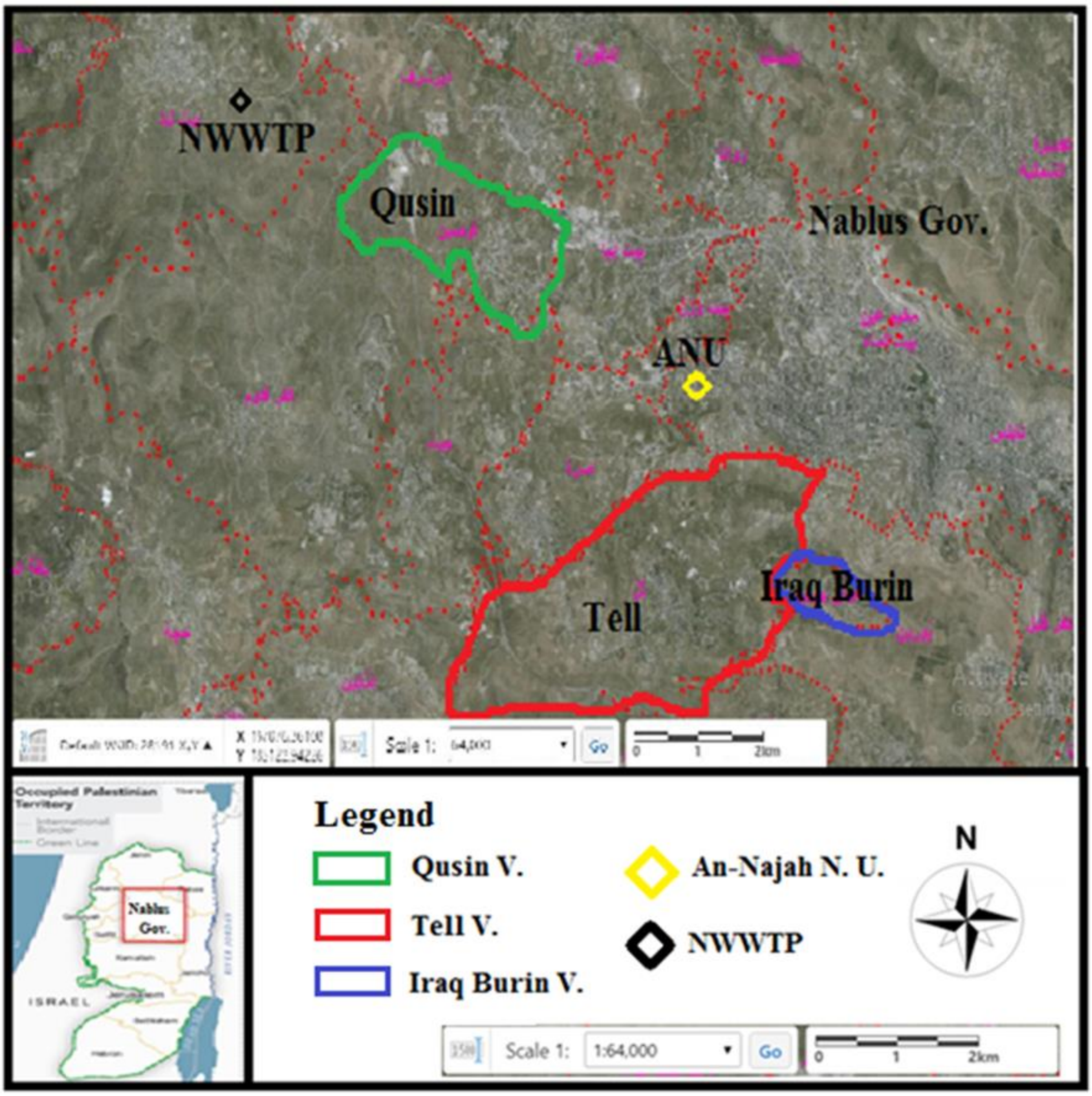


Figure 1.2: The location of the study area (ARIJ, 2018)

Figure 1.3: Photos for the study are villages

Table 1.1 shows the approximated number of houses in 2018 in each village of the study area.

Table 1.1: population and no. of houses in 2018 for the villages of the study area (PCBS, 2019)

Item \ Village name	Tell	Qusin	'Iraq-Burin
Population	5,216	2,275	1,019
No. of Houses (approximation)	1,023	446	200

1.5.1 Factors of selection of the study area

In this study, many factors were considered to specify the study area, these factors are:

1. Is there a wastewater collection network in the area?
2. Water consumption.
3. Septic pits and cesspits availability.
4. Septic pits and cesspits accessibility.
5. Culture.
6. Location.

Based on the previous factors, three villages were selected to be the study area of this research; Tell, 'Iraq-Burin, and Qusin villages. These villages are located in the west and north-west of Nablus city, Palestine. Moreover, none of the three villages have wastewater collection system as they are located in a rural region. The medium water consumption at the study area is around 66 l/c/d. In the three regions; cesspits are used to store the sewage and timely disposed the septage by vacuum trucks or tractors at natural wadis or streams. Figure 1.4 describes this situation.

Figure 1.4: Discharge of the septage in the natural wadis.

1.6: Stakeholders and Beneficiaries

The main expected Stakeholders and beneficiaries from this study are:

- The people who lives in a region which is similar to the case study.
- Ministry of Agriculture; knowing the characteristics of septage will help the Ministry of Agriculture to predict its effects on plants, agricultural lands and wadis. Additionally, the ministry could benefit by using the treated septage in irrigation practices.

- Palestinian Water Authority (PWA); by knowing the potential use of septage and its characteristics and its suitability as a non-conventional water resource.

- Farmers; by improving their awareness about the risks related to disposal of such waste in their lands

- Academic and research sector; the study will be a motivator for other researchers to carry out similar studies in other locations considering the recommendations in the current work as it is the first of its kind in Palestine.

1.7: Thesis Outline

This thesis comprised of six chapters. The first chapter presents the introduction. The second chapter presents the literature review. Chapter three provides a research methodology and gives the methods and materials used in this research. Chapter four and five come to show, illustrate and discuss the results. Finally, chapter six summarizes the conclusions and recommendations.

Chapter Two:

Literature Review

Chapter Two: Literature Review

2.1 Introduction

The rationale for this research is to fill the gap in knowledge about the fecal sludge which limits the scientific decision making and implementation of the appropriate method of fecal sludge management exercise in the study area.

This chapter summarizes the relative topics on characteristics and pre-treatment of septage, some of fecal sludge management studies, and the relation between the current work and previous literature.

This will feed into Environmental Sanitation Policy which seeks to develop a platform for adequate data collection to improve the planning and management of environmental sanitation (Ghana, 2010; Wilson, 2014).

2.2: General background of Septage Characterization

The scarcity of water resources is one of the current problems in the world. In Palestine, the lack of water resources in some areas, especially in arid and semi-arid regions forced the decision makers and planers to look for a new of conventional and non-conventional water resources. Wastewater is one of the non-conventional water resources that can be used after treatment in many fields like agricultural activities and some of specific industrial activities (Hithnawi, 2004; Mopic, 1998).

Cesspit systems are simply an underground tank that collects and stores sewage upon its removal from the property. This system is the most common treatment units on household level in rural areas of the West Bank and Gaza Strip. About (65-70)% of the annual domestic wastewater in Palestine is currently collected in cesspits, where inadequate disposal might cause cumulative public health risks and annual environmental degradation. Management practices for wastewater disposal in the West Bank are limited to the collection of wastewater by piped sewage networks and household cesspits (PCBS, 2012). Figure 2.1 illustrates the shape of cesspit on the ground.

Figure 2.1: Cesspits shape on the ground (Sandra et al, 2012)

It was estimated that around 41.17 MCM of wastewater is collected in cesspits that serve 68% of the Palestinian population in the West Bank (PWA, 2012). Signals of groundwater pollution in Palestine have already been reported, e.g. the concentration of NO_3 in the groundwater is more than 50 mg/L within shallow aquefie. Adequate treatment and disposal of domestic septage are crucial to public health and environment.

The present practice of septage disposal in Palestine is mainly via an uncontrolled discharge in nearby wadis and open fields, and to a much lesser extent in public sewerage networks that might end up in the very few existing wastewater treatment plants. This type of disposal is uncontrolled and has several negative effects on both the sewerage system and the treatment processes. (Al-Atawneh et al, 2014).

A study by Al-Atawneh et al. (2014) of Wastewater Characteristics in Partially Sealed Cesspit revealed that raw wastewater was of medium strength according to the US-EPA classifications, and was more concentrated than Palestinian municipal sewage. The study characterized the composition of modern single residential source onsite raw wastewater and primary treated effluent (cesspits). Mentioned research - Al-Atawneh et al. (2014) - presented the results for the characterization of household raw domestic wastewater, and quantification of specific pollution load (g/c/d) and assessing the course of wastewater quality alteration in terms of BOD_5, COD, TKN, PO4-P, TS, TSS, TDS, pH, EC and heavy metals (Zn, Cu, Ni, Pb, Mn, Fe, Cr), in a partially sealed house onsite cesspit during the whole filling period of 4 months. The recommendation was to replace cesspits by proper wastewater treatment systems (Al-Atawneh et al, 2014).

The study of characterization of fecal sludge to make it a viable feedstock for the production of biodiesel, a renewable energy fuel was done in 2014. Fecal sludge from households were analyzed for their lipid content, moisture content, total solids and pH, the results of this topic were summarized in the table 2.1 below (Wilson, 2014).

Table 2.1 literature characteristics of septage (Wilson, 2014; Metcalf and Eddy, 2003)

Constituent	Concentration, mg/l	
	Range	Average
Total solids (TS)	5,000 – 100,000	40,000
Suspended solids(SS)	4,000 – 100,000	15,000
Volatile suspended solids (VSS)	1,200 – 14,000	7,000
BOD5	2,000 – 30,000	6,000
COD	5,000 – 80,000	30,000
Total Kjeldahl nitrogen (TKN)	100 – 1,600	700
Ammonia-nitrogen	100 – 800	400
Total phosphorus as P	50 – 800	250
Heavy metals	100 – 1,000	300

There are some factors which affect the physical characteristics of septage like climate, user habits, septic tank size, design, water supply characteristics, pumping frequency, piping material, and household chemicals (Brown and White, 1977). Moreover, the characteristics of septage vary depending on Daily practices, water consumption, whether the kitchen food waste grinder is used or not, and frequency of emptying the pits (EPA and ORD, 1994). Tables A.1, A.2, and A.3 in appendix A show the different characteristics of septage according to the United States Environmental Protection Agency (USEPA).

Also, household chemicals, volumes of cesspools, and intervals by which the septage is discharged. In regions where dry and wet seasons exist, seasonal changes in septage characteristics are thought to be significant but are usually not taken into account mainly due to the time of septage characterization before septage management options are discussed (Halalsheh et al, 2010; Thaher, 2012).

In addition, septage is a host for many disease-causing viruses, bacteria, and parasites. As a result, septage requires special handling and treatment (EPA and ORD, 1994). The handling and disposal of septage are based on the characteristics and volume of septic waste. Moreover, this information is also useful for design purposes and determining typical design values for treatment and disposal (Chowdhry and Kone, 2012).

Septage generation rate vary widely from month to month due to weather and geography. Daily and weekly variations in septage generation rates also arise due to inhabitants' habits and attitudes. There are several approaches that could be used to estimate septage generation rate (Rai et al, 2012).

From previous studies, the main constituents in the municipal wastewater are total solids, nitrogen, phosphorous, chloride, grease, BOD, pathogens, trace and heavy metals (FAO, 1992).

In addition to nitrogenous compounds, heavy metals likely to be present in septage. Heavy metals (Zn, Cu, Pb and Ni) are a worldwide problem because these metals are indestructible and most of them have toxic effects on living organisms, accumulate in reservoirs and enter the food chain (Farlane and Burchett, 2000; Loska and Wiechula, 2003). Heavy metals in household sewage might originate from feces, cleaners, paints, wear and tear of utensils and equipment, eroding pipes, and runoff from roofs (Dudka and Miller, 1999; Sorme and Lagerkvist, 2002).

The safe disposal of human excreta is of paramount importance for the health and welfare of population living in low income countries as well as the prevention of pollution to the surrounding environment. On-site sanitation systems are the most numerous means of treating excreta in low income countries, these facilities aim at treating human waste at source and can provide a hygienic and affordable method of waste disposal. However, current On-site sanitation systems need improvement and require further research and development (Alcantara, 2002).

Development of On-site sanitation facilities that treat excreta at, or close to its source require knowledge of the waste stream entering the system, and data regarding the generation rate and the chemical and physical composition of fresh feces and urine. In a study by Kanbara 2012 and Rose et al. (2015), the data was collected from medical literature and treatability sector, then summarized and statically analyzed to quantify the major factors that were a significant cause of variability of feces and urine characteristics. The impact of this data on biological processes, thermal processes, physical separators, and chemical processes was then assessed. Results showed that the median fecal wet mass production was 128 g/c/d, with a median dry mass of 29 g/c/d. Fecal output in healthy individuals was

1.20 defecations per 24 hour period and the main factor affecting fecal mass was the fiber intake of the population. (Rose et al, 2015 and Kanbara, 2012).

In Jordan during 2007, composite samples of septage discharging at the Khirbit As-Samra municipal wastewater treatment plant were analyzed during the period from February to the end of October 2007. Septage samples showed difference in concentrations of pollutants between summer and winter as illustrated in Table A.4, A.5, A.6, A.7 and A.8 in Appendix 1. The average total COD was 6,425 mg/L during summer, which is double the COD in winter (2,969 mg/L). (Halalsheh et al, 2010)

Moreover, the total BOD_5 represented 45% of total COD in both winter and summer seasons. Anaerobic biodegradability was 75% after 81 days of digestion at 35°C with a biodegradation rate constant (k) of 0.024 d^{-1}, which was lower compared with 0.103 d^{-1} calculated for wastewater with domestic origin in Jordan. Aerobic biodegradability for septage was 48% - COD basis - after 7 days of digestion at 35°C. The lower anaerobic biodegradation rate of septage compared with that of raw wastewater of domestic origin suggested that septage could have a negative effect on the performance of a domestic wastewater treatment plant if septage discharges were not taken into account in the original design of the treatment plant (Halalsheh et al, 2010).

In other cases, septage is transported to certain dumping sites where this stream is treated separately. In both situations, accurate characterization of the septage is critical before management options are discussed. The physical, biological, and chemical characteristics of the septage, however, can be highly variable even for the same region. Septage characteristics depend on factors as household habits, water supply characteristics, climatic and geological conditions, piping material, water conservation fixtures (Solomon, 1998).

Mahmoud et al. (2003) collected samples of raw wastewater and septage from Beit Dajan in Palestine. The samples were analyzed for TSS, TS, TDS, kjeldahl-nitrogen (Kj-N), COD, BOD and total PO4-P according to standard methods of American Public Health Association (APHA), 1995. Moreover, the samples were analyzed for temperature, Electrical conductivity (EC), heavy metals (Cu, Ni, Pb, Mu, Fe, Cr, Zn) and pH. Heavy metal concentrations were determined by ICP according to the standard method (ICP multi element stander solution 4 certiPUR lot- No. HC957274) atomic emission spectrometry (AES) (ICP OPTIMA 3000 Perkin Elemer), following acid digestion and using appropriate certified reference materials in addition to intra-laboratory standards. Tables A.9, A.10, A.11, A.12 and A.13 in Appendix A reveals that the results of the study (Mahmoud et al., 2003). Mainly, the raw wastewater characteristics of an individual home in Beit Dajan was of medium strength and it was relatively less concentrated than municipal. Mahmoud and his colleagues postulated the high sewage strength in Palestine to low water consumption and people’s habits. Raw sewage characteristics were very high according to the sewage strength classification and compared to sewage characteristics in other countries (Eddy, 1999; Henze et al, 2001).

In general, the main sources of septage are the following sanitation systems (Gracia-Dias and Carlos, 2005):

- Septic tanks.
- Cesspools.
- Privies/portable toilets.
- Aerobic tanks.
- Holding tanks (septic tanks with no drain field).
- Dry pits (associated with septic field).

Table 2.2 below shows the sources of septage, the rate at which these sources are emptied through pumping and the general trends of their characteristics.

Table 2.2: Septage sources, removal pump-out rate, and the characteristics (EPA and ORD, 1994).

Description	Removal pump-out rate	Characteristics
Septic tank	2-6 years, but can vary with location local ordinances	Concentrated BOD, solids, nutrients, variable toxics (such as metals), inorganic (sand), odor, pathogens, oil, and grease
Cesspool	2-10 years	Concentrated BOD, solids, nutrients, variable toxics, inorganic, sometimes high grit, odor, pathogens, oil, and grease
Privies/portable toilets	1week to months	Variable BOD, solids, inorganic, odor, pathogens, and some chemical
Aerobic tanks	Months to 1 years	Variable BOD, solids, inorganic, odor, pathogens, and some chemicals
Holding tanks (septic tanks with no drain field)	Days to weeks	Variable BOD, solids, inorganic, odor, and pathogens, similar to raw wastewater solids.
Dry pits (associated with septic field)	2-6 years	Variable BOD, solids, inorganic, and odor.

2.3: General treatment of fecal sludge

Fecal sludge (FS) needs adequate treatment and disposal to safeguard public health and the environment (Sandec, 2006; Cosgrove and Rijsberman, 2000). Fecal sludge treatment can be a complicated process; several different designs could be used, utilizing mechanical, biological, and chemical methods, in different combinations (Metcalf and Eddy, 2003; Wilson, 2014)

In a world has limited resource and suffer from lack of organic material to replenish agricultural soils, there is a strong argument for viewing sanitation as a cycle, in which excreta are collected, transported and treated before being returned to the land as a soil conditioner or fertilizer. The stages of this cycle as it applies to on-site sanitation systems are shown in Figure 2.2.

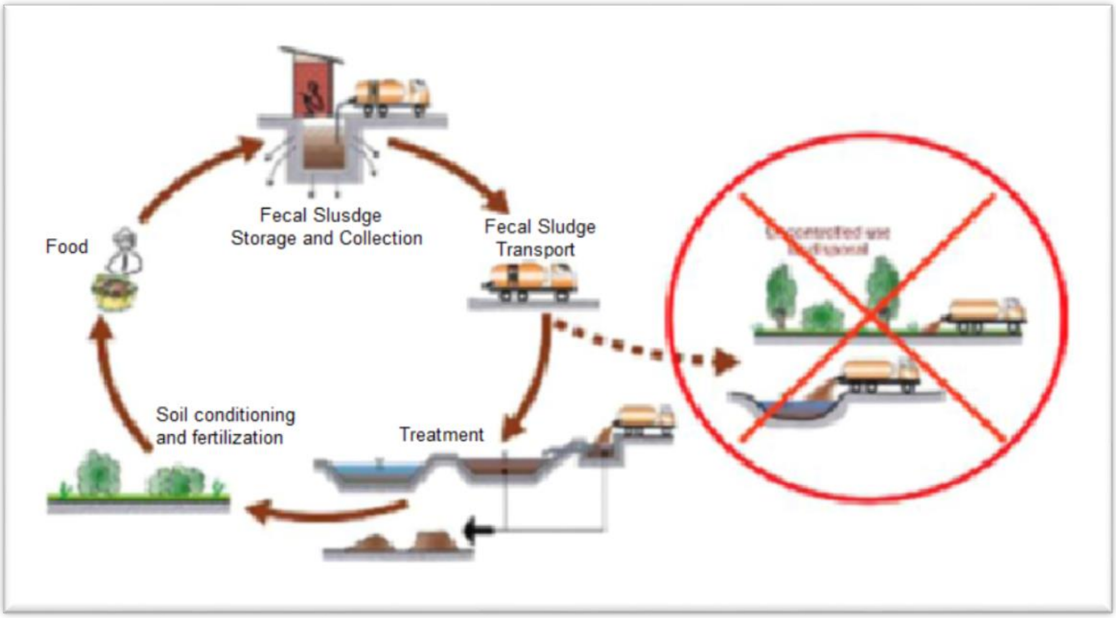


Figure 2.2: Stages in the cycle of Human Waste Management (Sandra et al, 2012)

Sludge treatment is required in order to render the sludge safe for either disposal to environment or reuse in agriculture or aquaculture. This requires the treatment plant or facility to be managed in a way that ensures the pathogen levels in the sludge are reduced to safe levels. In Indonesia, the Tegal city treatment plant consists of an Imhoff tank and collector, one anaerobic pond, one facultative pond, one maturation pond, and a sludge drying bed. The total area of the site is about 3,000 m^2. This is being replaced by a new similar plant, with three ponds and a sludge drying bed.

The new Jombang city - Indonesia facility has a reported capacity of 200 m^3/day and consists of an intake, a covered and vented stabilization lagoon, roofed drying bed, a filter and a maturation pond (Sandra et al, 2012).

The purpose of the secondary ponds is to treat the liquid component of the sludge. The solid component is separated in the primary tank or pond and then dried on the drying beds. When separated from the liquid fraction of the septage, the solid sludge will contain a large number of pathogens and these must be removed to be safely used. Detailed assessment of sludge treatment options to remove pathogens is beyond the scope of this research but as a general rule pathogen removal can be achieved by composting or by drying sludge for several weeks.

Once treated, effective marketing and distribution systems must be in place if sludge will be sold as a soil conditioner or fertilizer. There are precedents for this in Indonesia, and no substantial cultural or religious barriers. (Sandra et al, 2012).

On-site sanitation facilities (especially septic tanks) can be efficient to remove biological contamination (bacteria, viruses); however, the exact level of efficiency depends on both the facility's design and the final infiltration device. If the tanks are not waterproof, wastewater can contaminate groundwater resources, especially in limestone and sand areas. Moreover, septic tank efficiency for removing nitrogen and phosphate is generally very low. This means that most nitrogen and phosphate will ultimately infiltrate in the groundwater (Sandra et al, 2012).

In areas where sewer networks are not available, wastewater is discharged into percolating pits. Cesspits are emptied by vacuum tankers, which usually dump their contents in open areas, valleys, sewage networks and/or dump sites (PHG et al, 2011). The existing wastewater treatment plants (WWTPs) in the West Bank have not been designed to specifically treat the sludge collected from cesspits, but some treatment plants accept these trucks, like e.g. Al Bireh WWTP. Most vacuum trucks are owned by small private companies (PWA, 2013, PWA and Al-Quds Univ., 2016).

There are many approaches to septage's treatment and disposal, which include private or public ownership. Larger municipalities are capable of managing the whole process from handling and treatment to disposal, while other municipalities prefer to use privately owned facilities that alleviate some of the responsibilities of operating a facility. Land disposal of septage after adequate treatment is also a popular option (Brown and White, 1977). But in Palestine, there is a lack of such responsibility to safe deal with septage. So, this study will take in consideration the appropriate and best practice to deal with septage.

Knowledge on sewage “treatment” in cesspits as anaerobic reactors is extremely limited. The degree of digestion of the solids in the cesspits most likely depends on the frequency of pumping. Published literature (ATV, 1985; EPA and ORD, 1994) indicated that septage quality could strongly differ from one place to another as many factors influence the physic-chemical characteristics of septage. In Palestine, emphasis was given to characterize and quantify sewage collected in sewer networks (Tahboub, 1999; Mahmoud et al., 2003). But so far very little effort has been made to quantify the cesspits septage generation rate, characteristics and environmental impact in terms of emanated pollutants fluxes to the surface and under surface environments.

Water pollution is a major global problem. One of the main causes of ground water contamination is the effluent from cesspits. Treatment of domestic wastewater using conventional cesspits is found to be inefficient leading to increased soil and ground water contamination. It's very important to protect surface and ground water from contamination. So, there is a need for improving conventional cesspits.

Rrtu and Anand (2016) investigated the effect of a modified septic tank system for treating domestic wastewater. Modified septic tank system was a simple means of treating domestic wastewater using the treatment mechanisms such as anaerobic digestion and disinfection. The effect of vertical baffles coupled with an anaerobic reactor on septic tank system was analyzed. The reactor selected for the study consists of copper modified zeolite as an adsorbent which will also act as filter media on which attached growth process takes place. The results showed that Vertical Baffled Septic Tank (VBST) coupled with zeolite filter formed a good treatment system. The vertical baffled septic tank had a removal efficiency of 99.99% total coliforms, 99.57% of TSS, 46.83% Ammonia nitrogen, 31.08% of nitrate nitrogen, 48.39% of total kjeldahl nitrogen, 94.4% of BOD and 71.74% of Phosphates. This study focused on an economical and efficient decentralized treatment method for treating domestic wastewater (Rrtu and Anand, 2016).

In tropical regions, where most of the developing countries are located, septic tanks, cesspits, and other onsite sanitation systems are the predominant form of storage and pre-treatment of excreta and wastewater, generating septage and other types of sludges. The septage is disposed untreated, mainly due to lack of affordable treatment options.

Koottatep et al. (2005) research presents lessons that had been learned from the operation of pilot-scale constructed wetlands (CWs) for septage treatment since 1997. The experiments were conducted using three CW units planted with narrow-leave cattails (Typha augustifolia) and operating in a vertical-flow mode. Based on the experimental results, the optimum solids loading rate was 250 kg TS/m^2. yr and 6-day percolate impoundment. At these operational conditions, the removal efficiencies of CW units treating septage were at the range of 80–96% for COD, TS and TKN, respectively. The biosolid accumulated on the CW units to a depth of 80 cm and had never been removed during 7 years of operation, but bed permeability remained unimpaired. The biosolid contained viable helminth eggs below critical limit of sludge quality standards for agricultural use. Subject to local conditions, the suggested operational criteria should be reassessed at the full-scale implementation (Koottatep et al., 2005).

During 2012, a series of pilot scale freezing bed experiments were conducted to evaluate and model the freeze–thaw treatment of septic tank sludge (septage). Filtrate quality was similar to a low strength domestic wastewater and the sludge cake had a dry matter content of 25% with E. coli numbers below 2.0×10^6 CFU/g dry solids. Experimental results showed no impact of snow cover on bed performance in a region with moderate snowfall (1.3–1.6 m) as new layers of sludge effectively melted any accumulated snow; suggesting that it was not necessary to cover the bed or remove the snow in areas where sludge dosing exceeded snowfall. Both freezing and thawing processes were successfully modeled with readily available climatic data. Model output for North American climatic conditions indicated that the freezing bed technology can be widely applied throughout the northern United States and Alaska and most of Canada with the exception of coastal areas and southern Ontario(Kinsley, 2012).

Tan et al. (2015) found that the biochemical stability and high concentration of solids and nutrients were the major technical challenges towards effective treatments in the existing wastewater treatment systems. A subsurface Vertical-Flow Engineered Wetland (VFEW) was therefore, introduced as a feasible decentralized septage treatment option for small or medium communities due to its abilities in achieving excellent treatment and energy efficiency and reasonable cost through a simple operation (Tan et al, 2015).

In general, the VFEW removes suspended solids, organic matter and nitrogenous components constituted in raw septage efficiently and sustainably. Tan et al, 2015 paper presents a critical review on the state-of-the art of septage treatment using vertical-flow engineered wetland with regards to their characteristics and operation. The system-factor (such as substrate profile) and operational factors (such as Solid Loading Rate (SLR) and frequency of loading) have been generally agreed as major factors governing the effectiveness of VFEWs. The selection of substrates is crucial to ensure a long-term usability of the VFEW with regards to the clogging phenomenon. The SLR, which ranged from 30 to 250 kg TS, is of great importance to the treatment capability. The frequency of loading determines the rate of oxygen renewal, microbial growth and mineralization of the accumulated sludge deposit within the VFEW system (Tan et al, 2015).

In 2015, Mateo-Sagasta et al. (2015) found that in general areas which produced large amounts and very diverse types of waste including wastewater. The quality of this waste depended on their source, the way in which they were collected and the treatment they received. The final fate of this waste was also very diverse. To better understand these systems definitions and reuse typologies were provided beside common reuse patterns and their driving factors. While the prospects for resource recovery from wastewater and sludge are promising the potential is still largely untapped, except in the private sector. The resources embedded in approximately 330 km^3/year of municipal wastewater that is globally generated would be theoretically enough to irrigate and fertilize millions of hectares of crops and to produce biogas to supply energy for millions of households. However, only a tiny proportion of this wastewater is currently treated, and the portion which is safely reused is significantly smaller than the existing directly and indirectly used untreated wastewater, which is posing significant potential health risks. The research ended with a call for standardized data collection and reporting efforts across the formal and informal reuse sectors to provide more reliable and updated information on the wastewater and sludge cycles, essential to develop proper diagnosis and effective policies for the safe and productive use of these resources (Mateo-Sagasta et al, 2015).

Nearly half of Indonesia’s 238 million individuals live in urban areas. As portion of the Government of Indonesia’s Increasing speed of Sanitation Improvement in Human Settlements Program, the utilization of an on-site sanitation frameworks in urban regions will proceed. In dense regions, little decentralized wastewater treatment plants will be utilized, resulting in expanding request for septage purging administrations as well (Sandra et al, 2012).

Predicting this request, the Service of Public Works assessed the plan and execution of numerous existing septage offices in planning for recovery and unused development. The assessments concluded that in numerous cities there was sub-optimal possession of the septage treatment offices by neighborhood governments; the regulation courses of action for working the offices and the operation and support budgets were destitute, and the staffing and staff capacity was poor. Moreover, later in 2011, the

Ministry of Public Works asked specialist to support national speculations in septage infrastructure, focused on helping neighborhood governments develop urban septage administration. In specific, the help was pointed at creating maintainable administration models for working and keeping up septage frameworks (Sandra et al, 2012). Field work was conducted in two Indonesian cities, it focused on the proposed models for Tegal (pop 250,000) in Central Java and Jombang (pop 200,000) in East Java. The key issues addressed in that field work were; Current septage system practices and shortcomings, proposed management models with potential for extending the sanitation value chain by reuse of septage, Incentives and disincentives to local Government for improved operation, Short and medium term actions for local government, and Application of lessons learned for other cities in East Asia and elsewhere. (Sandra et al, 2012)

2.4 The focus of this research

This study focuses on characterize the septage and develop an on-site treatment model. It seeks to provide information on parameters such as pH, TN, BOD_5, COD, TSS, TDS … etc. These parameters if determined will be crucial in predicting the path to consider in the treatment of septage.

This research seeks to develop a treatment model to treat the characterized septage for those who cannot afford safe sanitation disposal and treatment services.

Chapter Three

Research Methodology and Materials

Chapter Three: Research Methodology and Materials

3.1 General

As the septage is inhomogeneous, consists of a liquid phase, settled and partly settled solids, scum and dissolved solids, thus representative sampling from cesspits is very difficult. The development of a standardized sampling method appears nearly impossible as the conditions of sampling vary from one place to another; and due to different vacuum trucks and variable construction design of the septic tank (Hithnawi, 2004).

This chapter presents the sampling procedure, various lab analysis including the assumptions and calculations. All the analyses were carried out in the Water Engineering Laboratory of the Institute for Water and Environmental Studies, An-Najah National University, Nablus.

Many obstacles were faced; getting samples from the trucks was the main problem, where the trucks empty the septage in open land, due to high cost of disposal in the WWTP which is located to the west of Nablus as this cost them the fees and the transportation costs. See Picture 3.1

Picture 3.1: Disposal of septage on the land

Another hindrance was the cooperation with some of the truck drivers or the operators who are working with truck driver and house-owners in the study area, as some of them refused to cooperate for taking a sample from the septage trucks or to answer some questions about their cesspits. Thus, getting samples was a big problem, it required standing in the sun with exposure to unpleasant odor for hours during the vacuum of septage from cesspits and transferred to the place of disposal, then filling the samples bottle after a long explanation for the drivers about the objectives of taking these samples.

3.2 Methodology flowchart

The methodology of the research was divided into 7 steps as summarized in the following flowchart, see Figure 3.2

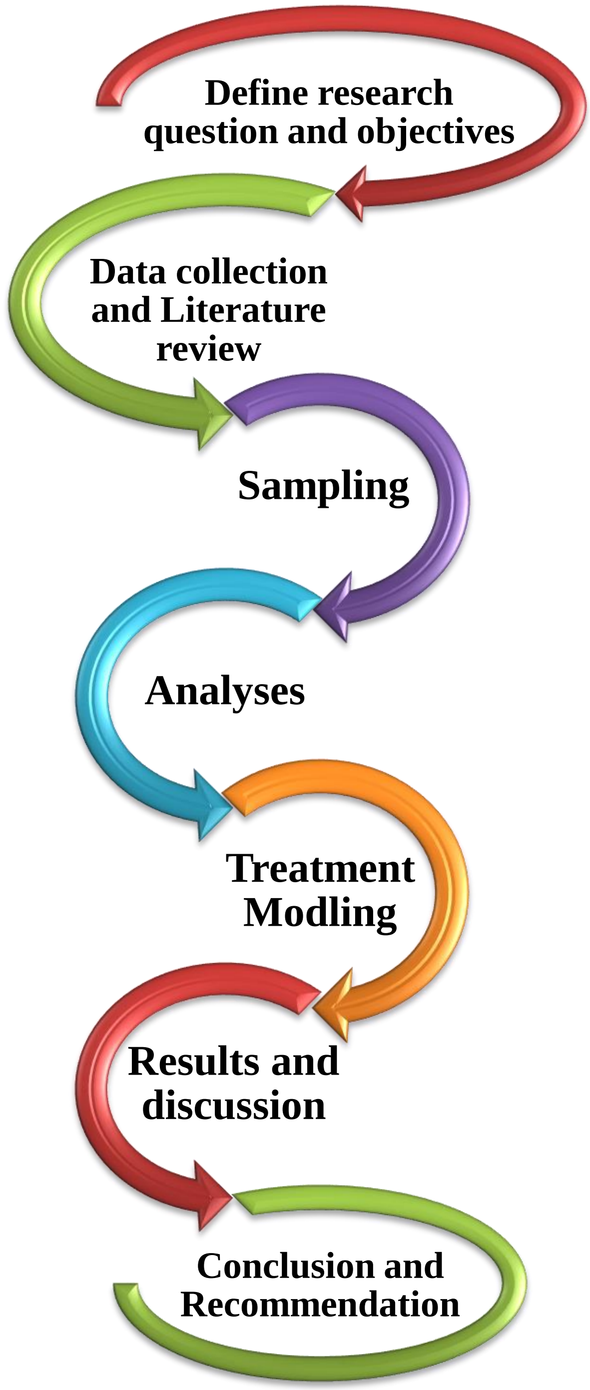


Figure 3.2: Flowchart of research methodology

3.3 Research Methodology and Methods of Laboratory Analysis

3.3.1 Data collection

- The required data related to water and wastewater sources, type of pits, and disposal methods of septage were collected from several sources like previous reports, PWA, municipalities, interviews, field visits, and published work.

- Scientific data such as: definition of process parameters was collected from literature.

3.3.2 Sampling and Storage

The objective of sampling is collecting a portion of material small enough in volume to be transported conveniently and handled in the laboratory while still accurately representing the material being sampled. This objective implies the relative proportions or concentrations of all pertinent components will be the same in the material being sampled, and that the sample will be handled in such a way that no significant changes in composition occur before the tests are made (APHA, 2001).

The sampling techniques used for a wastewater or septage survey must ensure that representative samples are obtained, because the data from the analysis of the samples will ultimately serve as a basis for designing treatment facilities. Special procedure is necessary to handle problems when sampling wastes that vary considerably in composition. Thus, suitable sampling locations must be selected, and the frequency and type of sample to be collected must be determined (Metcalf and Eddy, 1991)

Information from samples can be valuable for selecting treatment technology and properly operating the system (APHA, 2001). A good sampling program should:

- Ensure that the sample is representative.
- Use proper sampling technique.
- Protect the samples until they are analyzed.

In this research, samples were collected from different trucks, different places at different times. The samples were preserved at 4°C in special insulated boxes during transportation to laboratory at An-Najah University. See Figure B.1 in appendix B.

The sampling process followed these steps:

1. An agreement with the laboratory about the schedule of the lab and the time needed for analyses.
2. Preparing clean sampling bottles.
3. Identifying the sources of septage, which is three cesspits in three deferent locations as mentioned in the section of the study area.
4. Identifying the sources of stools and urine, which is two houses in two deferent locations in one of the villages of the study area which is Tell Village.

5. Coordinating with trucks which transport the septage in each location.
6. Collecting representative samples from a truck during emptying the septage by mixing the amount taken from the beginning, center and end to form a homogeneous sample.
7. Labeling all the bottles immediately and record them, each bottle name should contain the location, time, and date.
8. Analyzing samples immediately. Otherwise, stored at a low temperature (less than 4°C) immediately after collection to preserve samples.

3.3.2.1 Sampling of Septage

FS was collected from trucks at the disposal site. Classification of FS was private septage based on EAWAG/SANDEC classification (Klingel et al, 2002). Sampling was done for three continuous months in the summer season. During this period, eighteen samples from different nine locations were collected, these locations were in the three mentioned villages in chapter 1. Two homogenous samples were taken from each location monthly.

To take the sample from the truck, a three-point sampling was implored, thus taking portions of the sample at the beginning of discharge, at about mid-point and at about the end of discharge, homogenizing the portions and drawing the amount needed for storage and analysis. Because of wide variations in septage characteristics, two individual samples were collected from the homogenous portion to grantee a fairly representative sample.

3.3.2.2 Sampling of stools and urine

Stools and urine samples collected from two houses in Tell village for five different persons. The age ranges of the individuals from whom the samples were taken vary over the periods of each estimated period of ten years, starting from the first decade to the fifth decade. Sampling was done in two deferent times: one for stools and one for urine during two weeks. See Figure B.2 and B.3 in appendix B.

The stools samples were composite sample that included the pure feces, urine, and 4 liters of tab water, as (60 – 70) % of people flushing 4 liters after they were using the toilet in the study area.

3.3.2.3 Storage of samples

(APHA, 2001) Recommend immediate analysis after collection, if possible, analyzing samples immediately after the collection, because preservatives often interfere with the test. Otherwise, store at a low Temperature (< 4°C) immediately after collection to serve most samples. Preservation types are showing in Table A.14 in appendix A.

Apart from the pH and EC analysis which was done at the point of sampling to avoid any changes that may occur between the point of sampling and storage which could not be accounted for, the samples after collection were taken to the lab to continue experimental analysis. However, due to the volume of work that needed to be done on each sample, there was the need to store the samples in a refrigerator to preserve them and use them on subsequent working days in the lab. Therefore, after every lab working day the samples were stored in a refrigerator at 4°C.

3.3.3 Characterization of Fecal Sludge (FS)

In characterizing the samples, a number of parameters were considered. All of parameters listed in Table 3.1 were taken in characterization of the septage.

Table 3.1: Parameters were considered to characterize the samples

Type of analyses	Parameter names
Physical Analysis	pH, Torpidity (NTU), Temperature, TS, TSS, TDS, VS, VSS, VDS.
Chemical Analysis	BOD_5, COD, NH_4-N (Ammonia), NO_3-N (Nitrate), TN, TKN, PO_4-T, PO_4-P, Alkalinity (as $CaCO_3$), EC, Fat & Grease
Heavy Metals Analysis	Ag, Al, Ba-1, Be, Bi, Cd, Cr, Co, Cs, Ga, In, Li, Mn, Mo
Microbial Analysis	Total Coliform Count TCC (/1ml), Fecal Coliform Count FCC (/1ml)

Lab analysis were conducted according to the Standard Methods (APHA, 2001). Heavy metals analyses were done by Inductively Coupled Plasma Mass Spectrometry (ICP-MS) device. See Figure B.4 in appendix B.

The pH and EC tests were done on site just after sampling to avoid as much as possible degradation of the FS that may not be accounted for. A digital measuring kit with a probe was used. Figures B.5, B.6, B.7 in appendix B show some process of analysis.

3.3.4 Statistical Analysis of data on Characterization of FS

A statistical approach was used to analyze the data on characterization of fecal sludge, to determine the variation in the means of the data obtained based on the sources and the months of sampling.

3.3.5 Septage pre-treatment process

3.3.5.1 General Treatment options

The potential treatment processes that were identified as suitable for developing countries were: Planted drying beds (constructed wetlands), Waste Stabilization Pond (WSP), combined composting ("co-composting") with organic solid waste, Anaerobic Digestion with biogas utilization and Unplanted Drying Beds (Cofie et al, 2006; Heinss et al, 1998; Klingel et al, 2001; and Koottatep et al., 2005). The treatment processes above can be used alone or in combination to achieve the required standards of the sludge and leachate. Usually, there is a high content of coarse wastes such as light plastics, tissues and paper in the fecal sludge discharged by collection and transport trucks, thus, a preliminary screening is needed for most treatment technologies (Strauss and Montangero, 2002).

3.3.5.2 Selection of treatment options

The selection of a feasible treatment option is always decided according to a set of factors that requires careful analysis. The first step is to pre-screen the technology options and exclude unfeasible technologies for example co-treatment with wastewater is not feasible for a city without a sewer system. Secondly the preselected potentially feasible options are compared based on the selected criteria as shown in Table A.15 and Table A.16 in appendix A. The final step is for decision-makers to evaluate and weigh the different options against the same criteria and select the most suitable option(s) for the fecal sludge management concept (Montangero and Strauss, 2002).

3.3.5.3 Septage Quality Determination

Quality parameters are needed as input to the proposed treatment model, they were determined based on the results of septage characterization. These parameters include: pH, BOD_5, COD, TS, TSS, TDS, Ammonia, Total Nitrogen, and Total Phosphorus.

3.3.5.4 Software selection

Many programs deal with wastewater treatment plant modeling see Table 3.2. GPS-X 7.0 program was chosen because it is free, and capable to achieve the objectives of this research. GPS-X 7.0 can deal with two sides: wastewater and sludge treatment.

Table 3.2: Simulator Software Products

Product name	Manufacturer (location)	Website
BioWin	EnviroSim Associates, Ltd. (Flamborough, Ontario, Canada)	**www.envirosim.com**
EFOR	DHI Software. (Hørsholm, Denmark)	**/www.dhisoftware.com /efor**
GPS-X	Hydromantis, Inc. (Cambridge, Ontario, Canada)	**www.hydromantis.com**
SimWorks	Hydromantis, Inc. (Cambridge, Ontario, Canada)	**www.hydromantis.com**
STOAT	.WRc plc (Blagrove, Swindon, England)	**http://www.wrcplc.co.uk/stoat.aspx**

3.3.5.5 Modeling by GPS-X 7.0

The septage treatment plant modeling is a critical point in this research, so the following points were considered:

1. Treatment plant modeling steps:

- Determining model's goal.

The main objective is to build a treatment model and to study the fit of proposed treatment plant effluent with the local treated wastewater specifications by EQA.

2. Data analysis:

The data needed and relevant information to the treatment plant were analyzed, and the missing data were identified from literature or from laboratory experiments.

3. Model setup:

The treatment plant was represented using GPS-X 7.0 program tool. Also the model type (ASAL1) option was chosen which meets septage treatment properties. ASAL1 requires sewage retention time greater than 2-4 hours, and the modeling effort was directed at effluent quality. This model incorporates oxidation, nitrification and denitrification processes.

4. Data Management:

The results obtained from the modeling of treatment plant were discussed, and executive plan were recommended to build the simulated cases.

3.3.6 End-use and disposal

End products of the treated sludge (for example dried or partially dried sludge, compost, leachate, and biogas), have an intrinsic value, which can turn treatment from merely a method for environmental and public health protection to resource recovery and value creation (Weemaes and Verstraete, 2001). Historically, the most common resource recovery from sludge has been as a soil conditioner and organic fertilizer, as fecal sludge contains essential plant nutrients and organic matter that increases the water retaining capacity of soils. Researchers are underway to recover end products as a bio-fuel (Diener et al, 2014; Muspratt et al, 2014), for example pyrolysis, gasification, incineration and co-combustion or as resource recovery of organic matter through the growth of Black Soldier flies for protein production. Table 3.3 gives a summary of potential resource recovery options from fecal sludge. With the implementation of resource recovery, it is important to evaluate constituents that may impact both humans and the environment. These include the presence of pathogens and heavy metals. Social factors such as acceptance in using products from fecal sludge treatment and market demand also need to be taken into account` in order to ensure uptake of the intended endues (Diener et al, 2014).

Table 3.3: Summary of potential resource recovery options from fecal sludge Source: (Kengne et al, 2014)

Produced Product	Treatment or Processing Technologies
Soil conditioner	✓ Untreated fecal sludge ✓ Sludge from drying beds ✓ Compost ✓ Pelletising process ✓ Digestate from anaerobic digestion ✓ Residual from Black Soldier fly
Reclaimed water	✓ Untreated liquid fecal sludge ✓ Treatment plant effluent
Protein	✓ Black Soldier fly process
Fodder and plants	✓ Planted drying beds
Fish and plants	✓ Stabilization ponds or effluent for aquaculture
Building materials	✓ Incorporation of dried sludge
Biofuels	Biogas from anaerobic digestion Incineration/co-combustion of dried sludge Pyrolysis of faecal sludge Biodiesel from faecal sludge

Chapter Four

Characterization of the Fecal Sludge – Results and Discussion

Chapter Four

Characterization of the Fecal Sludge – Results and Discussions

4.1: General

Two of the objectives of this study were to characterize the septage, feces and urine in rural area in Nablus Governorate. The following results and discussions show these characteristics.

Detailed results are shown in appendix A as following:

- Details of cesspits sampled (Tables 18, 19 and 20).
- Septage characteristics (Tables 21, 22 and 23).
- Feces and urine characteristics (Tables 24 and 25).

4.2: Measured Parameters for fecal sludge

4.2.1: Septage characteristics

4.2.1.1 Physical Septage characteristics

Physical Septage characteristics from three villages are presented in the Table 4.1; this table entails the number, range of values, averages, and standard deviations.

Table 4.1: Physical Septage characteristics for Rural Nablus.

Parameters	N*	Range of values		AVG.	STD
		Min.	Max.		
pH	18	7.15	8.14	7.74	0.38
Turbidity (NTU)	12	150.00	820.00	438.00	242.26
Temperature	18	20.60	24.50	22.09	1.43
TS	14	1030.00	2245.00	1620.54	368.46
TSS	12	142.50	572.50	328.25	162.25
TDS	12	786.00	1498.00	1001.08	234.10
VS	14	732.00	1244.00	965.50	171.86
VSS	10	132.00	400.00	203.50	90.09
VDS	14	447.50	944.00	651.68	141.35

N*: number of samples analyzed.

All units are (mg/l), except pH(-) and which specified

4.2.1.2 Chemical Septage characteristics

Chemical Septage characteristics from three villages are presented in the Table 4.2; this table entails the number, range of values, averages, and standard deviations.

Table 4.2: Chemical Septage characteristics for Rural Nablus (2018).

Parameters	N*	Range of values		AVG.	STD
		Min.	Max.		
EC (ms/cm)	14	2.30	2.83	2.59	0.16
BOD_5	14	150.00	900.00	371.43	239.16
COD	14	540.00	1690.00	1086.86	376.23
NH_4-N (ammonia)	18	73.50	192.00	149.36	39.17
NO_3-N (nitrate)	18	0.00	1.40	0.29	0.46
N-T	12	80.00	255.00	178.33	69.04
TKN	18	80.00	254.09	188.96	69.03
PO_4-T	12	8.30	15.60	12.10	2.86
PO_4-P	14	7.60	14.90	11.22	2.89
Fat & Grease	18	32.50	109.50	71.67	24.15
Alkalinity (as $CaCO_3$)	16	800.00	1500.00	1178.13	220.58

N*: number of samples analyzed.
All units are (mg/l), except pH(-) and which specified

4.2.1.3 Bacterial Septage characteristics

Chemical Septage characteristics from three villages are presented in the Table 4.3; this table entails the number, range of values, averages, and standard deviations.

Table 4.3: Bacterial Septage characteristics for Rural Nablus (2018).

Parameters	N*	Range of values		AVG.	STD
		Min.	Max.		
TCC (C/1ml)*	7	1.96E+06	4.83E+07	1.95E+07	1.80E+07
FCC (C/1ml)	14	3.60E+03	3.80E+04	1.12E+04	8.59E+03

N*: number of samples analyzed.

C/1ml: Colony per one milliliter

4.2.1.4 Heavy metals Septage characteristics

Chemical Septage characteristics from three villages are presented in the Table 4.4; this table entails the number, range of values, averages, and standard deviations.

Table 4.4: Heavy metals Septage characteristics for Rural Nablus (2018).

Parameters	N*	Range of values		AVG.	STD
		Min.	Max.		
Ag	4	0.04	0.12	0.07	0.04
Al	4	3.93	5.82	4.64	0.87
Ba-1	6	0.41	0.67	0.51	0.11
Be	6	0.00	0.00	0.00	0.00
Bi	6	0.00	0.00	0.00	0.00
Cd	6	0.00	0.00	0.00	0.00
Cr	6	0.10	0.12	0.11	0.01
Co	6	0.00	0.01	0.01	0.00
Cs	6	0.00	0.00	0.00	0.00
Cu	4	0.31	0.38	0.35	0.03
Fe	5	11.88	22.74	17.52	5.04
Ga	6	0.00	0.01	0.01	0.00
In	6	0.00	0.00	0.00	0.00
Li	4	0.01	0.02	0.01	0.00
Mn	6	0.26	0.47	0.37	0.10
Mo	6	0.01	0.05	0.03	0.01
Ni	6	0.08	0.10	0.09	0.01
Pb	6	0.04	0.12	0.08	0.03
Rb	6	0.03	0.11	0.08	0.03
Sr	6	0.35	0.59	0.41	0.10
V	6	0.00	0.03	0.01	0.01
Zn	6	3.95	4.83	4.37	0.41

N*: number of samples analyzed.

All units are (mg/l).

Table 4.5 shows a Comparison of constituents present in septage data from rural area and EPA. The values of septage parameters in EPA were higher than those presented in the study area. This could be due to the following:

Cultural and behavioral differences between the study area and The United States where EPA specifications were developed.

Cesspits design and pump out interval in rural area or in the study area is different from The United States where EPA specifications were developed.

Kitchen grinders are seldomly used in Palestine which is used to reduce the volume of kitchen waste and dispose of it through sewers, thus increasing the concentrations of organic matter in the septage. Also, the Lifestyle and hygiene approaches are different, where soiled toilet papers are partly discharged through sanitary facilities and usage of tab water for hygienic cleaning purposes.

Source of septage is from central unsewered urban dwellings, where short hydraulic retention time prevailed in most cesspits leading to weak anaerobic transformation processes.

Table 4.5: Comparison of domestic septage between Rural Nablus and EPA,(1993)

Parameter	Septage range	Septage range (EPA, 1994)
BOD_5	150 – 900	440 – 78,600
COD	540 – 1,960	1,500 – 703,000
NH_4-N	73 – 192	3 – 116
PO_4-P	7.6 – 14.9	–
Alkalinity	800 – 1,500	522 – 4,190
TKN	80 – 254.1	66 – 1,060
Oil & Grease	32 –109.5	208 – 23,368
TS	1,030 – 2,245	1,132 – 130,475
TSS	142.5 – 1,498	310 – 93,378
VS	732 – 1,244	353 – 71,402
pH	7.15 – 8.14	1.5 – 12.6

Values expressed as mg/l, except for pH (-)

4.2.2: Stools characteristics

Feces characteristics from five persons in Tell village are presented in the Table 4.6; this table entails the number, range of values, averages, and standard deviations. The results revealed that the parameters value in stools were higher than in septage; the reasons are the dilution of wastewater with other uses of water in the house and also the treatment of wastewater inside the cesspit while the cesspit is not being emptied.

Table 4.6: Stools characteristics for Rural Nablus (2018).

Parameters	N*	Range of values		AVG.	STD.
		Min	Max		
pH	5	6.07	8.62	7.32	1.02
EC (μs/cm)	5	1,575.00	2,700.00	2,089.80	560.80
Torpidity (NTU)	3	204.00	595.00	363.67	205.12
Temp.	5	21.50	23.40	22.46	0.78
BOD5	5	700.00	2,500.00	1,840.00	746.99
COD	3	1,240.00	5,390.00	3,156.67	2,093.04
NH4-N (ammonia)	5	50.00	155.00	97.00	44.94
NO3-N (nitrate)	3	0.10	0.20	0.17	0.06
N-T	5	350.00	480.00	408.00	52.03
TKN	5	349.90	479.80	402.40	56.86
PO4-T	4	13.70	19.90	16.60	2.61
PO4-P	4	16.40	23.40	19.08	3.16
TS	3	3,096.00	3,838.00	3,389.33	394.64
TSS	4	1,260.00	3,146.67	2,227.50	913.98
TDS	5	922.00	4,220.00	1,756.40	1,396.53
VS	3	566.00	928.00	701.33	197.53
VSS	3	86.67	130.00	108.89	21.69
VDS	3	426.00	553.33	490.89	63.70
Fat & Grease	3	21.50	115.50	67.17	47.06
Alkalinity (as Caco3)	3	1800.00	2,000.00	1,900.00	100.00
TCC (C/1ml)	5	3.00E+06	1.60E+07	6.64E+06	5.36E+06
FCC (C/1ml)	4	1.00E+04	1.50E+05	6.25E+04	6.70E+04

N*: number of samples analyzed.

All units are (mg/l), except pH(-) and which specified

4.2.3: Urine characteristics

Urine characteristics from five persons were analyzed and presented in the Table 4.7; this table entails the number, range of values, averages, and standard deviations. From the results it was noticed that none of the samples contain any type of solids (TS, TSS, TDS, VS, VSS and VDS), oil and grease.

Table 4.7: Urine characteristics for Rural Nablus (2018).

Parameters	N*	Range of values		AVG.	STD.
		Min	Max		
pH	5	5.15	5.79	5.57	0.30
EC (µs/cm)	4	7.20	16.12	12.08	3.84
Torpidity (NTU)	4	3.24	7.71	5.20	2.04
Temp.	5	20.90	21.20	21.04	0.13
BOD5	4	1,150.00	1,950.00	1,551.54	452.20
COD	4	4,285.00	9,300.00	6,645.00	2,435.72
NH4-N	4	86.00	165.00	129.00	38.17
NO3-N	3	1.00	1.50	1.33	0.29
TN	4	1,080.00	1,850.00	1,447.50	317.63
TKN	4	1,078.50	1,849.00	1,446.40	317.77
PO4-T	5	49.20	56.30	52.66	2.53
PO4-P	5	38.20	48.00	42.54	4.62
TS	0	0.00	0.00	0.00	0.00
TSS	0	0.00	0.00	0.00	0.00
TDS	0	0.00	0.00	0.00	0.00
VS	0	0.00	0.00	0.00	0.00
VSS	0	0.00	0.00	0.00	0.00
VDS	0	0.00	0.00	0.00	0.00
Fat & Grease	0	0.00	0.00	0.00	0.00
Alkalinity (as Caco3)	4	500.00	600.00	550.00	57.74
TCC (/1ml)	5	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FCC (/1ml)	5	0.00E+00	0.00E+00	0.00E+00	0.00E+00

N*: number of samples analyzed.

All units are (mg/l), except pH(-) and which specified

4.3 Specific parameters in details

4.3.1 pH and EC:

Measurement of pH and EC is essential for the understanding of water chemistry processes, such as acid-base chemistry, alkalinity, neutralization, biological stabilization, precipitation, coagulation, disinfection, and corrosion control (APHA, 2001).

From Figure 4.1 below, the average value of pH of septage from cesspits in rural Nablus was (7.74±0.38). Also, the average of EC of septage from cesspits in rural Nablus was (2.59±0.16 ms/cm). Moreover, the average of the septage pH was within the average of pH in the inlet of Nablus WWTP for municipal wastewater (7.84±0.15), on the other hand, the average of the EC was more than the average of EC in the inlet of Nablus WWTP (1.63±0.18 ms/cm). This variation is related to the absence of wastewater in the cesspit for a period of time (NWWTP, 2018).

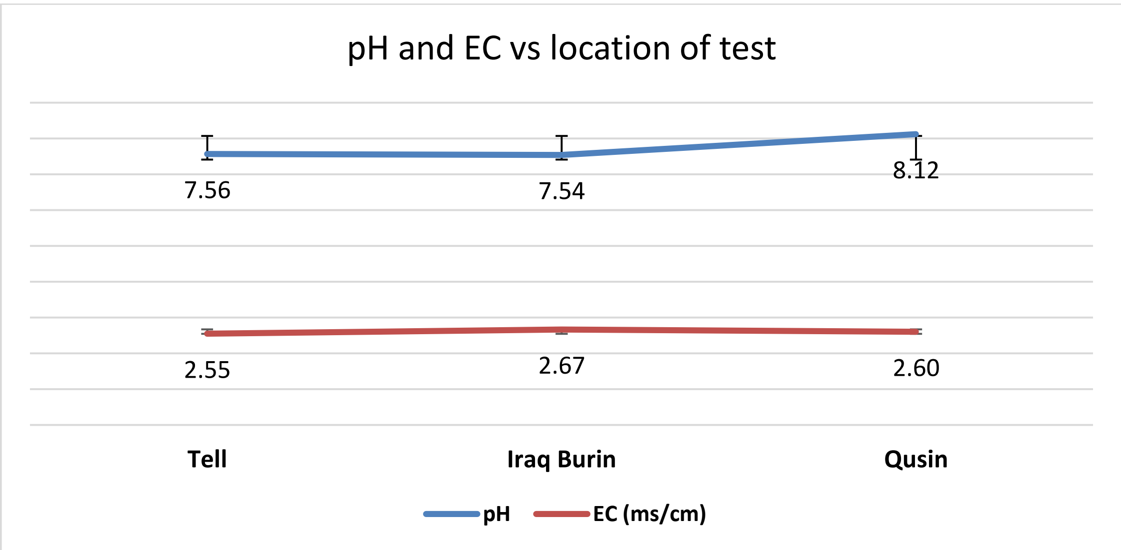


Figure 4.1: pH and EC Average values for septage analyzed at rural Nablus

4.3.2 Turbidity

The measurement of Turbidity is one of the important tests when trying to determine the characteristics of wastewater to measure the level of turbidity. From Figure 4.2 below, the average value of turbidity of septage from cesspits in rural Nablus was (483.0±242.26 NTU). The big variation between these locations is related to the water consumption, frequency of emptying the cesspit, and to soil content. The lower readings were in Iraq Burin and this is due to the nature of this village as it is located on a rocky mountain.

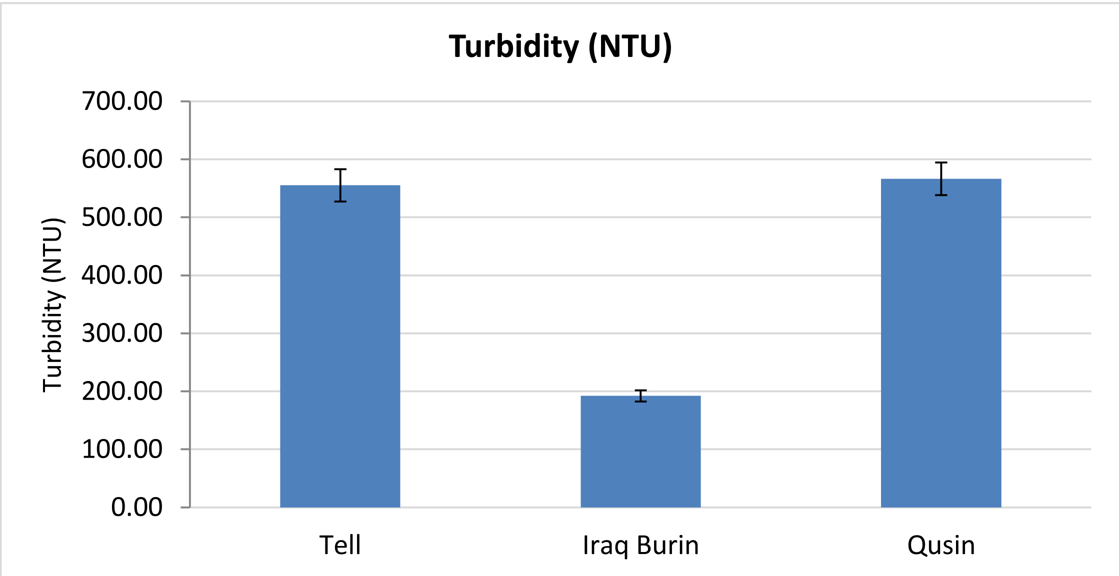


Figure 4.2: Turbidity average values for septage analyzed at rural Nablus

4.3.3 COD/BOD_5

The measurement of COD and BOD5 are important when trying to determine the characteristics of wastewater as these parameters determine the degree of pollution and the biological and chemical demand for oxygen. It can be noticed from Figure 4.3 below that the average values of

COD and BOD5 of septage from cesspits in rural Nablus were (1086.86±376.23) and (371.43±239.16) respectively in mg/l. The large variation between these locations is related to the water consumption, frequency of emptying the cesspit, soil context and for the other factors mentioned in section 2.2.

Also, it can be noticed in Figure of 4.4 that the factor of COD/BOD5 was around 3.4 and it was greater than the average ratio of raw wastewater at inlet of Nablus WWTP in the same period which equaled 2.0 (NWWTP, 2018), this is due to the high dilution factor of municipal wastewater, and the context of septage as it contains chemical solutions at the household level more than at the municipal level.

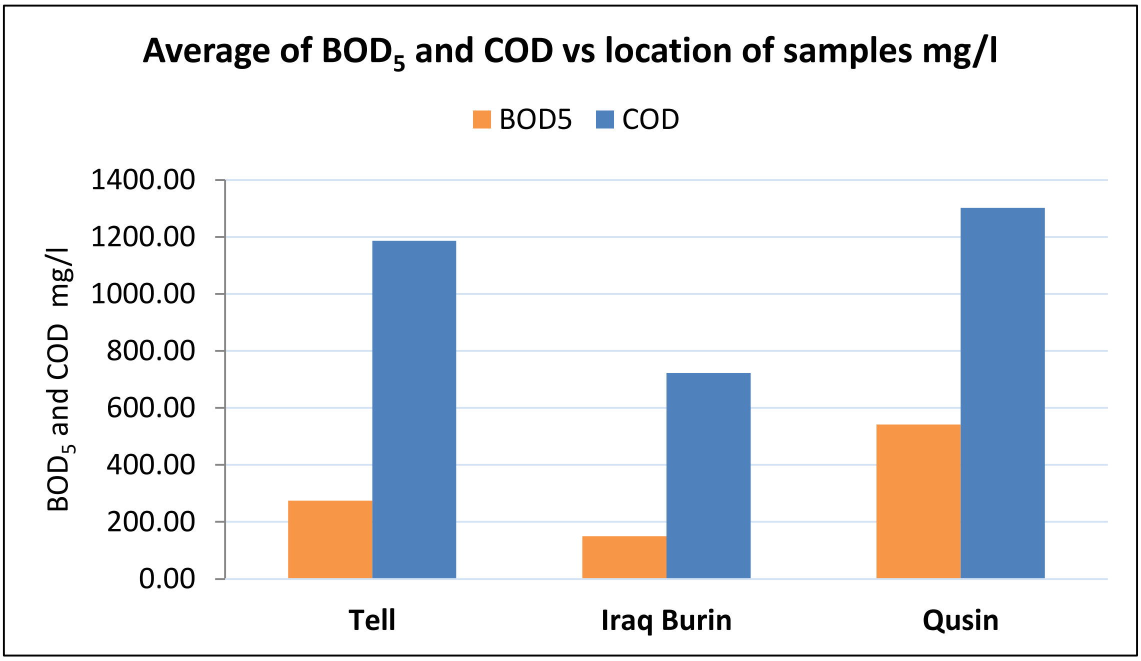


Figure 4.3: COD and BOD_5 Average values for septage analyzed at rural Nablus

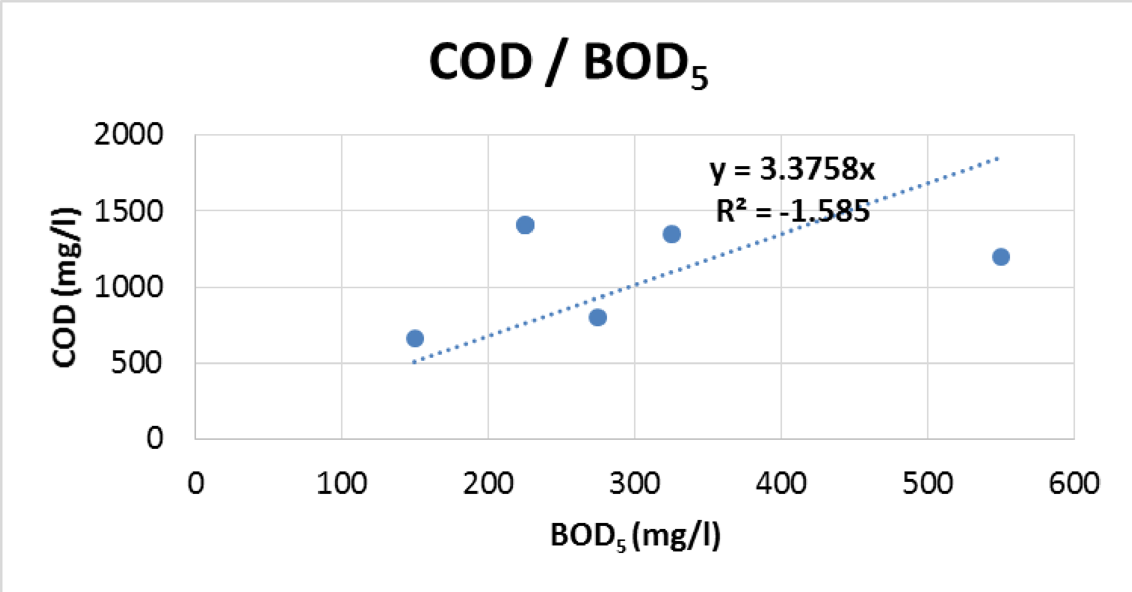


Figure 4.4: COD/BOD5 ratio for septage analyzed at rural Nablus

4.3.4 Total Nitrogen and Ammonia

As noticed in Figure 4.5 below, the average value of TN of septage from cesspits in rural Nablus was: 178.33±69.04 mg/l.

The measurement of TN is an important test when trying to determine the characteristics of wastewater. And if the average of TN in septage is compared with the average of TN at the inlet of Nablus WWTP for municipal wastewater (84.67±7.57 mg/l) it could be conclude that, the average TN in septage was larger (NWWTP, 2018).

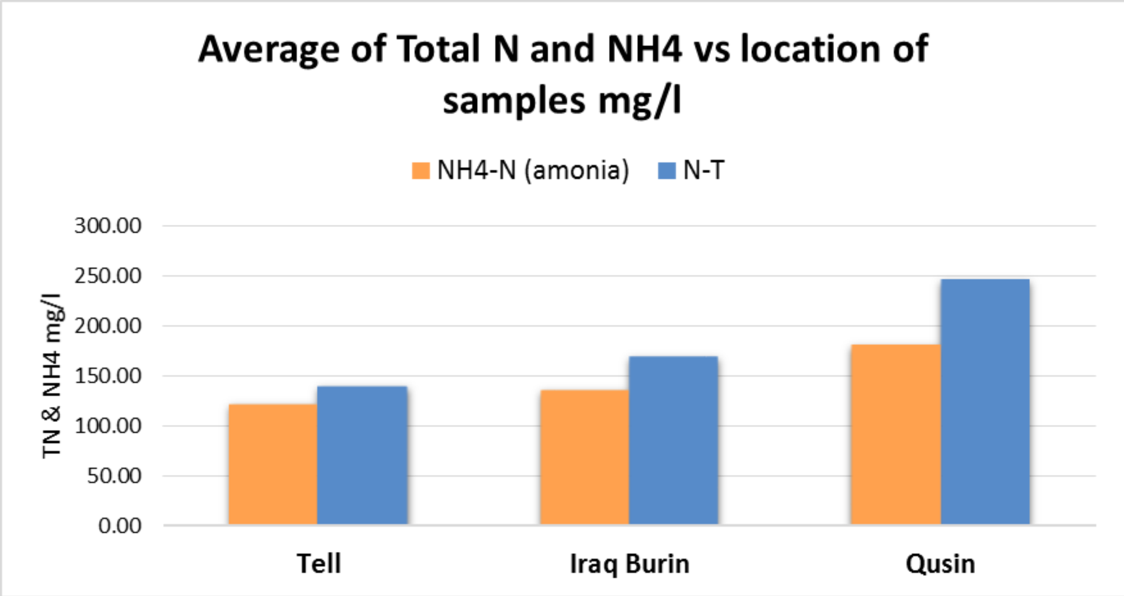


Figure 4.5: Total N and Ammonia Average values for septage analyzed at rural Nablus

4.3.5 TS, TDS, and TSS

Samples from the cesspits have high TS, TSS, and TDS compared with raw wastewater(Hithnawi, 2004). Table 4.6 shows the average values of the TS, TSS and TDS respectively. (1620.54±368.46), (328.25±162.25), (1001.08±234.10), all in mg/l.

For example, the TSS at the inlet of Nablus WWTP for municipal wastewater (474.67±69.62 mg/l) was less than the average of TSS in the septage in rural Nablus (NWWTP, 2018). The concentration of TSS becomes higher as the septage dense due to leaking the water content through the soil.

The large variation in these tests among the results is due to several reasons in addition to the factors mentioned in section 2.2, such as the error in balancing after burning the samples on 105^{o}C and due to the dilution of the samples as they were very dense of solids.

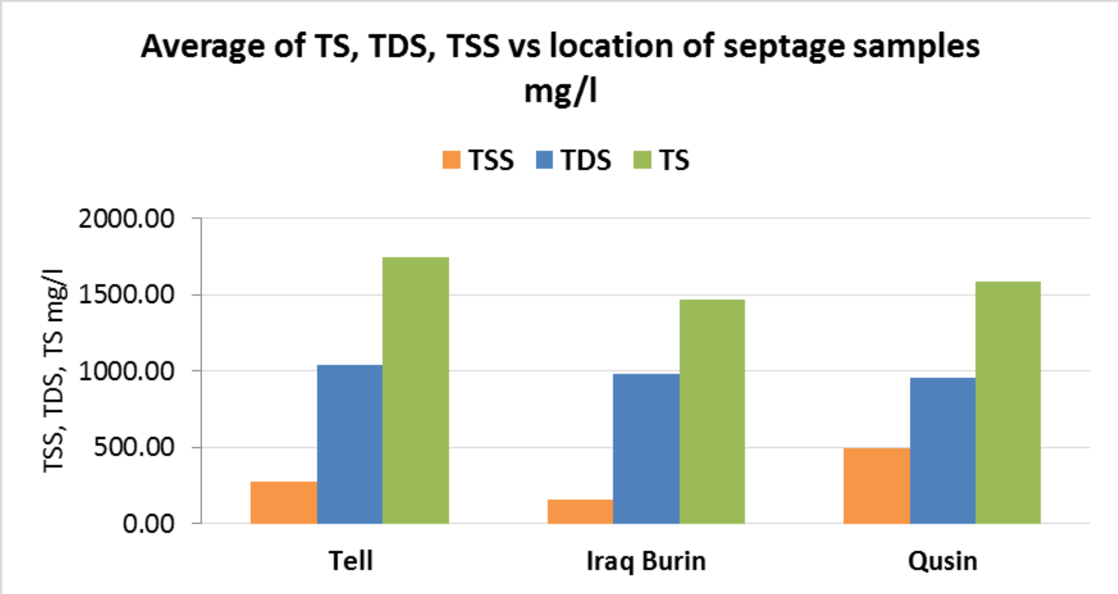


Figure 4.6: TS, TDS, and TSS average values for septage analyzed at rural Nablus

4.3.6 VS, VDS, and VSS

Samples from the cesspits will have high VS, VSS, and VDS compared with raw wastewater (Hithnawi, 2004). Table 4.7 shows the average values of the VS (965.50±171.86), VSS (203.50±90.09), and VDS (651.68±141.35) all in mg/l.

The huge variation in these tests among the readings is due to several reasons in addition to the factors mentioned in section 2.2, such as the error in balancing after burning the samples on 550°C and due to the dilution of the samples as they were very dense of solids.

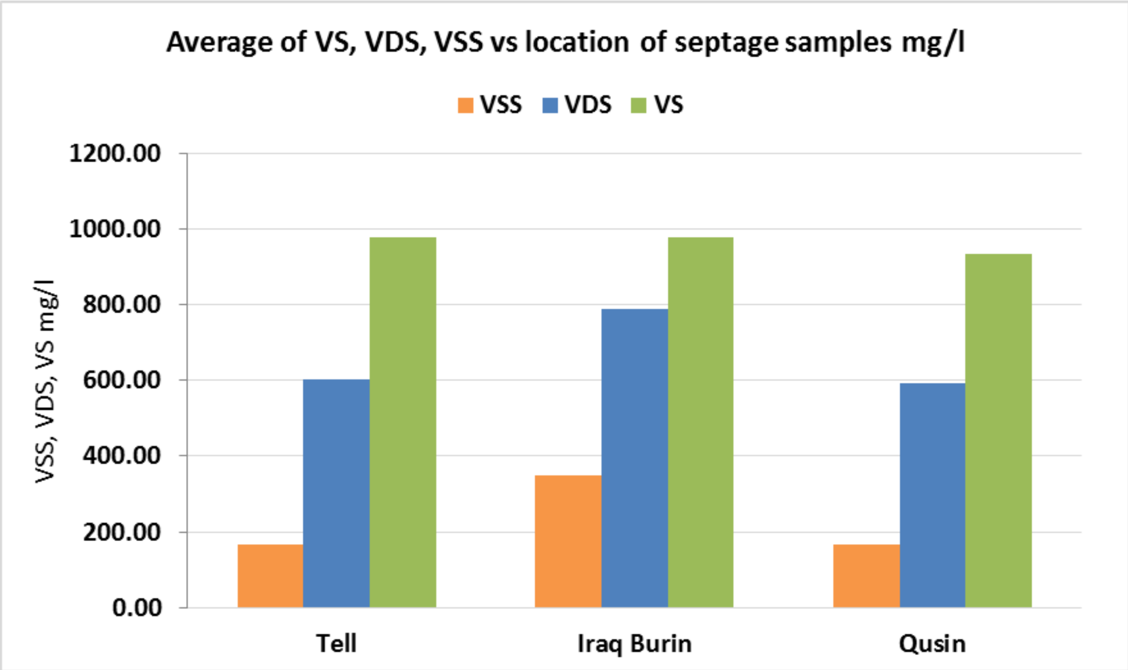


Figure 4.7: VS, VDS, and VSS average values for septage analyzed at rural Nablus

4.3.7 PO4-P and PO4-T

As noticed in Figure 4.8 below, the average value of PO4-P and PO4-T of septage from cesspits in rural Nablus were (11.22±2.89) and (12.10±2.86) respectively in mg/l.

The measurement of PO4 is an important test when trying to determine the characteristics of wastewater. Presence of washing machines, washbasins, and Industries that are connected to Nablus WWTP are significant contributors of phosphate in domestic wastewater. This lead to note that the average of PO4-P at the inlet of Nablus WWTP (26.57±5.43 mg/l) was more than the average of PO4-P in the rural Nablus septage (NWWTP, 2018).

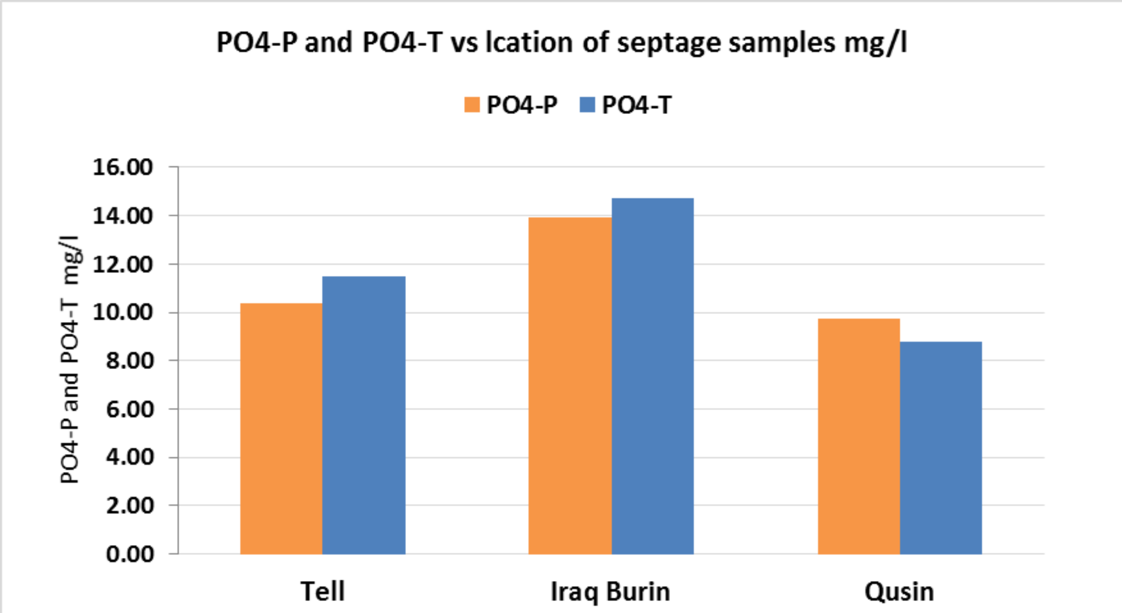


Figure 4.8: PO4-P and PO4-T average values for septage analyzed at rural Nablus

4.3.8 Fat & grease

Figure 4.9 shows Oil and Grease average value for septage at rural areas in Nablus was (71.67±24.15) mg/l.

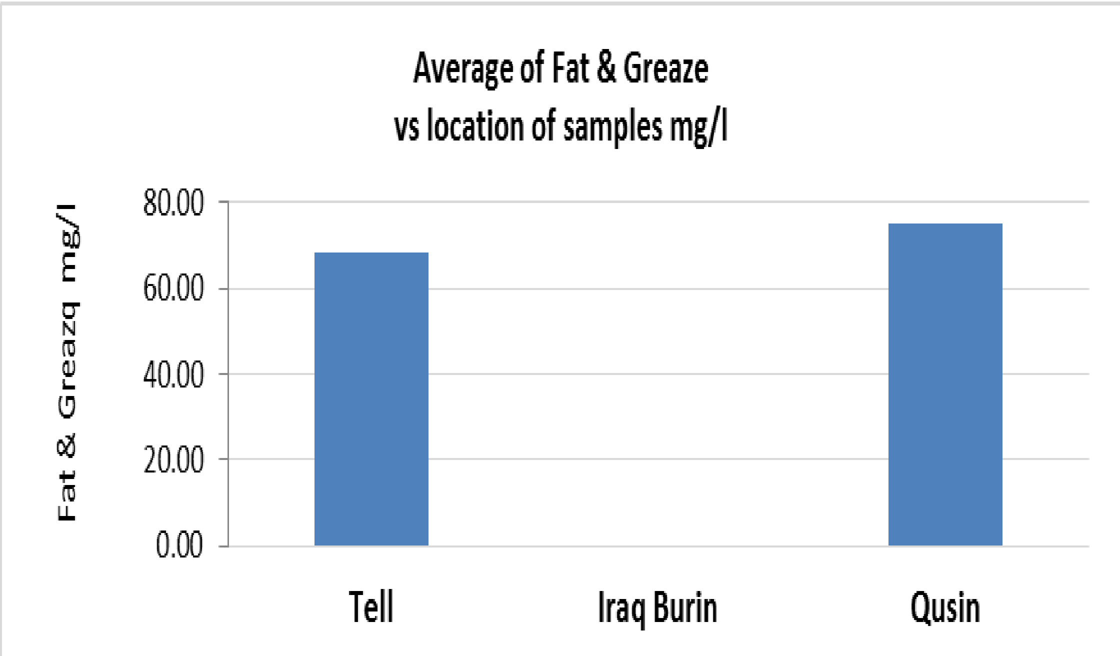


Figure 4.9: Fat and grease average values for septage analyzed at rural Nablus

4.3.9Alkalinity

The high value of alkalinity affect nitrification and denitrification process. The average value of alkalinity in this study was (1178.13±220.58) mg/l. Figure 4.10 shows the $CaCO_3$ average values for septage extracted from cesspits at the three locations of this study.

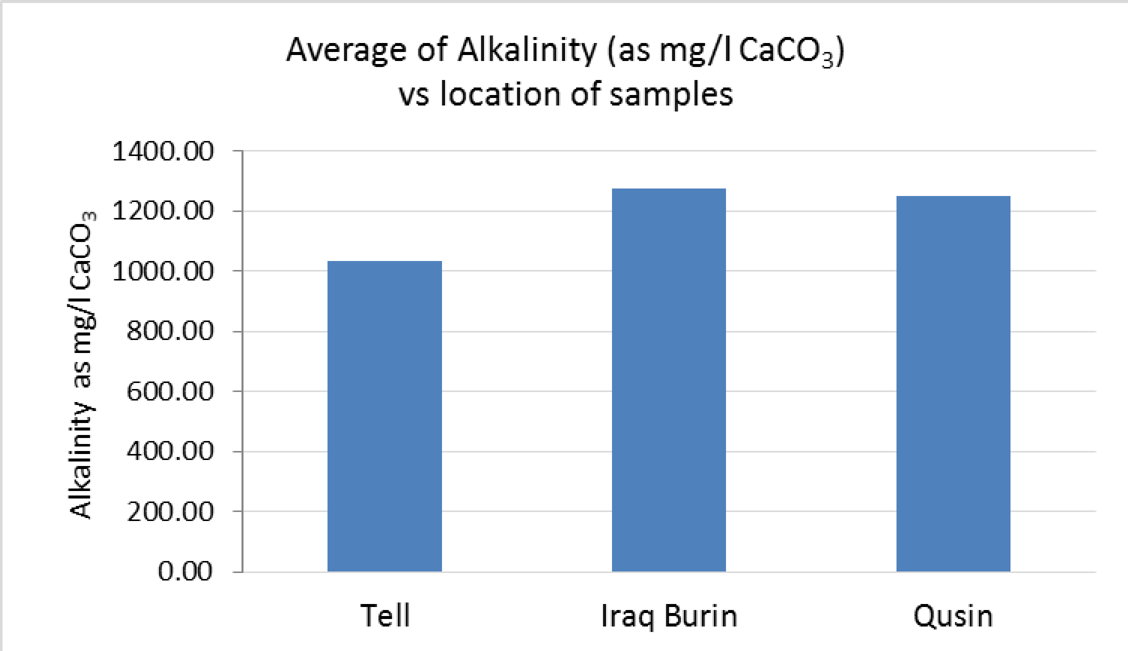


Figure 4.10: Alkalinity Average values for septage analyzed at rural Nablus

4.3.10 TC and FC

Figure 4.11 below shows, the average of the TC and FC per 1 ml of the septage analyzed in this study were (1.95E+07±1.8E+07) and (1.12E+04±8.59E+03) respectively. The high variation in the averages is related to high dilution during the testing processes and the value itself.

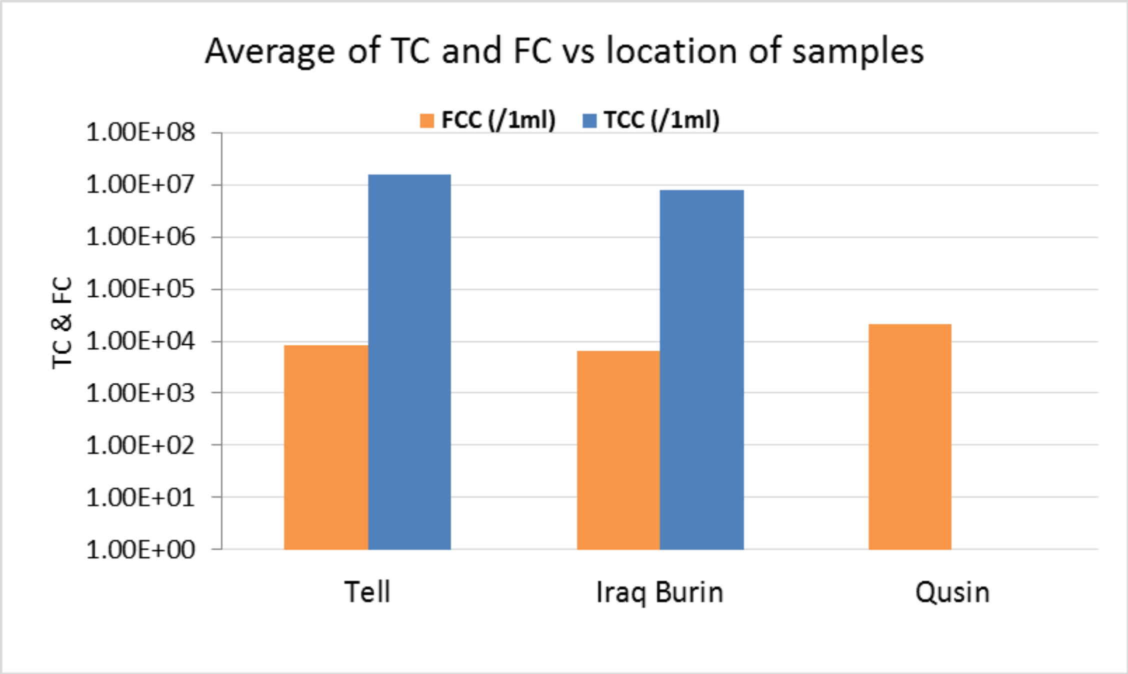


Figure 4.11: TC and FC Average values for septage analyzed at rural Nablus

Chapter Five

Pretreatment of the Fecal Sludge – Results and Discussions

Chapter Five

Pre-treatment of the Fecal Sludge – Results and Discussions

5.1 Case study

The second objective of this study was to enhance the quality of septage by on-site pre-treatment model. To achieve this objective; the following steps were followed.

5.2 Quantification of fecal sludge - Septage

- Assumptions made:
  - All the fecal sludge produced will be sent to the treatment plant.
  - The fecal sludge was not diluted by water during desludging.
  - The average household Size is 5.1 (PCBS, 2019).
  - The peak factor for design of septage TP is 2.0

The sludge production method was used to estimate the quantity of sludge that would be generated.

5.2.2 Quantification of domestic septage

The most accurate method for estimating future septage quantities is by reviewing historical data from local haulers. They should have records of the quantity of septage pumped over a specific period.

For this case study, as we have three areas two of them are close to each other (Tell and ‘Iraq Burin), there is a need to two pretreatment plants to treat the characterized collected septage. In this study, the proposed model is for Tell and ‘Iraq Burin. The same methodology could be followed for Qusin area septage. This model is applicable and expandable. The quantification and the capacity of the TP are:

- Number of households not connected to sewer network = 1,223
- Percent of households which disposed sewage by vacuum truck = 40%
- The annual increase in the percent of households which use of vacuum truck to dispose of the septage = 5%
- Average amount of septage per month produced by households = 12 m^3/month
- Number of years to use this TP as pretreatment plant = 5 years
- The peak factor = 2
- Capacity (m^3/day) = no. houses × % of vacuuming houses × % of expansion of study area × the Average of households septage production × peak factor = 1223×{0.40+(0.05×5)}×12×2 = 19,078.8 m^3/month = 635.96 m^3/day

5.3 Design Septage Characteristics

5.3.1 Untreated septage characteristics

This research characterized the septage in rural Nablus. And at this stage the septage will be treated for the following parameters pH, BOD_5, COD, TS, TSS, VS, VSS, and TN.

Table 5.1 below shows the design values of influent septage characteristics at the proposed septage treatment plant. As shown in the Table (5.1) the 85% Confidence Interval (CI) was obtained for the characterized samples in the study area. And then the maximum value of 85% of CI were taken as a design value for the treatment plant model.

Table 5.1: Design values of parameters for septage treatment plant model (Rural Nablus)

Parameter	85% CI	Design value
pH	7.74 ± 0.13	7.87
BOD_5	371.43± 84.99	456.42
COD	1086.86± 133.69	1220.55
TS	1620.54± 130.94	1751.47
TSS	328.25± 57.66	385.91
TDS	1001.08± 83.19	1084.27
VS	965.50± 171.86	1026.57
VSS	203.50±90.09	293.59
TN	178.33± 24.53	202.87

N*: number of samples analyzed.

All units are (mg/l), except pH (-) and which specified

5.3.2 Treated septage characteristics

The effluent of the septage treatment plant should be less than the upper limit of treated wastewater based on the Palestinian specifications, see Table 5.2.

Palestinian Standards for treated wastewater for multiple uses are shown in Table B.1 in Appendix B. The table shows the maximum limit of specific parameters for treated wastewater to be used among each activity. (MoEA, 2015).

Table 5.2: Classification of treated water according to its quality (MoEA, 2015)

Maximum limits of chemical and biological properties (mg / l) unless otherwise indicated	Treated water quality			
	High quality (A)	Good quality (B)	Medium quality (C)	Poor quality (D)
pH	6 - 9	6 - 9	6 - 9	6 - 9
EC (ms/cm)	-	-	-	-
BOD_5	20	20	40	60
COD	50	50	100	150
TS	-	-	-	-
TSS	30	30	50	90
TDS	1200	1500	1500	1500
VS	-	-	-	-
TN	30	30	45	60
PO4-T	-	-	-	-
PO4-P	30	30	30	30
FC (colony/100ml)	200	1000	1000	1000

5.4 Software design

Many programs deal with wastewater treatment plant modeling. GPS-X 7.0 program was chosen as it is free and capable to achieve the objectives of this research. GPS-X 7.0 can deal with two sides: septage and sludge treatment.

Advanced SBR model is a variant of ASP (activated sludge process). All the biological water treatment phases take place in a single tank. This differs from the conventional activated sludge process flow, which requires separate reservoirs for aeration and sedimentation of the treated water. These water treatment plants are made up of several tanks, which are equipped with electromechanical equipment such as pumps, mechanical and gravity filters, air diffusers, aerators, mixers and overhead rooms equipped with blowers, drying and packing sludge equipment, chemical dephosphating, disinfection and control sets etc. (Singureanu and Alexandru, 2019).

5.4.1 Treatment plant modeling steps

The following steps were followed to achieve the third objective of this study.

- Determining model goals.
- Building the TP model, which include building the scheme, data entry, validate the model, and model time management.

- Optimizing the appropriate model and run the model to see the results.

5.4.1.1 Determining model goals.

Septage TP modeling is an essential tool for the process of engineering design of modern water resource. It is very important for recovery facilities that experience increasing demands on wastewater effluent quality. Modeling of septage TP is the second objective of this study to enhance the quality of collected septage in order to make it environmentally friendly to be used for specific purposes in an appropriate way (Hegazy, 2017).

5.4.1.2Building the TP model

Modeling of on-site WWTP using GPS-X 7.0 program required input parameters as initial conditions.

Initial conditions parameters are the concentration of the constituents in the treatment plant before the period of modeling.

Period of simulation can be either short such as a few days or longer to achieve dynamic simulation. GPS-X 7.0 is one of the simulation programs which can deal with both cases. When short term simulation is used in activated sludge model the results from the model will be heavily dependent on the initial conditions that were used.

This research focused on the long-term simulation because the effects of the initial conditions were ignored. Also, during this long period the model may receive a shock of high or low concentration septage or WW, this shock will be directly considered and the behavior of the TP will be presented in the simulation figures.

Basically, the SBR system is a set of filling and evacuation tanks. Each tank in the SBR system is filled over a period of time and then functions as a discontinuous reactor. After the desired treatment, the mixed liquid is allowed to settle and the clarified supernatant is then discharged from the reservoir. The cycle for each tank in a typical SBR is divided into five distinct periods: filling, reaction, sedimentation or settling, evacuation or flushing, and idle as shown in Figure 5.1

An important purpose of this research is to simulate the on-site SBR processes for septage treatment at the rural area of Nablus using the GPS-X 7.0 simulator. Figure 5.2 presents on-site septage TP scheme represented by GPS-X 7.0 simulator, which comprises: the fine bar screen, a Grit removal, SBR, wastewater outlet pipe and excess sludge dewatering and outlet pipe.

As there are several models proposed by the International Water Association (IWA), describing the biological process in the activated sludge plant (ASM1, ASM2, ASM3) (Serdarevic and Dzubur, 2016). The ASM1, ASM2 and ASM3 models incorporate carbon oxidation, nitrification and denitrification, and ASM2 also describes the biological and chemical phosphorus removal. The ASM models have been “updated” over the time and most of the problems identified in the earlier versions have been corrected. The models are based on COD units (use chemical oxygen demand to define organic pollution) and ASM3 has a Total Organic Carbon (TOC) based version as well. In this study, ASM3 process modeling was used as the characterized septage fit with ASM3 specific limitations such as temperature within (8 - 23) C^0, ph in the range of (6.5 – 8.3) (Heryk Melcer et al, 2003).

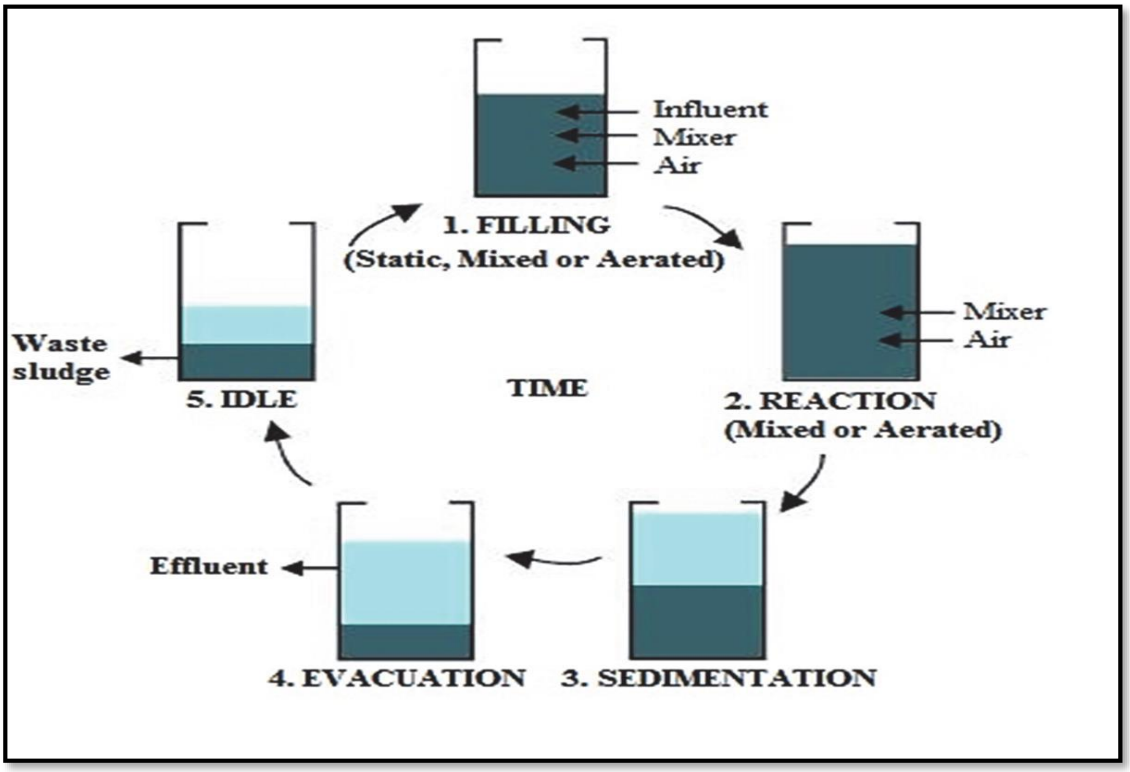


Figure 5.1: SBR operation for each tank in a single cycle with the five distinct periods (Singureanu and Alexandru, 2019)

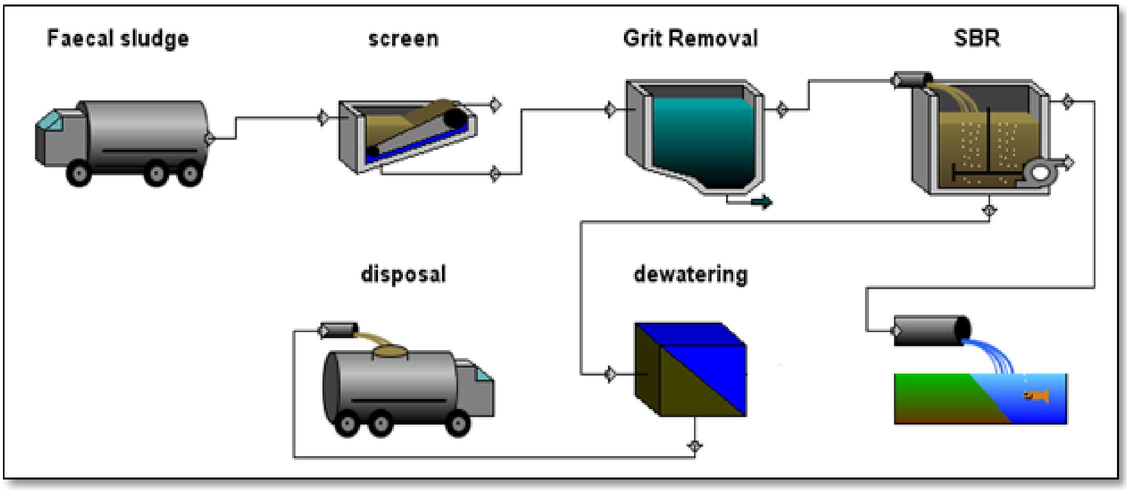


Figure 5.2: Designed wastewater treatment plant unit scheme for septage pretreatment represented by GPS-X7.0 simulator

5.4.1.2.1 Data entry

The mathematical model of a septage TP usually depends on analyzing a group of mathematical equations that represent the biological and chemical reactions, physical properties that can affect the treatment process, and the reactions' rate constants. The existence of modeling software can help to facilitate the solving of these equations without long substitution analysis process.

A septage TP usually consists of a set of activated sludge tanks, combined with a sedimentation tank, with a range of electron acceptor conditions occurring in the tanks. Depending on the concentrations of Dissolved Oxygen (DO) and nitrate present in the tanks, aerobic (oxygen present), anoxic (nitrate present, no oxygen) or anaerobic (no oxygen, no nitrate) tanks can be distinguished (Krist et al, 2004).

The determined influent characteristics that pass through the model are shown in Figure 5.3 and 5.4. The concentration values of the influent were used to investigate the efficiency of the SBR model on dealing with high contaminated septage to meet the specifications requirement after the treatment processes.

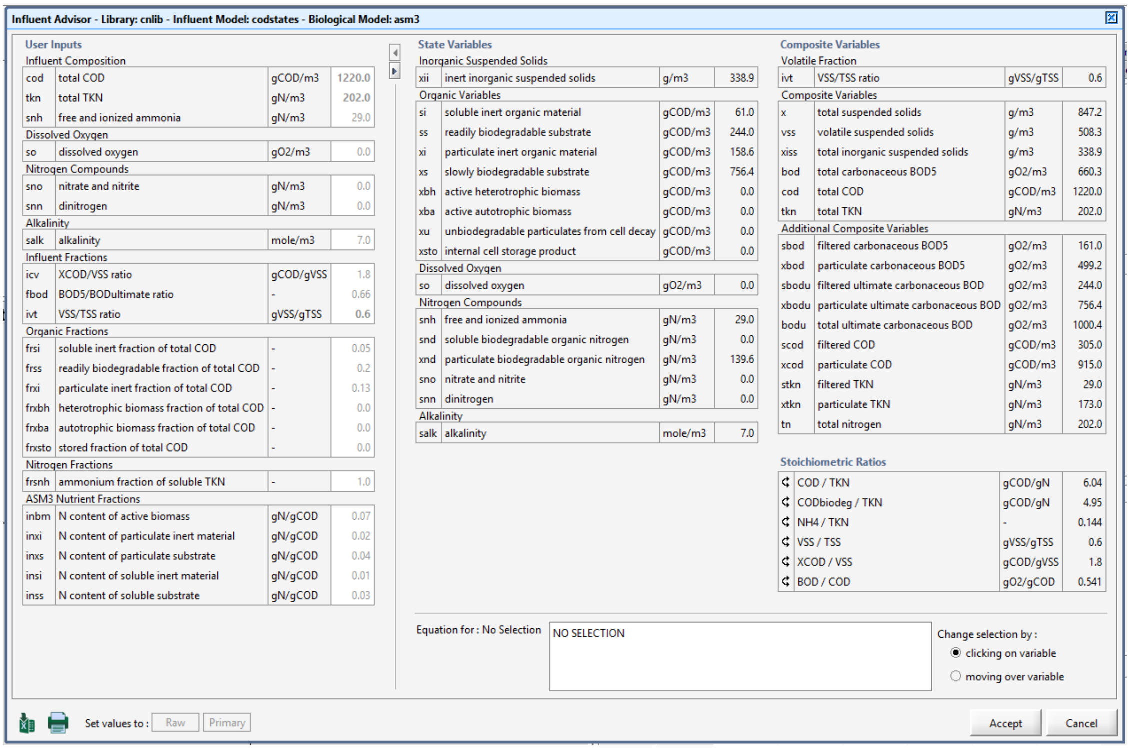


Figure 5.3: Influent Characteristics of Septage treatment plant model designed by GPS-X7.0 simulator

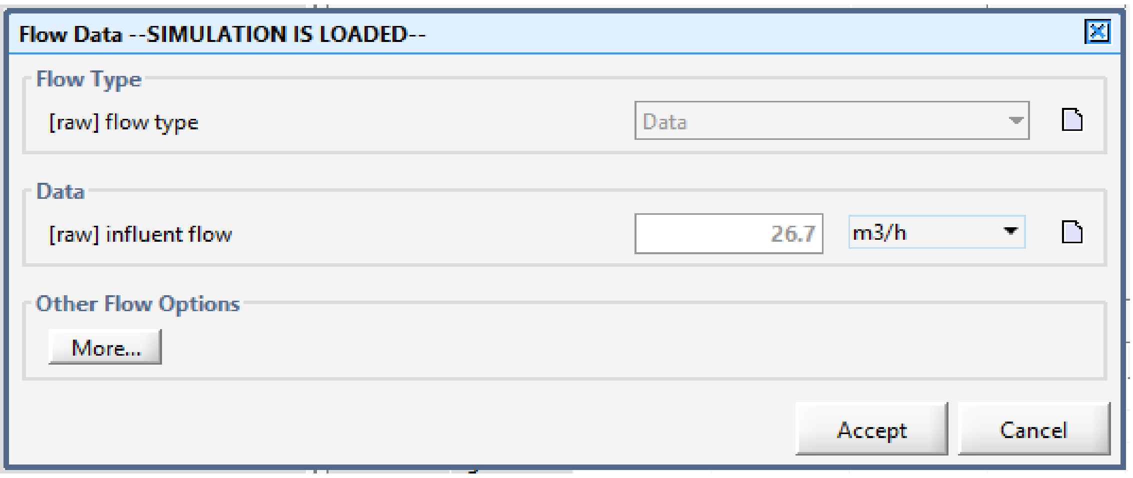


Figure 5.4: Influent flow of Septage treatment plant model designed by GPS-X 7.0 simulator

5.4.1.3 Optimizing the appropriate model and run the model to see the results.

This research focuses on investigating the action of anoxic/aerobic phases of treatment Model composed of two SBR units in parallel in order to improve the treatment efficiency, the scheme of the optimized model is shown in the Figure 5.5 below. The volume of each SBR is 200 m^3 with surface area of $40m^2$.

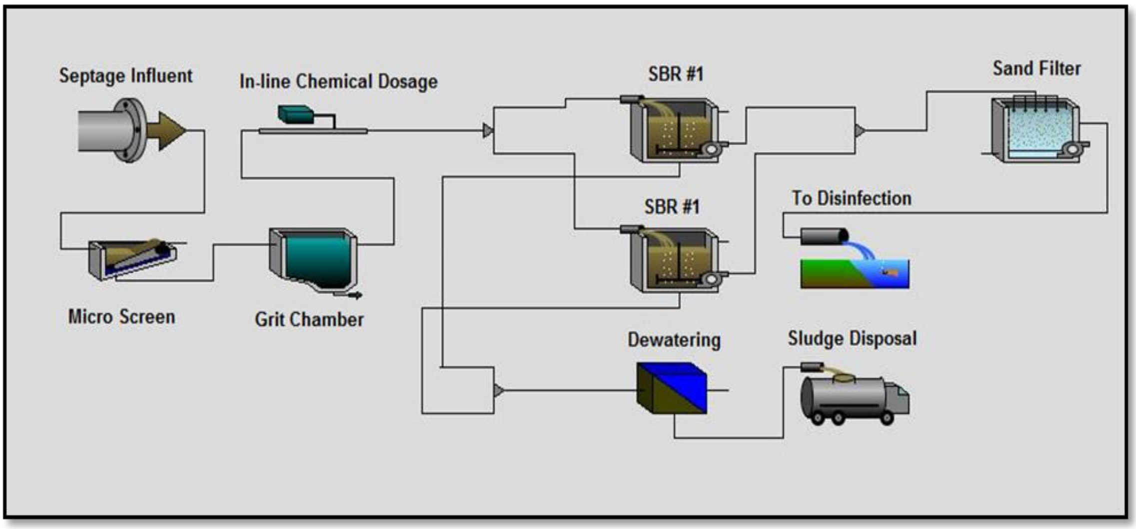


Figure 5.5: Septage treatment plant model scheme designed by GPS-X 7.0 simulator

The Initial conditions for each SBR used in this TP as follows:

- The initial volume was 115 m^3 as shown in the Figure 5.6.

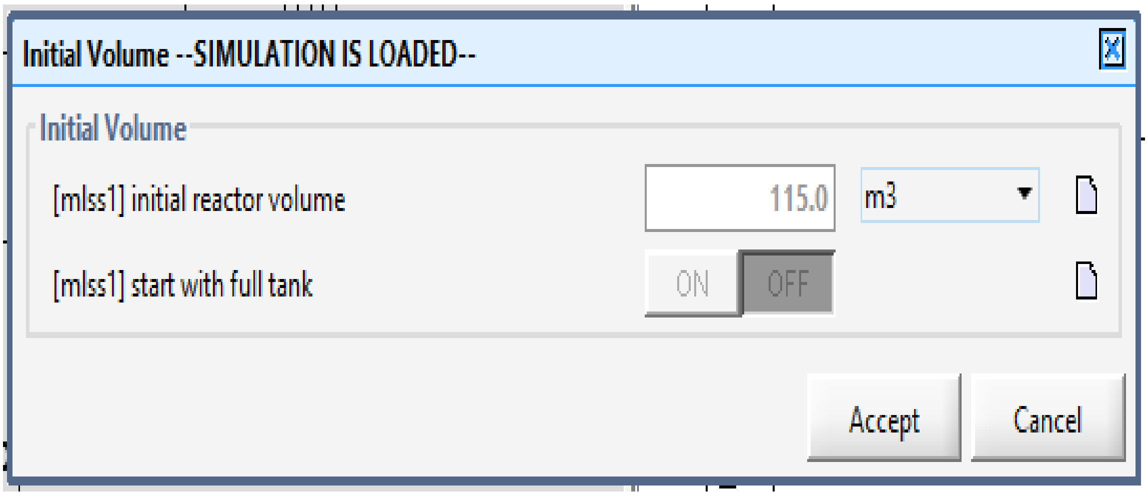
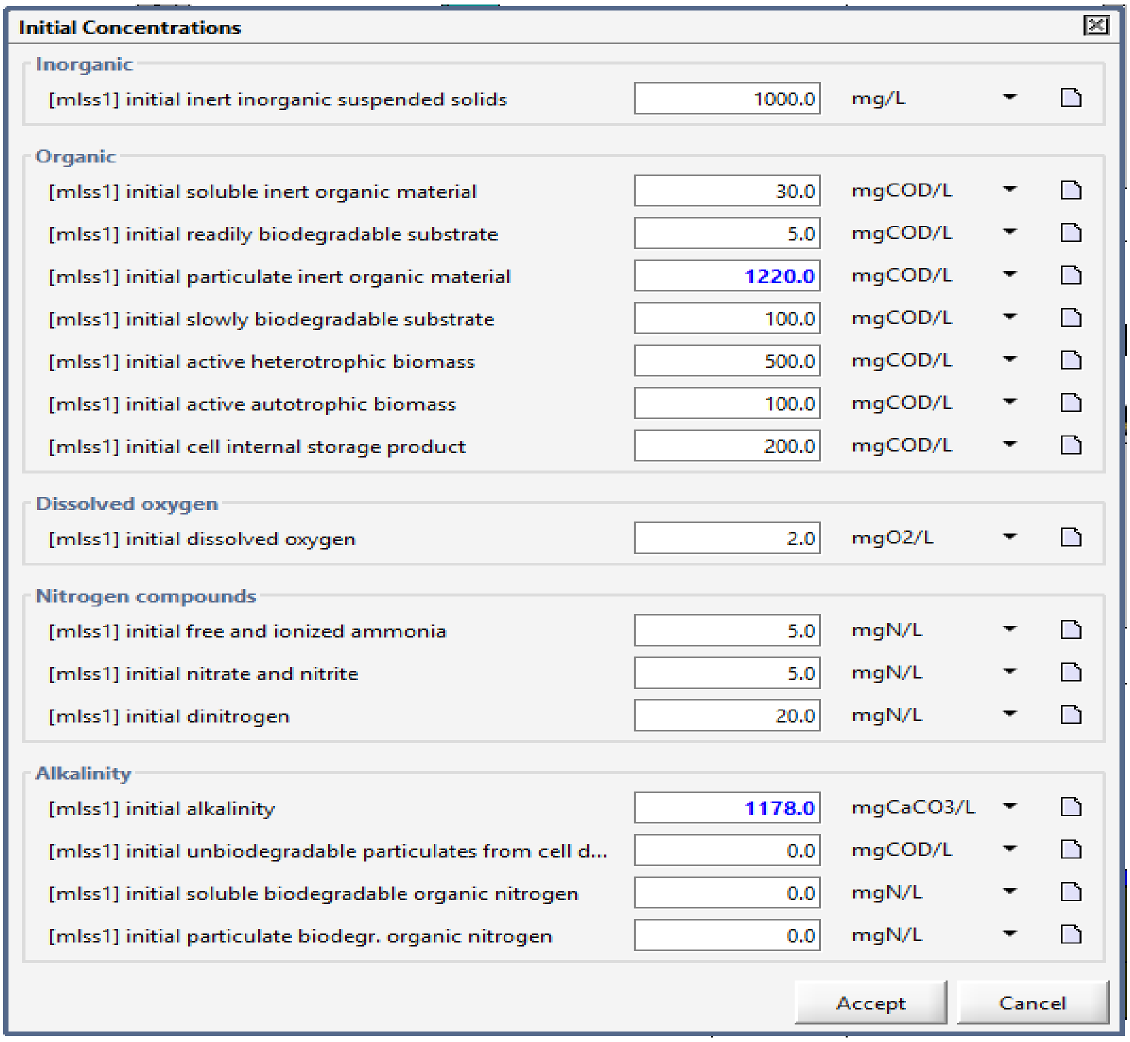


Figure 5.6: Initial Volume of SBR tank for septage treatment designed by GPS-X 7.0 simulator

- The filled initial materials were considered to have specific concentrations as shown in the Figure 5.7, which is similar to the influent characteristics.


Initial Concentrations

Inorganic

[mlss1] initial inert inorganic suspended solids	1000.0	mg/L

Organic

[mlss1] initial soluble inert organic material	30.0	mgCOD/L
[mlss1] initial readily biodegradable substrate	5.0	mgCOD/L
[mlss1] initial particulate inert organic material	1220.0	mgCOD/L
[mlss1] initial slowly biodegradable substrate	100.0	mgCOD/L
[mlss1] initial active heterotrophic biomass	500.0	mgCOD/L
[mlss1] initial active autotrophic biomass	100.0	mgCOD/L
[mlss1] initial cell internal storage product	200.0	mgCOD/L

Dissolved oxygen

[mlss1] initial dissolved oxygen	2.0	mgO2/L

Nitrogen compounds

[mlss1] initial free and ionized ammonia	5.0	mgN/L
[mlss1] initial nitrate and nitrite	5.0	mgN/L
[mlss1] initial dinitrogen	20.0	mgN/L

Alkalinity

[mlss1] initial alkalinity	1178.0	mgCaCO3/L
[mlss1] initial unbiodegradable particulates from cell d...	0.0	mgCOD/L
[mlss1] initial soluble biodegradable organic nitrogen	0.0	mgN/L
[mlss1] initial particulate biodegr. organic nitrogen	0.0	mgN/L

Accept Cancel

Figure 5.7: Initial concentrations of SBR tank materials for septage treatment designed by GPS-X 7.0 simulator

These initial conditions ensure that the high shocked will be absorbed and high removal efficiency will be obtained.

The proposed TP consisted of two in parallel SBR's. The first one will be filled and start its operation cycle 3 hours before the other SBR. Each cycle will take a round 3 hours by one-fourth of daily designed volume (160.2 m^3) for both. The percent of cycle time among the SPR units are shown in Table 5.3 below.

Table 5.3: Percent of phases cycle time of SBR by GPS-X 7.0

Phase	Time
Filling	3.0 hr
React (Aeration)	1.5 hr
Settling	0.75 hr
Decanting	0.5 hr
Idle	0.25 hr

The research objective was to study the efficiency of the TP model using SBR technology. The specifications of the run shown in Table 5.4. The operation variables of the two SBR reactors were the same because we considered the investigation of the performance of the two SBR reactors are done under similar working conditions for both SBR units.

Table 5.4: The SBR model run specifications using GPS-X 7.0

Description	Unit	Value
Simulation Period	Day	60
Communication Interval	Min.	5
Analyze type	-	Steady State
Liquid Temperature	C^0	20
Modeling type	-	COD STATE
Surface Elevation	AMSL (m)	600

After modeling the influent flow for the proposed treatment plant, the effluent characteristics are illustrated in Table 5.5. The Palestinian regulations for the treated WW are also shown in the same table.

Table 5.5: Effluent characteristics of septage TP using GPS-X 7.0 vs. Pal. Treated WW type-C limits

Parameter	Influent value	Effluent Value	Palestinian Regulations (Type C) (MoEA, 2015)	Efficiency %
BOD_5	456.42	7.91	40	98.3%
COD	1220.55	73.93	100	93.9%
TS	1751.47	29.27	-	98.3%
TSS	385.91	6.45	50	98.3%
VS	1026.57	15.12	-	98.5%
VSS	293.59	4.32	-	98.5%
TN	202.87	44.28	45	78.2%

The formula which was used to determine the removal efficiency is:

$$\text{Efficiency} = [(C_{inf} - C_{eff})/C_{inf}] \times 100\%$$

Where:

C_{inf}: Influent concentration

C_{eff}: Effluent concentration

The results showed that, the TP had a 98% removal efficiency for BOD and 94% for COD. Moreover, the removal efficiency for SS and TN were 98% and 78% respectively. All the affluent parameters fitted with Palestinian regulations and limits for treated WW for type C. Figure 5.8 and 5.9 show the results of COD, BOD_5, and TN in mg/l for the output of the model. Also, they show that the process took 27 days until the sludge activated and the process started to run regularly.

Figure 5.10 shows the SBR cycle during the process of treatment, it is clear that there were 4 cycles per day and each cycle had filling, decant, Idle and volume (react and settling).

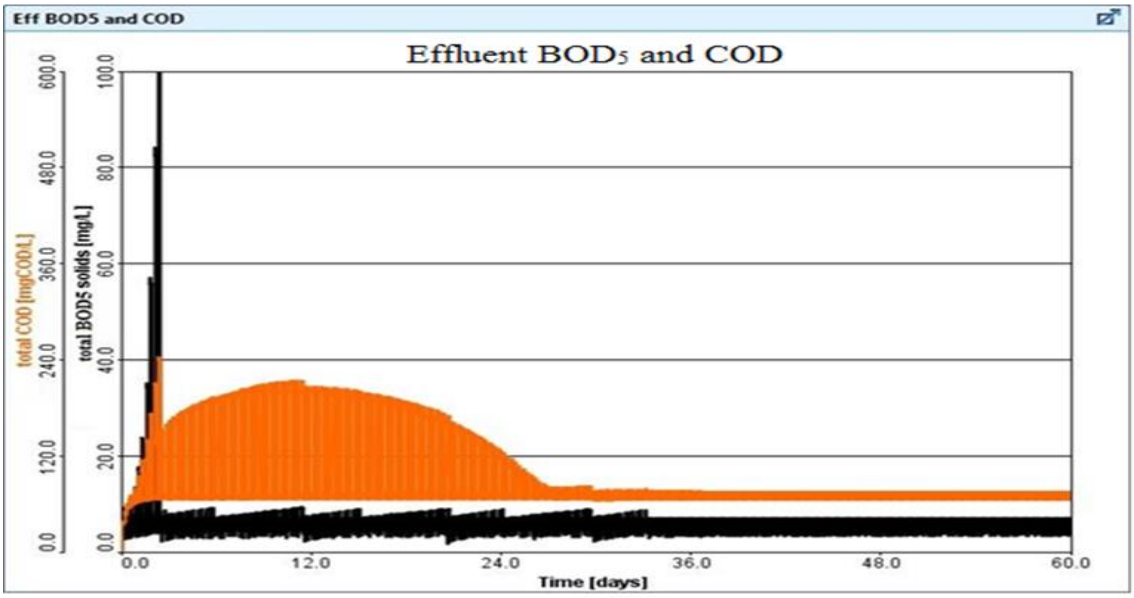


Figure 5.8: SBR effluent BOD_5 and COD parameters of septage treatment designed by GPS-X 7.0 simulator

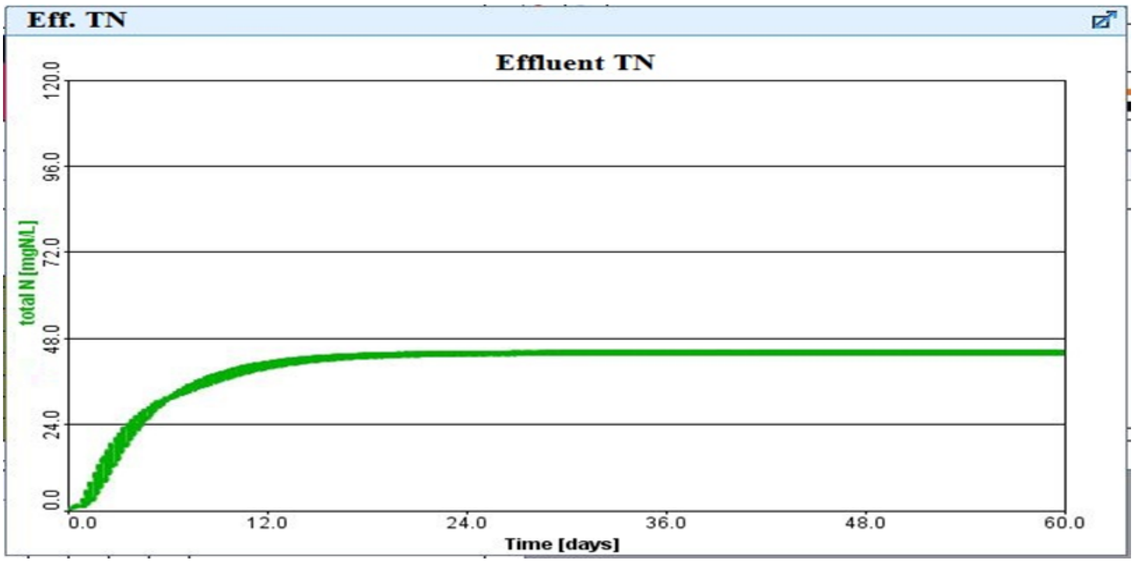


Figure 5.9: SBR effluent TN parameter of septage treatment designed by GPS-X 7.0 simulator

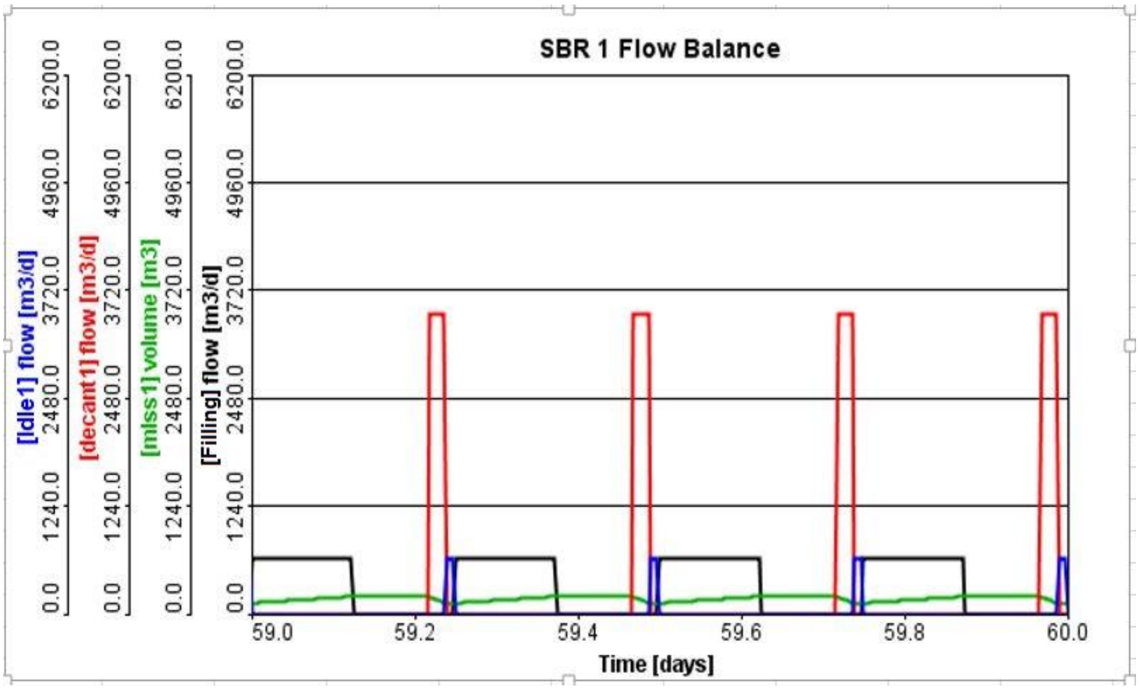


Figure 5.10: SBR flow balance for septage treatment designed by GPS-X 7.0 simulator

Figure 5.11 below shows the details of the influent and the effluent of the treated septage through the sand filter. The removal efficiency of this equipment was 80% for TSS, 65% for BOD_5, and 27% for COD.

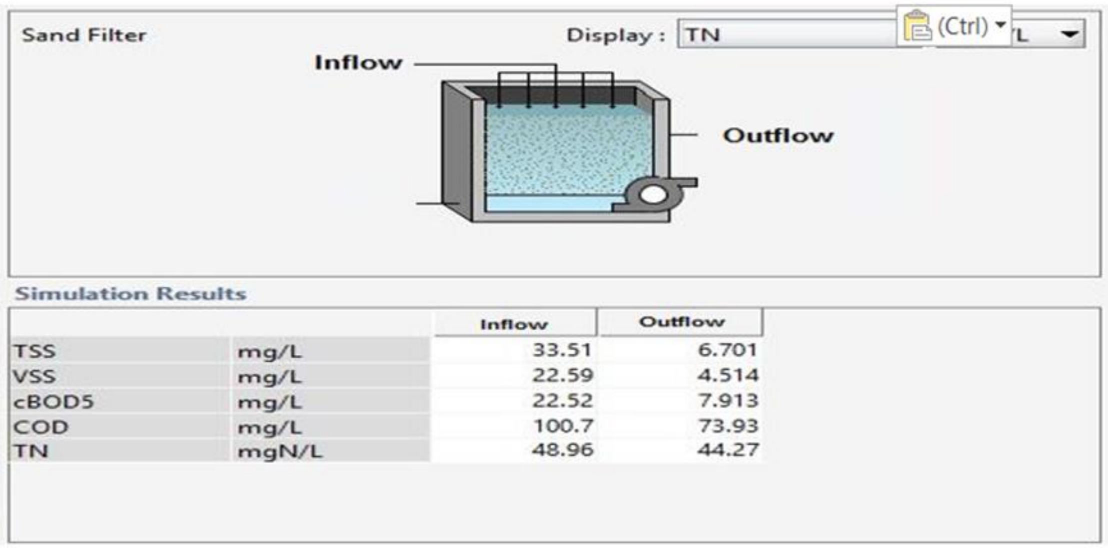


Figure 5.11: Sand filter operation for septage treatment designed by GPS-X 7.0 simulator

5.5 Treatment Plant Estimated Cost Breakdown

The construction and operation of a wastewater treatment plant is an economic activity, specific in any case. Several resources are required in order to achieve an increase in services, within a definite time margin; fact that will result in meeting the population needs.

A sophisticated examination of the cost elements that derive from the construction and operation of a WWTP is consequently required. The principal cost components that determine the total cost of a WWTP depending on the daily flow rate of septage, as well as the system of treatment, the costs of land, design, construction, operation and maintenance. The main elements of analysis are the direct and indirect expenditure of the economic resources such as the use of land, materials and instruments, man-hours of design and construction.

The cost estimation breakdown for the modeled TP is as follow:

1) The cost of land: the cost of land required for the purpose of serving the facilities depends on the required surface and the unit price of the land surface in the specific area of the facility. In our case, around 750 m^2 required for such plant. And the unit price is around 21 USD$/$m^2$ in the selected area; as this area is already classified as agricultural area. The total cost of the land is updated for the period of time as a construction take place.

2) The construction cost: The cost of study is mainly a function of the cost estimate for the construction of the treatment plant, the size of the plant, the type of soil and the topography of the facility's area, the distances for the transportation of materials. In this case study, the construction cost defined as civil works and the cost of the arrangement of the space, roads, etc. as far as conventional systems are concerned, the percentage of the construction cost of the building works of the main installation makes up 65%, the main network cost makes up 12.5%, and the cost of the arrangement of the space makes up 22.5%. the total estimated cost for the civil works for 1 HH around to 35 USD$.

3) The material costs: the term material corresponds to the various parts of the WWTP mechanical equipment and control panel for the operation steps. In our case study, the equipment and control panel costs are around 35,000 USD$.

4) The Energy cost: the financial cost of the electric power construction of the WWTP is a function of the quantity of electric power consumed for the purpose of the WWTP's operation. In this case study, the estimated daily average electric consumption is a round 1.8 USD$.

5) The operation and maintenance cost: The core individual elements of the maintenance and operation cost are the salaries and wages cost, and the the spare parts expenditure. In this case study, the operation

and maintenance cost depend on the performance and working hours. The spare parts anr available in the markets and the useful life of the installed material is a round 10 years. So, this item to be identified when operation and maintenance take place. The energy cost was extracted from the O&M cost.

Chapter Six

Conclusion, and Recommendations

Chapter six

Conclusion and Recommendations

6.1: Conclusions

This study aimed to characterize the septage, fresh feces and urine in three villages in the rural area of Nablus governorate, where the septage was disposed in open area (such as agricultural lands) by vacuum pumps. The other objective of this study was to make an evaluation of the performance of SBR model dealing with Septage characterized by high organic loadings. The study findings revealed the following;

- Almost all values of septage parameters in rural Nablus were within the values of EPA and USA septage parameters except BOD and COD as they are less than the ranges.

- The values of septage parameters in EPA were higher than those of rural areas in Nablus. This could be due to variation in septic tank design and pumping out intervals between the study area and The United. In addition to the difference in soil profile from one place to another. Moreover, the lifestyle and hygiene approaches in Palestine are different from other countries, where soiled toilet papers are partly discharged, and water is used for hygienic cleaning purposes. And the source of septage in rural areas is from un-sewered rural dwellings, where short hydraulic retention time prevailed in most cesspits leading to weak anaerobic transformation processes

- The rural Nablus septage characteristics were higher than the municipal wastewater received to NWWTP. Also the septage parameters were higher than the design value in NWWTP. So as expected that septage need an independent treatment facility.

- The parameters of Turbidity, TN, PO4-T, TS, VS, TSS, VSS, Alkalinity, and FC had the highest values for septage in Qusin village and lowest in Tell village. Mainly due to behavior of people in households, the soil context, cesspit criteria, and frequency of emptying.

- Variation in the chemical and physical composition of feces and urine was widespread throughout the study. This means that technology developments must be robust and flexible in order to deal with this uncertainty.

- The determined time intervals between cleanings of cesspits in rural area depended on the water consumption, soil index, and capacity of cesspits. In this study almost all of the sampled cesspits were cleaned once or twice per month.

- Heavy metals concentration in the rural septage were within the acceptable rang according to the previous studies, EPA and USA septage specifications, and the Fe, Aland Zn had the highest concentration. Iraq Burin had the highest values for Fe and Al while Qusin had the lowest. In contrast Tell village had the highest value for Zn. These parameters depend directly on the soil index for each location.

- Septage content of the heavy metals were not in compliance with heavy metals concentration limits according to the Palestinian regulations for wadi disposal and effluent reuse in agriculture. This entails that septage disposal in wadi and agricultural fields was not safe.

- The removal efficiencies of COD, BOD_5, TSS and TKN in the proposed TP model were acceptable according to the process guide lines that reached to 94%, 98%, 98%, and 78% respectively. And the effluent from run are within with the Palestinian limitation's of 2017 regulations for type C. Which made the treated water suitable for irrigation of Almond, Olive, Citrus and Forest trees. Also, for Industrial crops, grains, Dry feed. Moreover, and the most important it can feed the aquifer by filtration.

6.2: Recommendations

The following recommendations will be requested for any future developing of this study, in order to build on the achieved results:

- Increasing the proportion of sludge transported to the treatment facilities should be the immediate priority. This will require better fecal sludge management, starting with improved record keeping, and enforcement of legislation prohibiting indiscriminate dumping of fecal sludge.

- In other to gain a better overall understanding of the composition of FS, there is the need to conduct further studies in different locations at different seasons.

- Due to the large variability in the results obtained for the characteristics of fecal sludge, it is also recommended that a more specific sampling approach, targeting smaller communities or groups of people.

- It is recommended to implement the modeled TP to examine the operation and efficiency of such TP on the ground and to make calibration for the model if needed.

- Flow which enters the treatment plant should be measured and logged continuously; classification of that flow will be helpful in the simulation process.

- It is Recommended for operation of SBR a fully control of the factors which affect the system efficiency such as temperature, organic loading rates, ph and oxidation reduction potential.

- Further researches should be carried out to improve this technology and enhance the effectivity of such TP.

- In order to benefit from operating of the treatment plant, a feasible strategy for effluent water reuse should be elaborated.

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Appendices

Appendix A: Tables

Table A.1: Characteristics of domestic septage (EPA and ORD, 1994)

Parameter	Min. Concentration	Max. Concentration
Total solids (TS)	1,132	130,475
Total volatile solids (VS)	353	71,402
Total suspended solids (TSS)	310	93,378
Volatile suspended (VS)	95	51,500
Biochemical oxygen demand (BOD)	440	78,600
Chemical oxygen demand (COD)	1,500	703,000
Total Kjeldahl nitrogen (TKN)	66	1,060
Ammonia nitrogen (NO_3-N)	3	116
Total phosphorus (TP)	20	760
Alkalinity ($CaCO_3$)	522	4,190
Grease	208	23,368
pH (-)	1.5	12.6
Total Coliform (TC)	10^7/100 ml	10^9/100 ml
Fecal Coliform (FC)	10^6/100 ml	10^8/100 ml

Note: All data are in mg/l unless otherwise indicated.

Table A.2: Physical and chemical characteristics of septage (EPA, 1994)(EPA, 1993)

Parameter	US			Europe		
	Average	Minimum	Maximum	Average	Minimum	Maximum
TS	34,106	1,132	130,475	33,800	200	123,860
TVS	23,100	353	71,402	31,600	160	67,570
TSS	12,862	310	93,378	45,000	5,000	70,920
BOD_5	6,480	440	78,600	8,343	700	25,000
COD	31,900	1,500	703,000	28,975	1,300	114,870
TKN	588	66	1,060	1,067	150	2,570
NO_3-N	97	3	116	-	-	-
Total-P	210	20	760	155	20	636
Alkalinity	970	522	4,190	-	-	-
Grease	5,600	208	23,368	-	-	-
pH	-	1.5	12.6	-	5.2	9

Values expressed as mg/l, except for pH(-)

Table A.3: Characteristics of septage and sewage sludge (CWRS, 2001)

Compounds	Waste characteristics (mg/l)	
	Septage	Sewage
TSS	15,000	30,000
VSS	10,000	23,000
BOD_5	7,000	18,500
TN	700	750
Total-P	250	480
Grease	8,000	-
pH	6	-

Table A.4:Physical characteristics of Septage discharging at Khirbit As-Samra treatment plant (Halalsheh et al, 2010).

Time	Temperature (C^0)	pH	EC (µS/cm)	Alkalinity as $CaCO_3$ (mg/l)
Winter	18.4 (1.6)	7.27 (0.76)	6,146 (2.386)	1,680 (1,163)
Summer	21.9 (3.3)	7.48 (0.90)	5,626 (2.077)	1,510 (675)

Note: Values shown are means and standard deviations, the latter in parentheses

Table A.5: Organic constituents of the septage discharging at Khirbit As-Samra treatment plant (Halalsheh et al, 2010).

Parameter	COD_{tot} (mg/l)	COD_{ss} (mg/l)	COD_{ss} / COD_{tot} (%)	COD_{dis} (mg/l)	$BOD_{5(tot)}$ (mg/l)	$BOD_{5(sol)}$ (mg/l)
Winter	2,969 (2,939)	2,132 (2,999)	71 (54)	484 (247)	1,532 (1,600)	857 (750)
Summer	6,425 (11,790)	2,869 (10,422)	57 (56)	1,949 (2,699)	2,179 (2,000)	1,344 (750)

Note: Values shown are means and standard deviations, the latter in parentheses. The range here is defined as the difference between the maximum and the minimum values of the data collected.

Table A.6: Average concentrations of lipids, TKN, and ammonia for septage during winter and summer, (Halalsheh et al, 2010).

Parameter	Lipids (mg/l)	TKN (mg/l)	NH_4^+ (mg/l)
Winter	147 (86)	456 (217)	121 (65)
Summer	223 (55)	248 (148)	106 (46)

Note: Values shown are means and standard deviations, the latter in parentheses.

Table A.7:Pathogenic pollutants in the septage discharging at Khirbit As-Samra treatment plant (Halalsheh et al, 2010).

Season	Total Coliforms (MPN/mL)	Fecal Coliforms (MPN/mL)	Nematode Eggs (Eggs/L)
Winter	$1.40*10^{7} – 9.00*10^{10}$	$1.70*10^{5} – 9.00*10^{9}$	80-150
Summer	$1.60*10^{10} – 9.00*10^{13}$	$1.60*10^{10} – 9.00*10^{13}$	80-100

Note: Values shown are minimum and maximum values.

Table A.8: Mean concentrations of heavy metals in the septage discharging at Khirbit As-Samra treatment plant compared with values reported from the USA and the EPA (Halalsheh et al, 2010; EPA, 1993).

Element	Winter (mg/L)	Summer (mg/L)	EPA (mg/L)	US (mg/L)
Zn	1.76	5.33	49.0	27.4
Cu	0.72	0.36	6.4	8.27
Mn	0.64	1.19	5.0	3.97
Cd	ND	0.18	0.71	0.27
Ni	0.04	0.61	0.9	0.75
Fe	53.59	6.19	200	191
Pb	1.00	-	8.4	5.2

Table A.9: Raw sewage and septage characteristics of individual home in Beit Dajan/ Palestine. (Al-Atawneh et al, 2014)

Parameter	Raw		Septage	
	Range	Average	Range	Average
pH	5.8-8.26	7.8 (0.7)	6.66-6.99	6.85 (0.1)
BOD_5	407-512	470.6 (38)	448-527	504 (29)
COD	863-1240	995 (99)	1533-1793	1681 (107)
TN	111-322	199 (54)	308-378	340 (27)
PO_4-P	5.8-15.16	10.45 (2.7)	11.3-16.5	15.11 (2)
TSS	304-4952	1290 (1314)	352-2495	1491 (998)
Temperature	15-28	22 (5)	19.8-25.6	24.4 (2.29)
EC	554-1143	819.4 (1143)	891-1422	1141 (170)
TDS	265-552	383 (87)	427-580	499 (49)

Note: All parameters are in (mg/L), except pH (-), EC (μS/cm) and Temperature (C^0); Sampling period 1/4/2012-25/4/2012, # of raw samples 15, and septage 6 samples; Standard deviations are presented between brackets.

Table A.10: Sewage characteristics of individual home in Beit Dajan and different cities and countriesin Europe, Africa, Asia and Latin America.(Al-Atawneh et al, 2014)

Parameter	Palestine	Palestine	Jordan	Egypt	Turkey	Netherlands	Brazil	Colombia
	Beit Dajan	Al Bireh	Amman	Rural Areas	Istanbul	Bennekom	Campina Grande Pedregal	Cali
COD_t	995	1586	1183	824.9	410	528	727	267
NKj-N	199	104	109	33.8	43	70	44	24
TP	-	13	-	8.9	7.2	18	11	1.3
PO_4^{3-}-P	10.45	12.9	-	3.87	4.5	14	8	-
TSS	1460	736	420	310	210	-	492	215
Temp.	21.8	-	16-24	-	0	20-8	24-26	24.4-25

Note: All parameters are in mg/l except temperature (C^0).

Table A.11: Comparison of raw sewage range between Beit Dajan and Other studies.(Al-Atawneh et al, 2014)

Parameter	Beit Dajan	EPA (2002)	WERF	Crites and Tchobanoglous (1998)
TSS	304-4,952	155-330	22-1,690	100-350
BOD_5	407-512	155-286	112-1,101	110-400
TN	111-322	26-75	139-4,584	20-85
Total Phosphorus	5.8-15.16	6-12	0.2-32	12-20

Note: All parameters are in mg/l

Table A.12: Heavy metals concentration in raw sewage and the cesspit septage of a household in Beit Dajan. (Al-Atawneh et al, 2014)

Parameter	Raw		Septage	
	Average	Range	Average	Range
Cu	0.213 (0.081)	0.047-0.328	0.399 (0.170)	0.172-0.652
Ni	0.000 (0.000)	0.000-.000	0.038 (0.023)	0.0-0.068
Pb	0.007 (0.019)	0.000-0.060	0.18 (0.077)	0.096-.0286
Mn	0.115 (0.059)	0.050-0.242	0.790 (0.386)	0.388-1.454
Fe	1.567 (1.284)	0.460-4.600	23.685 (8.980)	12.48-36.4
Cr	0.005 (0.014)	0.000-0.042	0.055 (0.018)	0.032-0.08
Zn	0.711 (0.947)	0.228-4.080	2.937 (0.962)	1.64-4.26

Note: All parameters are in mg/l, raw sewage: monitored over 15 consecutive days of 24 hours composite samples each (number of samples 15); Septage monitored over the whole filling period of 120 days (number of samples 6)

Table A.13: Domestic septage and raw wastewater characteristics of Beit Dajan cesspit, Albeireh and Ramallah Palestinian cities and USA. (Al-Atawneh et al, 2014)

Parameter\ Location	Beit Dajan village Septage	Al Beireh city, raw wastewater	Ramallah city, raw wastewater	USA Septage
BOD_5	448-527	-	-	440-78600
COD	1533-1793	1586	2180	1500-703000
TN	308-378	104	99.4	66-1060
TS	1836-3767	-	-	1132-130475
TSS	352-2495	736	729	310-93378
TDS	427-580	-	-	353-71402
pH	6.66-6.99	7.2	17.45	1.5-12.6
PO_4-P	11.3-16.5	13	12.8	20-760
EC	891-1422	-	-	-

Note: All parameters are in mg/l, except pH (-) and EC (µS/cm)

Table A.14: Types preservation suitable for different determinants (APHA, 2001)

Determined	Method of Preservative	Holding period (maximum)
BOD	Refrigeration at 4°C	4-24 hours
COD	H_2SO4, 1-2 ml per liter of sample	1-7 days
Oil/grease	H2SO4, 1-2 ml per liter of sample	24 hours
Orthophosphate	Refrigeration at 4°C	24 hours
Total Keldahl nitrogen	Refrigeration at 4°C	Unstable
Nitrate (No_3)	Refrigeration at 4°C	1-7 days
Nitrites (No_2)	Refrigeration at 4°C	24 hours
Ammonia-N	Refrigeration at 4°C	1-7 days
pH		Analyzed as soon as possible, preferably on site
Dissolved solids		24 hours
Total solids		7 days
Turbidity		4-24 hours
Alkalinity	Refrigeration at 4°C	24 hours
Sulfate	Refrigeration at 4°C	7 days
Fecal coliform	Refrigeration at 4°C	6 hours
Total coliform	Refrigeration at 4°C	6 hours

Table A.15: Criteria for selecting treatment options for Nam Dinh, Vietnam(Klingel et al, 2001).

Performance criteria	Process simplicity and reliability criteria	Cost-related criteria
Achievable consistency and biochemical stability of biosolids	O & M requirements	Land requirement
Achievable hygienic quality of biosolids	Skills required for operation and monitoring	Investment costs
Achievable quality of liquid effluent	Risk of failure related to installations or to managerial or procedural measures	Operating and maintenance costs

Table A.16: Overview of design and performance of low cost treatment options. (Strauss, 2002)

Treatment process or option	Design criteria	Treatment goal/achievable removal.		
		Solids-Liquid separation	Organic pollutants in liquid fraction	Parasites (helminth eggs)
Settling / anaerobic pond	300-600g $BOD_5/m^3/d$ HRT: ≥ 15 days SAR*: 0.02 m3/m3 (Rosario) and 0.13 m^3/m^3 (Accra)	BOD5 > 60-70 %	Filtered BOD_5> 50 %	Concentrated in the settled and floating solids
Settling/thickening tank	SAR*: 0.13 m_3/ m^3 of raw sludge HRT: 4 h Surface: 0.006 m^2/cap (Accra)	SS: 60–70 % COD: 30–50 %	To be treated for further improvement in ponds or constructed wetlands	Concentrated in the settled and floating solids
Drying/dewatering beds	SLR*:100-200kgTS/m2/yr S 0.05 m^2/cap (Accra)	SS: 60–80 % COD: 70–90 % N-NH4+ : 40–60 %	To be treated for further improvement in ponds or constructed wetlands	100 % retained on top of the filter media
Planted Drying Beds	≤ 250 kg TS/m2/year SAR*:20cm/year (Bangkok)	SS > 80 % SAR: 20 cm/year	To be treated for further improvement in ponds or constructed wetlands	90 % retained on top of the filter media
Co-composting with solid waste	Mixing ratio of FS/SW 1:2 to 1:3	N/A	N/A	1-2 unit log
Facultative stabilisa-tion ponds	350 kg BOD_5/ha/d (Accra)	Not for this purpose	> 60 % removal of SS	Removed by settlement

***SAR: Solids Accumulation Rate**

Table A17: Palestinian maximum Standard requirements for treated wastewater (MoEA, 2015)

Parameter	Drainage to the seas is 500 meters at least	Feed the aquifer by filtration	Irrigation of dry feed	Irrigation of green fodder	Irrigation of playgrounds, gardens and parks	Irrigation of industrial crops and grains	Irrigation of forest trees and forests	Irrigation of citrus trees	Irrigation of olive trees	Irrigation of almond trees
BOD_5	60	40	60	45	40	60	60	45	45	45
COD	200	150	200	150	150	200	200	150	150	150
TDS	–	1500	1500	1500	1200	1500	1500	1500	1500	1500
TSS	60	50	50	40	30	50	50	40	40	40
pH	9–6	9–6	9–6	9–6	9–6	9–6	9–6	9–6	9–6	9–6
Fat Oil &Greas	10	0	5	5	5	5	5	5	5	5
NO_3 (N)	25	15	50	50	50	50	50	50	50	50
NH_4 (N)	5	10	–	–	50	–	–	–	–	–
O.K.N	10	10	50	50	50	50	50	50	50	50
PO_4 (P)	5	15	30	30	30	30	30	30	30	30
Al	5	1	5	5	5	5	5	5	5	5
Fe	2	2	5	5	5	5	5	5	5	5
Zn	5	5	2	2	2	2	2	2	2	2
Faecal Coliform	50000	1000	1000	1000	200	1000	1000	1000	1000	1000

Note: All parameters are in mg/l, except pH (-), EC (µS/cm), and Feacal Coliform (CFU/100ml).

Table A18: Details of sampled cesspits in Tell village in the study area

Item \ no. of Cesspit sampling	Location 1	Location 2	Location 3
Name of household owner	---	---	---
X	32.202624	32.198893	32.199024
Y	35.212082	35.217164	35.213679
Type, structure	Cesspit (Stone walls without ceiling ground)	Cesspit (Stone walls without ceiling ground)	Cesspit (Stone walls without ceiling ground, cone shape)
Age/no. of years to start cesspits desludging	15 years / after 5 years	5 years / after 1 year	20 years / after 10 years

Item \ no. of Cesspit sampling	Location 1	Location 2	Location 3
Desludging frequency	every 30 days	every 3 days	every 30 days
Depth	4 m	3 m	2.5 m
Surface area	4x3 m	4x4 m	2.5x3 m
Time of vacuum	10:30 AM	11:00 AM	12:00 AM
Time of sample	10:50 AM	11:30 AM	12:30 AM
Time to lab	70 min.	195 min.	135 min.
Average monthly water consumption	18 m3	(30 - 35) m3	(16 - 17) m3
date	30/5/2018	31/5/2018	3/6/2018

Table A19: Details of sampled cesspits in Iraq-Burin village in the study area

Item \ no. of Cesspit sampling	Location 1	Location 2	Location 3
Name of household owner	---	---	---
X	32.203424	32.200801	32.201498
Y	35.239105	35.241859	35.243153
Type, structure	Cesspit (Stone walls without ceiling ground)	Cesspit (Stone walls without ceiling ground)	Cesspit (Stone walls without ceiling ground)
Age/no. of years to start cesspits desludging	30 years / after 22 years	15 years / after 13 years	11 years / after 15 years
Desludging frequency	every 20 days	every 40 days	every 45 days
Depth	2.5 m	2.5 m	2.5 m
Surface area	3x3.5 m	4x4 m	3x3 m
Time of vacuum	10:30 AM	11:00 AM	12:00 AM
Time of sample	10:50 AM	11:30 AM	12:30 AM
Time to lab	20 min.	30 min.	30 min.
Average monthly water consumption	19 m3	16 m3	10 m3
date	11/6/2018	12/6/2018	13/6/2018

Table A20: Details of sampled cesspits in Qusin village in the study area

Item \ no. of Cesspit sampling	Location 1	Location 2	Location 3
Name of household owner	---	---	---
X	32.236029	32.236534	32.236029
Y	35.187891	35.186086	35.187891
Type, structure	Cesspit (Stone walls without ceiling ground)	Cesspit (Stone walls without ceiling ground, cone shape)	Cesspit (Stone walls without ceiling ground)
Age/no. of years to start cesspits desludging	30 years / after 13 years	33 years / after 8 years	33 years / after 8 years
Desludging frequency	every 30 days	every 20 days	every 30 days
Depth	2.5 m	2.5 m	2.5 m
Surface area	3x3.5 m	4x4 m	3x3 m
Time of vacuum	10:30 AM	11:00 AM	12:00 AM
Time of sample	10:50 AM	11:30 AM	12:30 AM
Time to lab	25 min.	60 min.	30 min.
Average monthly water consumption	12 m^3	12 m^3	10 m^3
date	9/7/2018	10/7/2018	11/7/2018

Table A21: Septage characteristics for Till village sampled cesspits

Tell village						
Parameter/ location	Location 1		Location 2		Location 3	
	Sample 1	**Sample 2**	**Sample 1**	**Sample 2**	**Sample 1**	**Sample 2**
pH	8.14	8.13	7.15	7.16	7.40	7.39
EC (ms/cm)	2.48	2.48	2.83	2.81	2.37	2.30
Torpidity (NTU)	370.00	396.00			636.00	819.00
BOD_5	200.00	250.00	300.00	250.00	350.00	300.00
COD	1690.00	1120.00	940.00	665.00	1505.00	1200.00
NH_4 (N)	172.00	166.00	78.00	73.50	126.50	117.00
NO_3 (N)	0.00	0.91	0.00	0.00	0.00	0.00

Tell village						
N-T		255.00	80.00	90.00	140.00	165.00
TKN	254.09	254.09	80.00	90.00	140.00	165.00
PO4-T	8.30	9.30	11.30	10.80	14.20	14.90
PO4-P	7.60	7.70	9.24	9.87	13.65	14.28
TS	1552.00	1286.00	1682.00	1592.00	2117.50	2245.00
TSS	396.00	474.00	162.00	212.00	152.50	252.50
TDS	786.00	922.00	1402.00	1498.00	817.50	812.50
VS	900.00	830.00	1124.00	794.00	1107.50	1117.50
VSS	132.00	138.00			152.50	245.00
VDS	478.00	720.00			620.00	595.00
Fat & Greaze	82.50	109.50	56.50	79.00	49.50	32.50
Alkalinity (as $Caco_3$)	1100.00	1000.00	800.00	950.00	1200.00	1150.00
TCC (/1ml)			3.45E+07	4.83E+07	2.30E+06	5.75E+06
FCC (/1ml)	6.00E+03	3.60E+03	1.00E+04	1.00E+04	1.00E+04	1.00E+04
Ag (mg/l)	0.04	0.12				
Al (mg/l)	4.77	5.82				
Ba^{-1} (mg/l)	0.50	0.67				
Be (mg/l)						
Bi (mg/l)	0.00	0.00				
Cd (mg/l)	0.00	0.00				
Cr (mg/l)	0.10	0.11				
Co (mg/l)	0.01	0.01				
Cs (mg/l)						
Cu (mg/l)	0.31	0.38				
Fe (mg/l)	12.82	18.13				
Ga (mg/l)	0.01	0.01				
In (mg/l)						
Li (mg/l)	0.01	0.01				
Mn (mg/l)	0.29	0.36				
Mo (mg/l)	0.04	0.05				
Ni (mg/l)	0.09	0.10				
Pb (mg/l)	0.07	0.08				
Rb (mg/l)	0.09	0.11				
Sr (mg/l)	0.46	0.59				
V (mg/l)	0.00	0.00				
Zn (mg/l)	4.61	4.11				

Table A22: Septage characteristics for Iraq-Burin village sampled cesspits

Iraq-Burin village						
Parameter/ location	Location 1		Location 2		Location 3	
	Sample 1	**Sample 2**	**Sample 1**	**Sample 2**	**Sample 1**	**Sample 2**
pH	7.59	7.59	7.38	7.37	7.65	7.64
EC (ms/cm)			2.65	2.68		
Torpidity (NTU)			202.00	150.00	210.00	207.00
BOD_5			150.00	150.00		
COD			785.00	540.00	720.00	845.00
NH_4 (N)			133.00	141.00		
NO_3 (N)	0.00	0.00	0.00	0.00	0.00	0.10
N-T			116.00	110.00	202.00	252.00
TKN			116.00	110.00	202.00	251.90
PO_4-T			13.00	15.00	15.20	15.60
PO_4-P			12.40	14.20	14.30	14.90
TS			1032.00	1030.00	1907.50	1897.50
TSS					142.50	172.50
TDS			922.00	1040.00		
VS	1196.00	1244.00	736.00	732.00		
VSS	400.00	300.00				
VDS	796.00	944.00	708.00	704.00		
Fat & Greaze						
Alkalinity (as $Caco_3$)	1400.00	1450.00	1000.00	1000.00	1500.00	1300.00
TCC (/1ml)				1.96E+06	1.50E+07	2.88E+07
FCC (/1ml)			1.00E+04	1.00E+04	1.00E+04	1.00E+04
Ag (mg/l)		0.07				
Al (mg/l)						
Ba^{-1} (mg/l)	0.41	0.44				
Be (mg/l)						
Bi (mg/l)	0.00	0.00				
Cd (mg/l)	0.00	0.00				
Cr (mg/l)	0.10	0.10				
Co (mg/l)	0.01	0.01				
Cs (mg/l)	0.00	0.00				
Cu (mg/l)	0.35	0.38				
Fe (mg/l)	22.01	22.74				
Ga (mg/l)	0.01	0.01				
In (mg/l)						

Iraq-Burin village						
Li (mg/l)	0.02	0.02				
Mn (mg/l)	0.47	0.47				
Mo (mg/l)	0.03	0.03				
Ni (mg/l)	0.08	0.08				
Pb (mg/l)	0.09	0.12				
Rb (mg/l)	0.09	0.09				
Sr (mg/l)	0.36	0.35				
V (mg/l)	0.03	0.03				
Zn (mg/l)	3.95					

Table A23: Septage characteristics for Qusin village sampled cesspits

Qusin village						
Parameter/ location	Location 1		Location 2		Location 3	
	Sample 1	**Sample 2**	**Sample 1**	**Sample 2**	**Sample 1**	**Sample 2**
pH	8.14	8.13	8.09	8.11	8.13	8.10
EC (ms/cm)	2.48	2.48	2.70	2.68	2.62	2.63
Torpidity (NTU)	370.00	396.00	820.00	680.00		
BOD_5	200.00	250.00	600.00	500.00	900.00	800.00
COD	1690.00	1120.00	958.00	1438.00		
NH_4 (N)	172.00	166.00	190.00	180.00	192.00	184.00
NO_3 (N)	0.00	0.91	0.50	0.30	1.10	1.40
N-T		255.00	240.00	235.00		
TKN	254.09	254.09	239.50	234.70		
PO4-T	8.30	9.30				
PO4-P	7.60	7.70	12.90	10.80		
TS	1552.00	1286.00	1740.00	1768.00		
TSS	396.00	474.00	532.50	572.50		
TDS	786.00	922.00	990.00	1115.00		
VS	900.00	830.00	994.00	1012.00		
VSS	132.00	138.00	167.50	230.00		
VDS	478.00	720.00	447.50	500.00	668.00	745.00
Fat & Greaze	82.50	109.50	48.50	52.50	80.50	77.00
Alkalinity (as $Caco_3$)	1100.00	1000.00	1400.00	1500.00		
TCC (/1ml)						
FCC (/1ml)	6.00E+03	3.60E+03	1.90E+04		3.80E+04	
Ag (mg/l)		0.04				
Al (mg/l)	3.93	4.05				

Qusin village						
Ba^{-1} (mg/l)	0.62	0.43				
Be (mg/l)						
Bi (mg/l)						
Cd (mg/l)						
Cr (mg/l)	0.12	0.10				
Co (mg/l)	0.00	0.00				
Cs (mg/l)						
Cu (mg/l)						
Fe (mg/l)	11.88					
Ga (mg/l)	0.01	0.00				
In (mg/l)						
Li (mg/l)						
Mn (mg/l)	0.26					
Mo (mg/l)	0.02	0.01				
Ni (mg/l)	0.10	0.10				
Pb (mg/l)	0.06	0.04				
Rb (mg/l)	0.03	0.04				
Sr (mg/l)	0.38	0.35				
V (mg/l)	0.00	0.00				
Zn (mg/l)		4.83				

Table A24: Stools characteristics

Stools characteristics					
Parameter/ sample	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**
pH	7.86	8.62	6.56	7.49	6.07
EC (µs/cm)	1575.00	2700.00	2670.00	1585.00	1919.00
Torpidity (NTU)	204.00	292.00		595.00	
Temp.	23.40	23.10	22.30	21.50	22.00
BOD_5	700.00	1600.00	1900.00	2500.00	2500.00
COD	1240.00	2840.00	5390.00		
NH_4 (N)	50.00	130.00	90.00	155.00	60.00
NO_3 (N)			0.10	0.20	0.20
N-T	440.00	395.00	350.00	480.00	375.00
TKN	439.10	393.30	349.90	479.80	349.90
PO4-T	15.70	17.10		19.90	13.70
PO4-P	16.40	19.40	23.40		17.10
TS	3096.00	3234.00		3838.00	
TSS		1260.00	3146.67	1650.00	2853.33
TDS	1130.00	1520.00	922.00	990.00	4220.00

Stools characteristics					
VS	566.00	928.00		610.00	
VSS		110.00	86.67	130.00	
VDS	426.00		553.33		493.33
Fat & Greaze	21.50			115.50	64.50
Alkalinity (as Caco3)		1900.00	2000.00	1800.00	
TCC (/1ml)	4.90E+06	3.40E+06	5.90E+06	1.60E+07	3.00E+06
FCC (/1ml)	1.00E+04	1.50E+05	8.00E+04		1.00E+04

Table A25: Urine characteristics

Urine characteristics					
Parameter/sample	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**
pH	5.15	5.35	5.78	5.76	5.79
EC (µs/cm)		13.88	11.12	16.12	7.20
Torpidity (NTU)		5.98	3.24	7.71	3.86
Temp.	21.10	21.20	21.10	20.90	20.90
BOD_5		1936.12	1170.04	1950.00	1150.00
COD		8100.00	4895.00	9300.00	4285.00
NH_4 (N)	157.00	165.00	86.00	108.00	
NO_3 (N)		1.50	1.00	1.50	
N-T		1480.00	1850.00	1080.00	1380.00
TKN		1478.50	1849.00	1078.50	1379.60
PO_4-T	49.20	53.10	56.30	52.50	52.20
PO_4-P	46.90	38.60	48.00	41.00	38.20
TS					
TSS					
TDS					
VS					
VSS					
VDS					
Fat & Greaze					
Alkalinity (as Caco3)	500.00	600.00		600.00	500.00
TCC (/1ml)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FCC (/1ml)	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

Appendix B: Figures

Figure B.1: Samples collection and preservation

Figure B.2: Sampling tool for stools collection

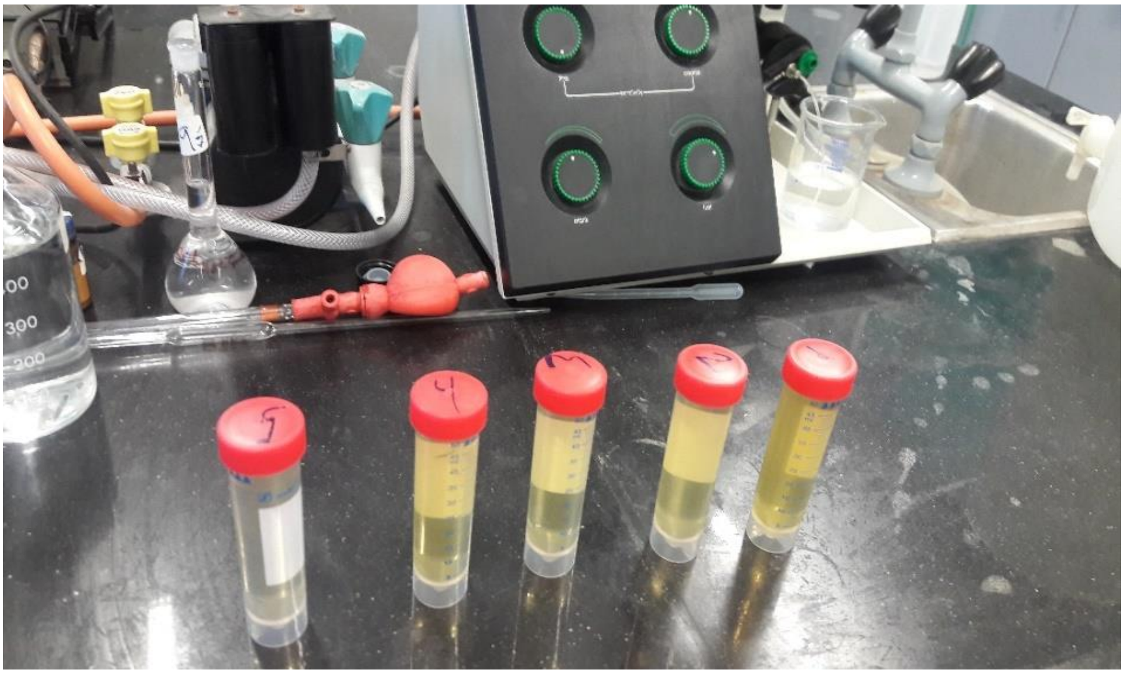

Figure B.3: Urine samples

Figure B.4: Inductively Coupled Plasma Mass Spectrometry (ICP-MS) device

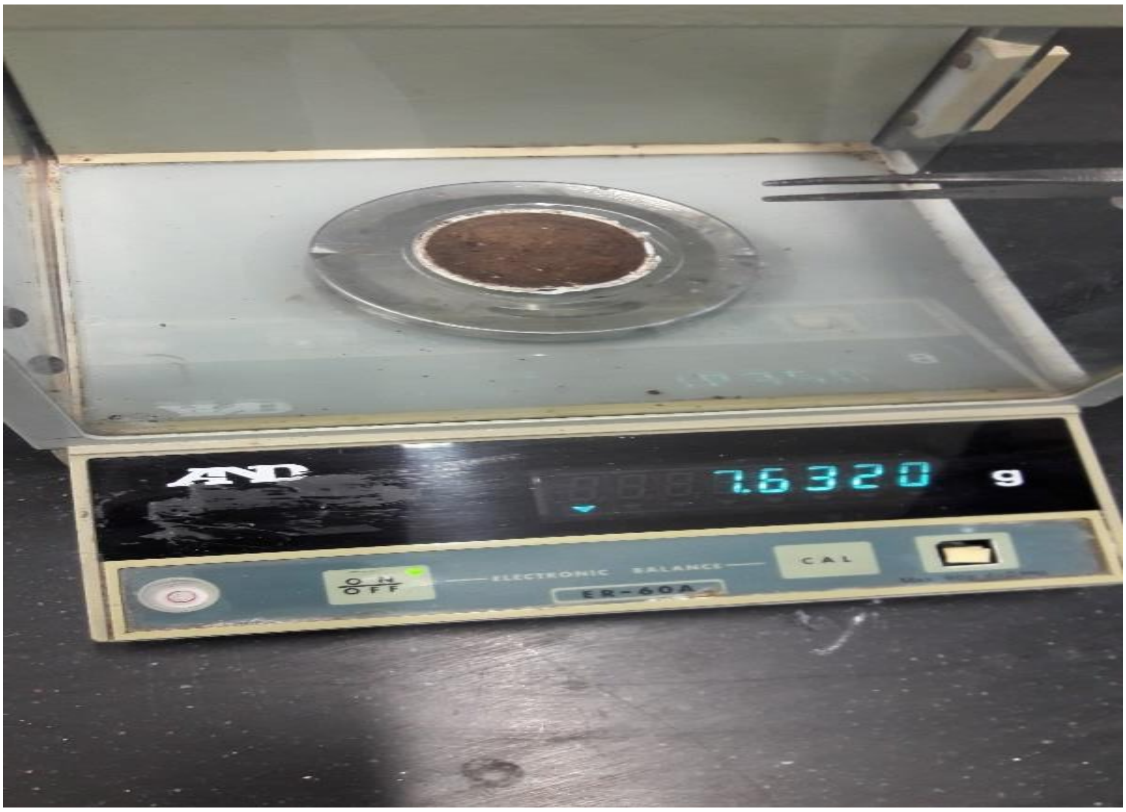

Figure B.5: Weighing the filter at 4-digit balance

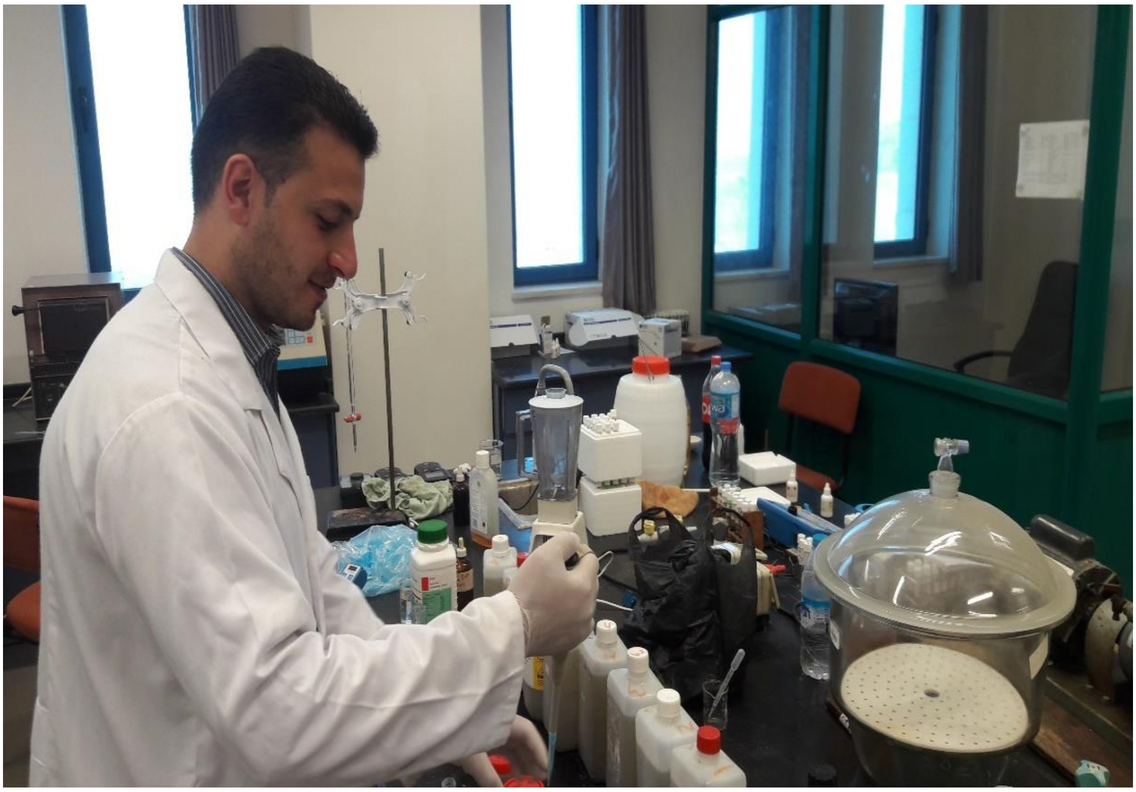

Figure B.6: Using of digital pipette for dilution process

Figure B.7: Counting the no. of colonies for FC and TC test

جامعة النّجاح الوطنيّة

كلية الدراسات العليا

توصيف الحمأة البرازية ومعالجتها في ريف نابلس

إعداد

محمد عبد السلام عبد الرحمن حسين

إشراف

د. عبد الفتاح راسم حسن

قدمت هذه الأطروحة استكمالاً لمتطلبات الحصول على درجة الماجستير في هندسة المياه والبيئة بكليّة الدراسات العليا في جامعة النّجاح الوطنيّة في نابلس، فلسطين.

2020م

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الملخّص

مع استمرار التحضر، أصبحت عملية إدارة أنظمة الصرف الصحي محل أنظار للباحثين. حيث تعد فلسطين واحدة من الدول التي لديها مشاكل جمة في قضية الصرف الصحي، حيث يعتمد معظم السكان على الحفر الامتصاصية للتخلص من المياه العادمة.

تخصصت هذه الدراسة بدراسة تحليلية لمعرفة الخصائص الفيزيائية والكيميائية والحيوية لمياه الصرف الصحي التي يتم جمعها في الحفر الامتصاصية الواقعة في ثلاثة قرى ريفية تابعة لمحافظة نابلس (قوصين وعراق بورين وتل)، كما تم اقتراح نموذج لمعالجة المياه العادمة المذكورة. فقد تم جمع عينات من صهاريج النضح المستخدمة لإفراغ الحفر الامتصاصية الواقعة في منطقة الدراسة. وبعد ذلك تم تحليلها لمعرفة تراكيز وقيم بعض المركبات مثل الرقم الهيدروجيني ومتطلب الأوكسجين الكيميائي COD ومتطلب الأكسجين الكيميائي الحيوي BOD والعكورة والفوسفور والأمونيا والنيتروجين والنترات والقلوية والموصلية والمواد الصلبة والقولونيات الكلية والبرازية والمعادن الثقيلة.

كانت تراكيز العينات التي تم تحليلها ضمن نطاق التراكيز للمياه العادمة المشابهة لها مقارنة في الدول الأخرى حسب ما ورد بالمراجع السابقة، فعلى سبيل المثال؛ في محطة معالجة مياه الصرف الصحي الواقعة غرب نابلس، يتم استقبال المياه العادمة للمعالجة بمعدل متطلب أوكسجين كيميائي حيوي BOD_5 مقداره 573 ملغم/لتر، وفي الوقت نفسه بلغ معدل متطلب الأوكسجين الكيميائي الحيوي BOD_5 للعينات التي تم جمعها وتحليلها خلال هذه الدراسة 371 ملغم / لتر. وأيضا بلغ معدل متطلب الأوكسجين الكيماوي COD في المياه العادمة الداخلة على

محطة التنقية الواقعة غرب نابلس وكذلك في العينات التي جمعها وتحليلها أثناء عمل هذه الدراسة 1174 و1087 ملغم / لتر على التوالي.

إن الغرض الأكثر أهمية من معالجة الشوائب هو تقليل تلوث المياه العادمة لاستعادة مياه الصرف الصحي لإعادة استخدامها. لقد تم عمل المحاكاة واختيار النموذج الأمثل لعملية معالجة مياه الحمأة البرازية في هذه الدراسة لتحسين كفاءة معالجة الحمأة البرازية. تم تصميم هذا النموذج لمعالجة الحمأة البرازية الموصوفة في هذه الدراسة حيث تتميز بتراكيز عالية للمواد العضوية والمواد الصلبة العالقة. فقد تم اختيار هذا النهج لتحسين عملية المعالجة من خلال وحدتين من المفاعلات الحيوية SBR باستخدام محاكي GPS-X 7.0.

فعلى الرغم من عدم وجود مواقع مخصصة للتخلص من الحمأة البرازية للقرى التي شملتها الدراسة؛ فانه يتم إلقاؤها والتخلص منها في المناطق المفتوحة في الأراضي الزراعية بدون معالجة. لذلك تم تصميم هذا النموذج ليحاكي محطة تنقية مبدئية لمعالجة الحمأة البرازية بحيث يضمن مطابقة المياه المعالجة بما يتناغم مع مواصفات المياه العادمة المعالجة من صنف ج حسب اللوائح الفلسطينية لإعادة استخدامها في المجال الزراعي. وكانت القيم التصميمية لهذا النموذج (456، 1221، 386) ملغم/لتر لكل من متطلب الأوكسجين الكيميائي الحيوي BOD_5 ومتطلب الأوكسجين الكيميائي COD والمواد الصلبة العالقة الكلية على التوالي.

استنادًا إلى النتائج، يظهر أن وحدتين من نوع SBR تعمل بكفاءة تصل إلى 98% لإزالة متطلب الأوكسجين الحيوي (BOD)، وكذلك بكفاءة تصل إلى 94٪ لإزالة متطلب الأكسجين الكيميائي (COD)، وبكفاءة تصل إلى 95٪ لتقليل إجمالي المواد الصلبة المعلقة (TSS).

كما تم عمل هذا النموذج لتحديد مؤشرات قياس الأداء بناءً على أهم المعايير التي يمكن أن تكون موثوقة وقابلة للتطبيق في أي محطة لمعالجة الحمأة البرازية. حيث إن النموذج المقترح تمت دراسته بحيث يكون مجديا وقابلا للتطبيق والتشغيل. ومن بعض التوصيات ضرورة اتباع نظام تحكم متكامل في العوامل التي تؤثر على كفاءة النظام المقترح لمعالجة الحمأة البرازية في

منطقة الدراسة وهو نظام SBR، حيث ينبغي إجراء المزيد من البحوث لتنفيذ النظام المقترح ودراسة كفاءته وتحسين هذه التكنولوجيا لتعزيز فعالية مثل هذه الأنظمة الفعالة.

الكلمات المفتاحية: توصيف الحمأة البرازية، محطات معالجة الحمأة البرازية، GPS-X، SBR، نمذجة، الحمأة النشطة.