



BIRZEIT UNIVERSITY
FACULTY OF GRADUATE STUDIES

**Characterization of Household Wastewater Streams as
a Tool for Pollution Control**

By

Haitham Kh. All-Halih

Student Number: 1025231

Supervised by

Dr. Nidal Mahmoud

February, 2008

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Water Science and Environment from the faculty of Graduate Student at Birzeit
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DEDICATION

To My Parents, My Brothers, My Sisters

To my wife Kifaya

To My Supervisor Dr. Nidal Mahmoud

To my friends

And For My Country "Palestine"

With My Love and Respect

Haitham Kh. All-Halih

February, 2008

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Abstract

Palestine, a country of arid or semi arid climate, suffers from water scarcity, which can be a bottleneck in future development of the country. Needless to say, speaking about water shortage is meaningless as long as the available high quality water resources are polluted. On one hand, the disposal of untreated wastewaters is a major threat of ground water pollution, the main source of potable water in Palestine. On the other hand, concentrated human wastes are diluted with large amounts of drinking water in order to transport the wastes from the site of production to the site of treatment/disposal. In many of the Palestinian villages, camps and urban areas, hardly any sanitation infrastructures have been implemented yet. Sensibly, for those places, the separation of black and grey wastewater at the household and the onsite treatment of those waste streams is a rational option.

On-site sanitation has so far not been investigated especially under Palestine condition, where domestic wastewater is characterized by high strength and seasonal temperature fluctuation. Mahmoud et al.(2003) claimed that high COD content of wastewater in Palestine and other countries in the Middle East, like Jordan, is not only due to low water consumption, but also due to people's habits. The reason of the extremely high concentration of pollution in Palestine is under studying.

The main objective of this research was to increase the knowledge on the quantity and quality of the various household wastewater streams. Formulating of innovative concepts for on-site sanitation, that enables the maximization of by products reuse, i.e. wastewater agricultural reuse, energy and nutrients. Those concepts will be basis for alteration of Palestinian household sanitation paradigm to more sustainable practices. Finally, formulating concepts which enable the reduction of the net water use by reusing treated grey water.

The results obtained revealed that domestic wastewater of the five studied houses (H1, H2, H3, H4 and H5) are of high strength classified as a strong domestic type due to high concentration of pollutants like COD, BOD, phosphorous, ammonia and *Fecal coliform*. Toilet and kitchen sink wastewater are the main sources of pollution. The wastewaters at community level in the research area have a typical domestic sewage of COD/BOD₅ ratio of 2.23 (STD (0.14)). The specific production of COD_{tot} is about 1802(316.7) mg/l which represents about 162.1(21.6) g/c.d. Where, the COD specific production for H1, H2, H3, H4, and H5 are 166.1(14.9), 182.5(29.1), 178.6(13.6), 154.6(32) and 128.8(17.6) g/c.d, respectively. The results also reveal that the main fraction of COD in the raw sewage is particulate (suspended and colloidal), which represented 71.7% of the total COD. The percentage of the COD_{dis} was 28.2%. In addition to COD, the wastewater characteristics at community level in the research area showed that BOD values were somewhat in the range of 652-915 with average value of 809(103) mg/l which represents 73.2(8.9) g/c.d. BOD₅ specific production for H1, H2, H3, H4 and H5 are 81.4(5.7) g/c.d, 80.6(9) g/c.d, 76.2(7) g/c.d, 66.2(9.3) g/c.d and 61.4(6.5) g/c.d, respectively. The wastewater characteristics at community level in the research area showed that VFA with average value of 214(35.1) mg/l which represents 7(1.1) g/c.d.

The selected two houses different in the way of clothes wash, one house use traditional way of clothes wash, while the other use the laundry way. The average COD concentration of both samples were 1229(72.8) mg/l with COD/BOD ratio 2.20(0.02), laundry washing of clothes produce more wastewater quantity and more pollution than traditional washing. Average ammonia (NH⁴⁺-N) is about 25(13) mg/l, BOD₅ specific production is about 558(39) mg/l, total PO₄ as P is about 12.6(8.4) mg/l and ortho-phosphate (PO₄³⁻ as P) is about 10.2(7.6) mg/l.

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List of Abbreviations

AVR	Average
AWWTP	Activated wastewater treatment plant
BOD	Biological Oxygen Demand
CEC	Council of European Communities
CFU	Colony forming unit

CO ₂	Carbon dioxide
COD	Chemical Oxygen Demand
COD _{col}	Colloidal COD
COD _{dis}	Dissolved COD
COD _{filt}	Filtered COD
COD _{ss}	Suspended COD
COD _{tot}	Total COD
DESAR	Decentralized Sanitation of Agricultural Reuse
EPA	Environmental Protection Agency
FC	<i>Fecal coliform</i>
g	gram
GC	Gas chromatograph
HE	<i>Helminthes eggs</i>
HRT	Hydraulic retention time (days or hrs)
K	potassium
Kg	Kilogram
L	Liter

List of Abbreviations (continue)

m ³	cubic meter
MAPET	Manual of Pit Latrine Emptying Technology
MCM	million cubic meter
MENA	Middle East and North Africa
mg	milligram
ml	milliliter
mm	millimeter
N	nitrogen
NH ₄ ⁺	ammonia
nm	nanometer
NO ₃ ⁻	nitrate
OWDTS	Onsite Wastewater Differentiable Treatment

	System
P	Phosphorous
PCBS	Palestinian Central Bureau of Statistics
PES	Palestinian Environmental Strategy
PO ₄ ³⁻	Ortho phosphate
PWA	Palestinian Water Authority
SS	Suspended Solids
SSWM	Small Scale Waste Management
STD	Standard deviation
TOC	Total organic carbon

List of Abbreviations (continue)

TSS	Total suspended solid
UASB	Upflow anaerobic sludge blanket
UV	Ultra violet
VFA	Volatile fatty acid
WHO	World Health Organization
WW	Wastewater
WWTP	Wastewater treatment plant

Chapter 1

Introduction

1.1. Background and problem definition

Mahmoud *et al.* (2003) showed that the specific waste production for Ramallah and Al-Bireh cities in terms of COD, N and P are much higher than those the household waste production, source and composition for some countries (Germany, Denmark and Sweden) and Holland (Henze, 1997). The Palestinian specific values are as high as the total (solid and waterborne) specific waste of the European countries and in Ramallah it can even be two times higher. Therefore, Mahmoud *et al.* (2003) suggested that the high COD content of wastewater in Palestine and other countries in the Middle East, like Jordan, is not only due to low water consumption, but also due to people's habits. Discarding the remaining food and used cooking oil in kitchen sinks is believed to play a central role in increasing sewage strength in Palestine.

Henze (1997) showed that the application of 'clean tech cooking' can reduce the COD load of grey water from 55 g COD/c.d to 32 g COD/c.d. However, there is no available knowledge on the characteristics of the various household waste streams in Palestine.

The design of wastewater collection, treatment and disposal systems in developing countries are usually based on assumed or imported parameters from the literatures. Planners and designers, in the absence of local data, tend to adopt classical parameter values from well-known foreign textbooks. The usual result is the over sizing of systems, units and equipment. In some cases, the opposite situation of an under-design can also occur, bringing process failures due to overloading. In both cases, obvious wastage of valuable financial resources occurs. Water from recycling systems should fulfill four criteria: hygienic safety, aesthetics, environmental tolerance and technical and economical feasibility (Nolde *et al.*, 1999).

According to Mahmoud *et al.* (2003), the characteristics of wastewater in the West Bank have not been subjected to good analysis; wastewater management in Palestine had been neglected for decades. It has been addressed as a high priority from perspectives of both environmental protection and resource conservation.

PECDAR (2001) reported that the present situation of wastewater collection and the lack of adequate treatment profound risks to the Palestinians. The resulting pollution poses public health risks and aquifer damage (ARIJ, 2001). Sanitation interventions are highly needed. Therefore, setting up an effective wastewater management system is given the highest priority in rural Palestine according to the Palestinian Environmental Strategy (PES) and was categorized on top of the PES eleven elements defined by Ministry of Environmental Affairs that need immediate action such as introducing of new technologies for small-scale wastewater treatment plants that could be applied in rural areas (MEnA, 1999).

In Palestine, separation of household wastewater into black wastewater and grey wastewater is an emerging process. Household wastewater derives from a number of sources. Wastewater from toilet is termed "black wastewater". It has a high content of solids and contributes a significant amount of nutrients (nitrogen, N and phosphorous, P). Black wastewater can be further separated into faecal materials and urine. Each person on average excretes about 4 Kg N and 0.4 Kg p in urine, and 0.55 Kg N and 0.18 Kg P in faeces per year (UNEP, 2004). In Sweden it has been estimated that the nutrient value of urine from the total population was equivalent to 15-20% of chemical fertilizer use in 1993 (Esrey *et al.*, 1998). This represents a considerable potential resource that is generally underutilized.

The other source of wastewater is grey wastewater. Grey wastewater which represents the major part of domestic sewage flow (60-75%), can be defined as a wastewater generated in household, excluding toilet wastes, and includes wastewater from bathroom sinks, baths, showers, laundry facilities, dishwashers and kitchen sinks (Jefferson *et al.*, 1999; Diaper *et al.*, 2001; Eriksson *et al.*, 2002). The characteristics of grey wastewater depend firstly, on the quality of the water supply, secondly, on the life

style and thirdly, on the activities of people in these houses. The compounds present in grey wastewater vary from source to source, where lifestyles, customs, installations and use of chemical household products will be of importance (Jeffrey and Jefferson, 2001; Eriksson *et al.*, 2002). Grey wastewater reuse on-site and off-site is more feasible as compared to domestic sewage. Wastewater must first be treated to reduce the concentration of suspended solids, organic materials and pathogenic organisms. The latter requirement proves to be the most restrictive in practice, where the World Health Organization (WHO) guidelines for irrigation in 1996 specify the maximum concentration of 1 helminth per liter and 10^3 fecal coliform colonies per 100 ml. A regional standard used for the effluent (see Table 1.1) that must be recommended to have as Palestinian standard.

Table 1.1. Standards for treated effluent in some countries (USEPA, 1992)

Parameter	Jordan	Israel	Palestine*
BOD ₅ (mg/l)	150	35	40
COD(mg/l)	500	-	150
TSS(mg/l)	200	30	50
Coliform(CFU/100ml)	1,000	250	1000

*That use as treated effluent discharge as surface water to Wadis or recharge to groundwater (PWA, 2003)

In Palestine, wastewater that treated can be used for toilet flushing or can be used in irrigation this can be accepted where no hygienic effect for using this water. The reuse of grey wastewater not only represents a sustainable solution, but also reduces the water bill with a reduction of water consumption by 30-35% (Diaper *et al.*, 2001).

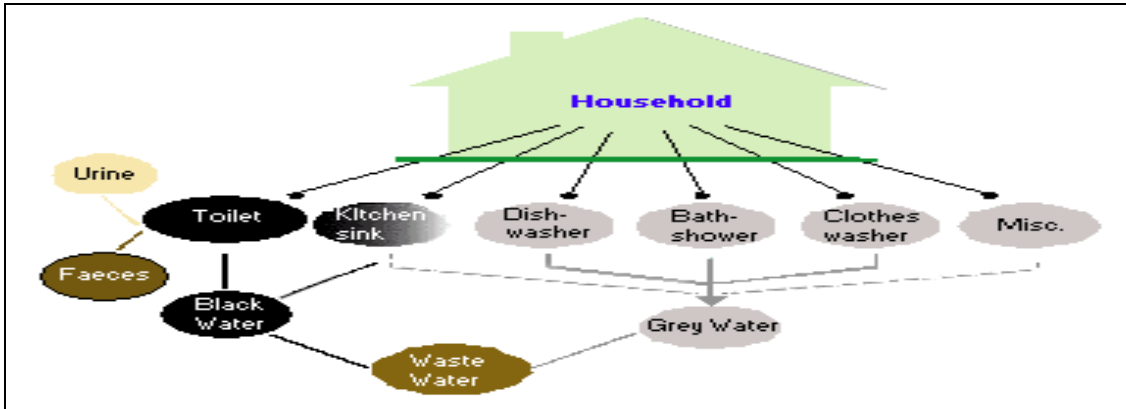


Figure 1.1. Household wastewater Sources (UNEP, 2004).

Separation of Grey wastewater and black wastewater is achieved through the use of separate plumbing. Wastewater separation is relatively easy to accomplish in new construction, but can range widely in cost and ease for retrofits of existing dwellings (EPA, 1978).

Mahmoud (2002) reported that in many of Palestinian villages and refugee camps, black wastewater is collected in cesspits, while grey wastewater is discharged via open channels. The majority of the collected wastewater from the sewerage localities is discharged into nearby wadis without being subjected to any kind of treatment. It is estimated that about 30% of the West Bank population is served with sewerage networks, but less than 6% is connected to treatment plants.

The need for adequate treatment of domestic wastewater is self evident in Palestine particularly for small rural communities, in which about 60% of the total populations in Palestine are living. The primary mode of wastewater disposal in rural communities is cesspits, which are installed on-site at residential dwellings and often associated with inefficiency, poor maintenance and groundwater pollution (PECDAR, 2001; CDM, 2002).

Knowledge about wastewater characteristics is necessary for design and operation of treatment facilities (Metcalf and Eddy, 1991) and to determine the sequence of treatment systems (Levine *et al.*, 1991). This is particularly true for wastewater flows from rural residential dwellings, commercial establishments and other facilities where

individual water-using activities create an intermittent flow of wastewater that can vary widely in volume and degree of pollution. Detailed characterization data regarding these flows are necessary not only to facilitate the effective design of wastewater treatment and disposal systems, but also to enable the development and application of water conservation system and for waste load reduction strategies. The treatment of wastewater depend strongly on the size distribution of the pollutants, since most treatment processes-physical, chemical or biological- for treatment of wastewater contaminants depend on particle size distribution (Levine *et al.*, 1985; Qdegaard, 1999).

Al-Sa'ed (2000) reported that the major sanitation problems in Palestine are due to the weak economy and low income, low level of technical expertise and very limited access to the existing advance wastewater treatment technologies.

The lack of sufficient wastewater management systems in both the West Bank and Gaza Strip highly contributes to the water resources depletion and water quality deterioration. It has also a direct adverse impact on public health, shoreline and marine pollution in Gaza, deterioration of nature and biodiversity as well as landscape and aesthetic distortion (MEnA, 1999; ARIJ, 2004).

1.2. Research objectives

Through literature search and based on experimental work, the specific objective of this research is to increase the knowledge on the quantity and quality of the various household wastewater streams in order to enable formulating innovative concepts which lead to maximizing reduction of the net water use by reusing treated effluent water.

1.3. Research Methodology

Five houses from Palestinian villages were chosen to be the locations of our experiment. These houses are located in Jerusalem area which is located in the central part of the West Bank. Four of the five houses (H1; H2; H3 and H4) are located in Anata village which lies about four kilometers east of Jerusalem. Its population is about 7000 inhabitants (PCBS, 1997). And one house (H5) is located in Hizzma village which lies about five kilometers north east Jerusalem. Its population is about 10000 inhabitants (PCBS, 1997). Table 1.2 shows the number of person in each house, number of babies, the sex of persons, their income and their education.

Table 1.2. Description of the five houses where this study was conducted.

	capita	Child (<10years)	Sex	Monthly income (in dollar)	Education (university degree)
H1	8	3	4M,4F	650	2
H2	11	5	5M,6F	550	2
H3	12	4	4M,8F	650	1
H4	12	5	6M,6F	1350	3
H5	13	4	5M,8F	700	1

The sanitary sewers in five houses have been separated out flow wastewater stream to enable the quantification and characterization of each wastewater stream. Toilet wastewater was separated alone for each house and the same was done for hand basin, kitchen sinks, shower and wastewater from Clothes washing. In this approach the

wastewater composition and flow were monitored for a total period of six months for all houses, each sample covered 24 hours for all separated wastewater streams in five houses, the sampling period covered both winter and spring periods. The volume of flow rate variation dictated the time interval for sampling; however, on the average every two hours a sample had been taken and the flow volume was measured. Finally, a composite sample was made. The composite samples were preserved by refrigeration (down to 4 °C) in special isolated boxes during the delay between sampling and transportation. For this composite sample, the amount of each individual sample that was added to the total mixture was proportional to the wastewater flow or volume at the time the sample was taken. For wastewater from Clothes washing that's didn't enter the sewerage system in our research, since people throw this wastewater out of the sewer system e.g., to the garden; it didn't enter the research calculations.

In average, the Clothes washed two times in the week for most of houses. The selected two houses different in the way of clothes wash, one house use traditional way of clothes wash, while the other use the laundry way. This difference in the washing has reflected on both wastewater quantity and quality. We can see that laundry washing of clothes produce more wastewater quantity and more pollution than traditional washing; we can see that in the concentration of COD, ammonia ($\text{NH}_4^+\text{-N}$), BOD_5 , and phosphorus.

1.4. Thesis structure

This thesis consists of six chapters. Chapter 1 is the research introduction in which background, aim of the research and objectives are introduced. Chapter 2 provides a comprehensive literature review on household wastewater characteristic, flow (quality and quantity of household wastewater) and probability of separation between black water and grey water, application of on site system as a tool for wastewater treatment. Chapter 3 deals mainly with materials and methods used in this experimental research. The results of this research are presented and discussed in Chapter 4; finally, conclusions and recommendations are summarized in Chapter 5.

Chapter 2

Literature Review

2.1. Introduction

Over the years, the severe shortage of water, primarily in the arid and semi-arid regions, has promoted the search for extra sources currently not intensively exploited. Treated wastewater is now being considered and used in many countries throughout the world, as a new, additional, renewable and reliable source of water, which can be used for agricultural production. By releasing freshwater sources of potable water supply and other priority uses, treated wastewater reuse makes a contribution to water conservation and expansion of irrigated agriculture, taking on an economic dimension on the country and on the human. It also solves disposal problems aimed at protecting the environment and public health and prevents surface water pollution by the direct discharge of pollutants into inland and coastal waters. The benefits, potential health risks and environmental impacts resulting from wastewater use for irrigation and the management measures aimed at using wastewater within acceptable levels of risk to the public health and the environment are well documented (WHO, 1973 and 1989; Hespanhol, 1990; Hespanhol and Prost, 1994; FAO, 1992; Jenkins *et al.*, 1994; Asano and Levine, 1996; Marecos do Monte *et al.*, 1996). Properly planned use of wastewater can reduce environmental and health related hazards, which have been observed with traditional wastewater disposal (Papadopoulos and Savvides, 2003).

Sewage management in the West Bank has been a neglected issue on both rural and urban communities. In the West Bank there are 642 communities, over an area of 5915 km² with total population of 2.2 million, people in the West Bank consume 60 MCM/year for domestic purposes, and based on the mentioned data above it is important to know that total sewage effluent discharge to the Wadis is 10 MCM/year (PWA, 2003).

Palestine suffers from both water scarcity and water pollution. Water supply is dependent upon annual precipitation, which replenishes the aquifers, natural springs and streams in Palestinian territories. Groundwater and rainwater collected in cisterns are exposed to severe pollution, especially from untreated wastewater. This problem can be more evident in rural areas where no sewer systems exist (Subuh, 2003).

In water stressed countries such as those of the Middle East and North Africa, every drop of water must count. Sustainable management of water resources can only be achieved if the water resources and wastewater management policies come together in addressing the water cycle in a holistic manner. Water must be used wisely and efficiently not only to control the consumptive use of water but also to reduce the wastewater flows. Wastewater flows must be managed effectively to protect the freshwaters from pollution. They must be reintegrated safely in the water cycle and accounted for in the water budget (Bakir, 2001).

Ecological wastewater management will play a key role in the quest for an efficient use and reuse of water, long-term soil fertility and protection of the natural waters. 'Zero Emissions' technology aims at 100% reuse of all material; this concept has been developed at the UN University in Tokyo, Japan for industrial production (Pauli, 2000). The same principles can be applied to municipal wastewater management, ending the concept of wastewater. Sanitation systems can be designed for high efficiency, old and new technologies can be applied in source control systems. We can consider sanitation as a production unit that can provide high quality reuse water, safe fertilizers and soil improving material (including processed bio-waste where appropriate) (Otterpohl, 2000).

Accelerated expansion of wastewater services in the Middle East and North Africa (MENA) is essential in order to address serious concerns over water scarcity and pollution in addition to meeting the demand for convenience and protecting public health. Centralized and conventional wastewater systems are currently the preferred choice of planners and decision makers. Water and funding are not available to provide these centralized conventional services to small communities (Bakir, 2001).

Wastewater recycling is emerging as an integral part of wastewater demands management, promoting as it does the preservation of high-quality fresh water supplies as well as potentially reducing the pollutant in the environment and reducing overall costs. Water recycling can be conducted both internally, where water is retained within a local process loop, and externally where water is sourced directly from a sewage treatment works. The preference in the UK currently is for internal systems such as industrial or domestic reuse, although some water utility companies are proactive in pursuing market opportunities in bulk reuse of treated municipal wastewater (Jefferson *et al.*, 1999).

The viability of internal recycling is to some extent contingent upon there being substantial differences in water quality and quantities demanded for different operations. The proportion of water used required to be of the highest quality is small. This then implies that most of the demands within the process scheme are for lower grade water, permitting reuse of water from one application to another. An example of this is in the domestic environment where the reuse of grey waters such as baths and showers for toilet flushing can be achieved with little or no treatment (Sayer, 1998).

Ellen *et al.* (2004) reported that In the Netherlands a new concept is developed called DESAR, in order to decrease the use of fresh water. In this concept the waste streams in houses are separated in two fractions. A large and diluted stream called grey water and a second smaller and highly concentrated stream from the toilets called black water. The grey water is slightly polluted by organic matter and can be treated by a simple treatment method like, sand filtration to such a standard that it can be reused.

The quantity and strength of domestic wastewater depends on the size and the socioeconomic behavior of the population constituting the community. These factors influence the design of the treatment plant, particularly the size of the plant. Less water consumed means less wastewater discharged and less volume of the wastewater to be treated in such communities (Mgana, 2003).

2.2. Effluent guideline for agricultural reuse and disposal

Standards or guidelines for water quality in Palestine must be establishment, for both water using in drinking and wastewater that discharged via open channels. It is very important to control with effluent of wastewater that treated before it discharge to land or Wadis, which can affect on the ground water quality. The resolution also establishes criteria for the hygienic quality in cases of reuse for irrigation. The Council of European Communities (CEC) and the World Health Organization (WHO) has set internationally important standards (Table 2.1) that shows the limits recommended by CEC and WHO for irrigation and surface water discharge. It can be noted that compared to the CEC and WHO resolution is more restrictive for the limits on BOD₅ and TSS, in cases of surface water discharge. In addition, the CEC resolution tends to be more restrictive than WHO recommendation for irrigation with treated sewage.

Table 2.1. Domestic wastewater standards that can be recommendations for discharge of treated sewage in surface water and reuse for irrigation (WHO, 1989; CEC, 1991).

Parameter	Unit	Desirable quality	Standard
COD	Mg/l	125 ⁽³⁾	CEC ⁽¹⁾
BOD ₅	Mg/l	25 ⁽⁴⁾	CEC ⁽¹⁾
TSS	Mg/l	< or = 150	CEC ⁽¹⁾
<i>FC</i>	CFU/100ml	< or = 10 ⁽³⁾	WHO ⁽²⁾
<i>HE</i>	No./l	< 1	WHO ⁽²⁾

(1) Surface water discharge; (2) unrestricted irrigation; (3) sample without filtration; (4) filtered sample.

2.2.1. Pathogens in household wastewater

Setting microbiology quality guidelines for recycled water is complicated, because the techniques for identifying pathogens are complex, time consuming and costly.

Furthermore, the quality and type of microorganisms found in domestic wastewater is so variable that standard method for all-purpose may not be useful, and routine monitoring for each organism is not impractical but also impossible. In particular, the

time required to analyze a pathogen of interests is so long that measurement is not a useful tool for providing treatment plants with feedback (WHO, 1996).

2.2.2. Fecal coliform

Total coliform bacteria are a collection of relatively harmless microorganisms that live in large numbers in the intestines of man and warm- and cold-blooded animals. They aid in the digestion of food. A specific subgroup of this collection is the *Fecal coliform* bacteria, the most common member being *Escherichia coli*. These organisms may be separated from the total coliform group by their ability to grow at elevated temperatures and are associated only with the fecal material of warm-blooded animals (Faruqui, 2003).

2.2.3. Environmental impact of Fecal coliform

The presence of *Fecal coliform* bacteria in aquatic environments indicates that the water has been contaminated with the fecal material of man or other animals. At the time this occurred, the source water may have been contaminated by pathogens or disease producing bacteria or viruses which can also exist in fecal material. Some waterborne pathogenic diseases include *Typhoid fever*, *Viral and Bacterial gastroenteritis* and *Hepatitis A*. The presence of *fecal* contamination is an indicator that a potential health risk exists for individuals exposed to this water. *Fecal coliform* bacteria may occur in ambient water as a result of the overflow of domestic sewage or non-point sources of human and animal waste (Faruqui, 2003).

2.2.4. Guidelines for pathogenic parameters

The main problem with the use of wastewater is the threat to public health, the water if reuse is not done carefully. While the main impact on health from reuse in developing countries is from diseases caused by helminthes, the worst-case situation occurs when untreated wastewater is used to irrigate vegetables or salad crops that are then eaten raw. This practice resulted in the *cholera* outbreak in Amman, Jordan in 1981 (Faruqui, 2003). Unfortunately, there are many on-going instances of raw wastewater reuse which, without doubt, result in occasional *gastro-intestinal* illness, but have the

potential for causing widespread illnesses. For example, due to water scarcity, the irrigation of market vegetables such as eggplant and cucumber with raw wastewater flowing in the Kedron Valley, West Bank is common (Faruqui, 2003).

The WHO (1989) technical report on "Health Guideline for the Use of Wastewater in Agriculture and Aquaculture" has discussed the integration of various measures available to achieve effective health protection. Limitation of the administrative or legal system in some countries will make some of these approaches difficult to apply, where as shortage treatment as the only control countries will place doubt upon reliance on wastewater treatment as the only control mechanism. To achieve greater flexibility in the use of wastewater application as health protection measure, where the irrigation systems must be developed to deliver wastewater with restriction on irrigation, and crops irrigated must become more common.

Wastewater must be treated to reduce the concentration of suspended solids, organic material and pathogenic organism. The World Health Organization (WHO) guidelines for irrigation in 1996 specify maximum concentration of 10^3 *Fecal coliform* colonies per 100ml. a regional standard used for the effluent (Table 1.1) that be recommended to have as Palestinian standard.

2.3. Wastewater collection and treatment in Palestine

Sewage networks are limited to major cities and refugee camps but most of them are poorly designed and suffer from leakage. The remaining population uses cesspits for wastewater disposal tanks in some cases (MOPIC, 1998).

Cesspits (or cesspools) are the traditional method for sewage disposal in Palestine. It has been used for centuries in all the communities before they were slowly replaced in the major cities by the sewage collection networks. However, they are still in the villages and the rural communities. A bout 73% of the households in West Bank have cesspit sanitation and almost 3% are left without any sanitation system (MOPIC, 1998). Cesspits are essentially covered pits that receive raw sewage. They are dug into

pervious soils. Most of the cesspits are left without a cement basement or liner so that sewage infiltrates into the earth layers and the owners avoid using the expensive services of the vacuum tankers to empty them (ARIJ, 2004). Therefore, cesspits themselves constitute a threat to freshwater if they overflow, as frequently happens, they contaminate the soil and groundwater with raw sewage. If they are pumped out, the sewage is usually dumped into the nearest water body without being subjected to any kind of treatment.

A better on-site sanitation method than cesspits is the septic tank. The septic tank is an underground covered watertight settling tank that collects and provides primary treatment of wastewater by holding the wastewater in the tank and allowing settleable solids to settle to the bottom while floatable solids (oil and grease) rise to the top. Up to 50% of the solids retained in the tank decompose, while the remainder accumulate as sludge at the bottom of the tank and must be removed periodically by pumping the tank. The effluent from the septic tank is either disposed of through soil absorption fields, e.g. trenches or beds, provided that site characteristics are appropriate, or subjected to further treatment employing a sand filter (USEPA, 2000).

While the septic system is a simple disposal method and provides primary treatment of the raw sewage, misapplication of the technology is common. Various NGOs with varying degree of success have piloted a version of the septic system in some portions of some of Palestinian villages. Main problems seem to be with the poor quality of construction and villagers expectations of the system (CDM, 2002). Factors that have hampered its widespread application versus cesspits are: it requires a larger land area and that it is more costly and its operational cost is higher due to the need for periodic desludging (Coelho *et al.*, 2003).

The wastewater effluent from a household or group of households is made up of contributions from various appliances, such as toilet, kitchen sink, wash basin, bath, shower, and washing machine. Separation of toilet waste (black-water) from the residential wastewater stream will reduce the mass of organic matters; pathogenic microorganisms; nitrogen and phosphorous in the remaining waste stream (grey water).

Figure 2.1 shows a hypothetical model for onsite wastewater with different treatment system. In this system, the separation of household wastewater into three types is essential. Reduced-volume black wastewater, higher-load grey wastewater that have some organics like kitchen sink and lower-load grey wastewater like hand basin and shower are new concepts that are introduced in this model. Here, treatment of black wastewater conceives a change in the traditional way of using the toilet; in other words, the use of water in the toilet is thought just to clean the toilet, not to transport the toilet wastes; this is a very important change. Reduced volume of black wastewater is practically eliminated from the household effluent by using the bio-toilet system. This system depends on separated water in toilet wastewater and reuses it again for flushing, while make compost from the solids and use it in agriculture. The lower-load grey water could be treated by utilizing the natural capacity of soil microorganisms; and higher-load grey water needs any conventional treatment process for reaching acceptable quality. In fractioning grey water into higher- and lower- load portion and planning a suitable treatment process for them, the information on quality, quantity and their fluctuation pattern of effluent from various appliances is essential (Funamizu *et al.*, 2001).

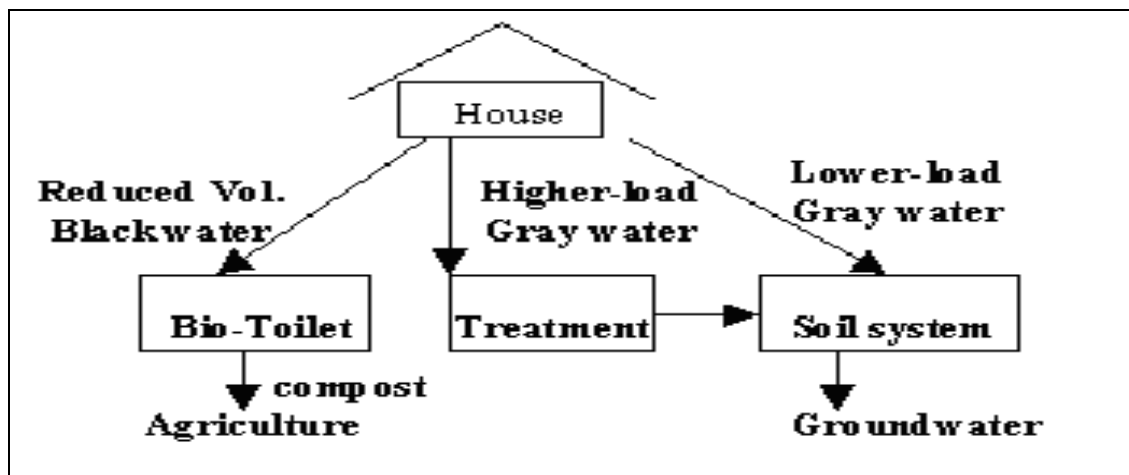


Figure 2.1 Hypothetical models for onsite wastewater treatment system (Funamizu *et al.*, 2001).

2.3.1. Grey wastewater characterization

Grey water is usually generated by the use of soap or soap products for body washing and as such, varies in quality according to, amongst other things, geographical location, demographics and level of occupancy. Grey water has a similar organic strength to domestic wastewater but is relatively low in turbidity, indicating that a greater proportion of the contaminants are suspended. Moreover, although the concentration of organics is similar to domestic wastewater their chemical nature is quite different. Grey water forms the large amount of daily effluent household domestic wastewater (Table 2.2) and characterized as being of "low strength" compared to black wastewater. (Table 2.3 shows characterization of grey water for different sources).

In general, wastewater in Palestine is characterized as being of "high strength" (ARIJ, 1996; CDM, 2002; Mahmoud *et al.*, 2003). The amount of Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), ammonia (NH_4^+ as N) and total phosphorus (PO_4^{3-} as P) in the wastewater is relatively high compared to other countries and according to the sewage strength classification proposed by Metcalf and Eddy (1991). The high strength of sewage can be attributed to low water consumption and people's habits (Mahmoud *et al.*, 2003). In addition, the generated sewage in rural communities could be more concentrated, because of the lack of water and the extreme frugality with which villagers use water.

Table 2.2. Effluent household wastewater streams (EFP, 2005).

Wastewater Source	Total wastewater		Total grey wastewater	
	% from total wastewater	Liters/day	% form total grey wastewater	Liters/day
Toilet	32	186	-	-
Hand basin	5	28	8	28
Bath/shower	33	193	54	193
Kitchen	7	44	-	-
Laundry	23	135	38	135
Total	100	586	100	356

Table 2.3. Typical composition of grey wastewater from various household wastewater streams (Jefferson *et al.*, 1999).

	BOD ₅ (mg/l)	COD(mg/l)	NH ₃ (mg/l)	P(mg/l)	Total <i>coliforms</i>
Hand basin	109	263	9.6 ^a	2.58	-
Synthetic grey water	181	-	0.9	-	1.5*10 ⁶
Single person ^b	110	256	-	-	-
Single family ^c	-	-	0.74	9.3	-
Block of flat ^b	33	40	10	0.4	1*10 ⁶
College ^b	80	146	10	-	-
Large college ^b	96	168	0.8	2.4	5.2*10 ⁶

^a Total nitrogen

^b Holden & Ward (1999).

^c Sayers (1998).

^d Surendran & Wheatley (1998).

It concluded that there is an urgent need for more information about the characteristics of different types of grey wastewater in order to be able to evaluate the potential for reuse and infiltration. It also illustrates the need for different types of treatment before any recycling of the water. It can also be concluded that the present knowledge about the characteristics of grey wastewater (physical, chemical and biological constituents) is limited. The information available shows that the focus has been on the content of oxygen consuming compounds (BOD and COD), nutrients and some microorganisms (Eriksson *et al.*, 2002).

2.3.2. Reuse of wastewater in irrigation agricultural crops

The reuse of treated effluent that is normally discharged to the environment from municipal wastewater treatment plants is receiving an increasing attention as a reliable water resource. The volume of this resource is being considered in the planning and implementation of water resources projects.

In the United States, it was reported that in 1995 the reuse of recycled wastewater approached 3.85 million cubic meters of which 2.72 million cubic meters were reused in irrigating agricultural crops (Solley *et al.*, 1998). This amount of reclaimed water reuse for 1995 in the United States represented an increase of 36% from 1990. Irrigating agricultural crops with recycled wastewater has been practiced in arid and semi arid regions and is rapidly getting popular in the countries of the Middle East. In Palestine and Jordan, irrigation with wastewater of different qualities has been practiced for along time (Tamimi, 2004). In 2000, it was reported by the Palestinian Water Authority (PWA) that the total expected treated effluent that would be available for irrigating agricultural crops would reach 92 million cubic meters in 2020 (PWA, 2000).

2.3.3. Wastewater reuse and recycling systems (on-site system)

Many arid and semiarid regions have been faced with water shortages, creating the need for more efficient water use practices. Depletion of ground water and surface water resources due to increased development, irrigation, and overall water use is also becoming a growing concern in areas. Residential development in previously rural areas

has placed additional strains on water supplies and wastewater treatment facilities. Decentralized wastewater management programs that include onsite wastewater reuse/recycling systems are a viable option for addressing water supply shortages and wastewater discharge restrictions. In municipalities where water shortages are a recurring problem, centrally treated reclaimed wastewater has been used for decades as an alternative water supply for agricultural irrigation, ground water recharge, and recreational waters (U.S. EPA, 2002).

Wastewater reuse is the processes of collection and treatment of wastewater for other uses (e.g., irrigation, ornamental ponds, and cooling systems). Wastewater recycling is the processes of collection and treatment of wastewater and its reuse in the same water-use scheme, such as toilet and urinal flushing (Tchobanoglous and Burton, 1991).

Wastewater reuse/recycling systems can be used in individual homes, clustered communities, and larger institutional facilities such as office parks and recreational facilities. The Grand Canyon National Park in USA has reused treated wastewater for toilet flushing, landscape irrigation, cooling water, and boiler feedstock since 1926, and other reuse systems are gaining acceptance (Tchobanoglous and Burton, 1991). Office buildings, schools, and recreational facilities using wastewater reuse/recycling systems have reported a 90 percent reduction in water use and up to a 95 percent reduction in wastewater discharges (Burks and Minnis, 1994).

Wastewater reuse/recycling systems reduce potable water use by reusing or recycling water that has already been used at the site for non-potable purposes, thereby minimizing wastewater discharges. A number of different onsite wastewater reuse/recycling systems and applications are available. Some systems, called combined systems, treat and reuse or recycle both black wastewater and grey water (NAPHCC, 1992). Other systems treat and reuse or recycle only grey wastewater. Separating grey wastewater and black wastewater is a common practice to reduce pollutant loadings to wastewater treatment systems (Tchobanoglous and Burton, 1991).

2.3.4. Alternative on-site systems for a single house

In the US, on-site wastewater treatment had long been thought of a system of “last resort” to be used only temporarily until central sewerage was available. The systems were not considered treatment systems but were designed to prevent direct human contact with the wastewater by discharging it below ground and distant from water supply wells and surface waters. Local health departments regulated their use with prescriptive rules that developed over time, which restricted their application to properties that met specific site criteria established out of local experience and folklore. The regulators assumed that if the systems were sited, designed, and installed in accordance with these rules, health problems would be avoided unless plumbing backups or pounding on the ground surface occurred. Only then might enforcement actions be taken (Richard, 2005).

Septic tank is the most known and commonly applied method for on-site (aerobic) treatment of sewage. However, the observed poor performance of septic tanks treating domestic wastewater from the literature (Mgana, 2003; Lettinga *et al.*, 1991) show that septic tanks operated in the present practical mode are not suitable as on-site treatment option for wastewater. Mgana (2003) found that the observed poor performance of the community on-site septic tank despite the long HRT is mainly attributed to the inherent design feature of septic tank, the horizontal flow mode of the influent sewage in septic tanks is the predominant design feature responsible for the insufficient contact between the influent and the active biomass available in the settled sludge. Most of the substrate from the horizontal flow mode in septic tanks reaches the active biomass by trickling through the sludge downwards from top. This is a very inefficient mechanism of enhancing contact between substrate and active microorganism.

2.3.5. Alternative on-site systems for a cluster of houses

It is more appropriate to employ a wastewater management system for a cluster of houses rather than installing individual ones for each single house. In such cases, there is a need to install a sewage collection system. Small diameter gravity and pressure sewers are appropriate for small communities as they are affordable and less water-intensive to the conventional sewage collection systems.

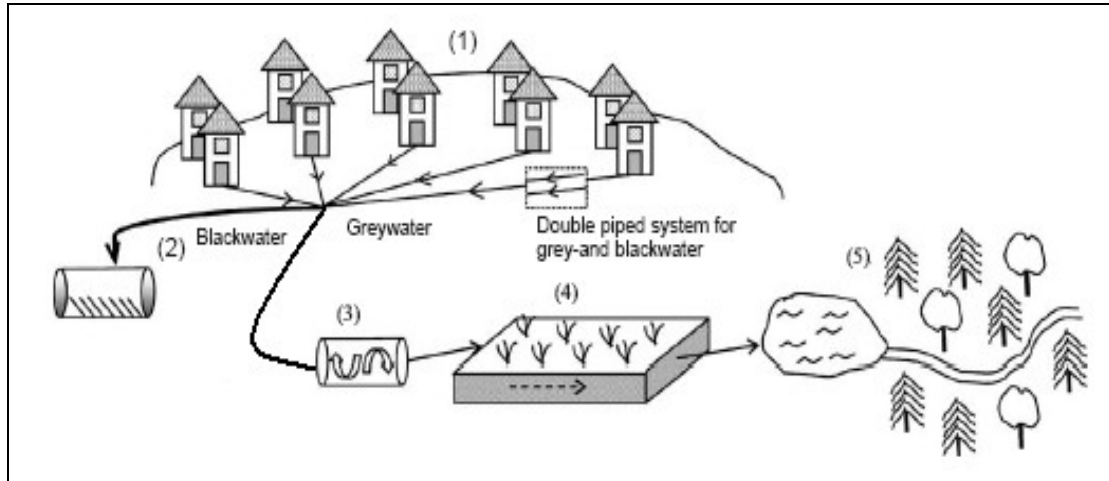


Figure 2.2. A schematic of the separate grey and black wastewater system at the housing area. Where (1) housing area, (2) separate pipes for grey and black wastewater, (3)&(4) simple process for treatment of grey wastewater, (5) released into a pond system (Palmquist & Hanæus ,2005)

The UASB-septic tank could be profitable to be applied in such cases; even though for small communities with densely-populated areas, like a UASB-septic tank for each street. It could be said that the one-step UASB-septic tank reactors configuration is a potential compact and effective community on-site pre-treatment unit for domestic wastewater. The system is more economical and affordable for local relatively poor communities since it can operate successfully without high expertise and does not require any external supply of energy particularly when gravity flow mode can be achieved (Al-Shayah, 2005).

2.4. In house alteration of wastewater

The quantity and quality of wastewater being treated are the primary factors used when designing onsite treatment and disposal systems (Santala, 1984). These factors also have a profound effect on the long-term performance of those systems (SSWM, 1978). The created wastewater characteristics are determined from the type of water uses in house. In the distant past, when all water used had to be carried per capita, water use was be somewhere between 10 and 50 liters per day. With indoor plumbing, water usage can rise to over 200 liters per person per day (Santala, 1984). Water use habits also influence the quality of wastewater. The use of a garbage grinder, for instance, adds 28

percent more biological oxygen demand (BOD) and 36 percent more solids (SS) to household wastewater (Kreissl, 1982). Altering the waste stream is one technique considered to permit onsite treatment and disposal on sites with less suitable soils (Siddoway, 1988).

2.5. Household wastewater stream separations

Siddoway (1988) reported that Wastewater characteristics vary widely from household to household, by time of day, and by season. Residential wastewater flows are affected by high water-use events such as wash day, or holidays and house guests, and periods of no flow, such as vacations. The following information describes average values for residential wastewater. Typical household wastewater is 99.9 percent water (by weight), and 0.02 to 0.03 percent suspended solids, plus minor amounts of other soluble and insoluble organic and inorganic substances. Wastewater also contains bacteria, viruses, and other microorganisms from the digestive tract, respiratory tract and skin (Siddoway, 1988).

Table 2.4. Physical/Chemical composition of household wastewater (Siddoway, 1988).

Activity	% of BOD in wastewater	% of Suspended Solid in wastewater
Kitchen activity	42.3%	26.7%
Bathing, Showering	6.2%	6.4%
Clothes washing	29.8%	31.2%
Toilet flushing	21.7%	35.7%
Total	100%	100%

The interest in the separation and reuse of different wastewater fractions (i.e. grey water and black water) has increased in recent years, largely due to economical, structural and ecological considerations. Grey water, here defined as wastewater without input from toilets is often extensively treated in the combined systems or separately in spread settings. The high-grade treatment of grey water has been questioned since it constitutes

a large fraction of the actual wastewater flow, but has a low degree of faecal contamination and local system are often ill adapted for reuse (Ottoson and Axel, 2001).

It was once thought that grey water might be suitable for surface application or subsurface discharge with minimal treatment. Several studies, however, indicate that household grey water contains significant concentrations of organic materials, solids, nutrients and fecal bacteria which require treatment equal to that of total household wastewater (Siddoway, 1988). Segregating waste does significantly reduce the amount of wastewater.

Siddoway (1988) reported that Toilet wastes (black wastes) contribute approximately 35 percent of the water, 36 percent of the suspended solids, and 68 percent of the total nitrogen to the household waste stream. If toilet wastes are treated separately without using water, then the volume and pollutant load of remaining water (grey wastewater) is reduced.

Otterpohl (2000) found that every one person produces about 500 liters of urine and 50 liters of faeces per year (black water). Today, the same person, having access to tap water, produces in a range of 20000 to over 100000 liters of wastewater (grey wastewater if not mixed with Black wastewater). Black wastewater and grey wastewater have very different characteristics. If the black wastewater would be collected separately with low dilution it can be converted to safe natural fertilizer, replacing synthetic products and preventing spread out of pathogens and water pollution, too. If toilet waste is mixed with a lot of water, the large volume turns to a potentially dangerous flow of waste that has to be treated at high costs. At the same time this mixing makes simple treatment and higher quality reuse impossible because of faecal contamination and excess of nutrients. The reason for this inappropriate handling of important resources is the long lasting lack of technical development of flushing toilets. Flushing faeces to surface waters helped spreading diseases and devastating epidemics in 19th century Europe (Evans, 1987) and in more and more developing countries around the world in the last decades. According to WHO around 4 million people die from polluted water every year.

Separation of different qualities and their respective appropriate treatment for reuse is common in industrial wastewater management. This type of source control thinking is fundamental for new concepts. Due to the very different characteristics of black wastewater (from the toilets) and grey water (household wastewater without black wastewater) new sanitation concepts will produce fertilizer from black wastewater and give a good opportunity for reuse of treated grey water. Black wastewater has a composition where most of the organic matter and particulate nutrients are in the solids (brown wastewater). In contrast, the yellow wastewater (urine) contains nearly all of the valuable soluble nutrients as N, P, K and others (Otterpohl, 2000).

2.6. Source separation of grey wastewater

Urine is a valuable nutrient resource with about 90% of the nitrogen and 67% of the phosphorus in the human excrements. Source separating toilets are available under different trademarks in Sweden. They transfer urine to a tank for a subsequent recycling on agricultural land (Günther, 1998).

Regarding the treatment of faeces, the source separating toilets can be classified into two different types. One type (the 'dry' type) collects the faeces in a composting chamber for the elimination of pathogens during a 6-month composting process. The other type (the 'wet' type) uses water for the transport of faeces to a tank or uses a device for subsequent separation of flush water and faecal matter. In some cases, this fraction is let out to the conventional system. Urine separating toilets have recently been discussed in the literature as a solution to the wastewater problem (e.g. Hancus *et al.*, 1997; Hellstrom and Karrman, 1997; Jonsson *et al.*, 1997; Drangert, 1998). Regardless of type, a main advantage of the source separating toilets is that the grey water remains uncontaminated by faecal matter and urine.

2.7. Wastewater quantity

Whether a system serves a single home or an entire community, it must be able to handle fluctuations in the quantity and quality of wastewater it receives to ensure proper treatment is provided at all times. Systems that are inadequately designed or hydraulically overloaded may fail to provide treatment and allow the release of pollutants to the environment. To design systems that are both as safe and as cost-effective as possible, engineers must estimate the average and maximum (peak) amount of flows generated by various sources. Because extreme fluctuations in flow can occur during different times of the day and on different days of the week, estimates are based on observations of the minimum and maximum amounts of water used on an hourly, daily, weekly, and seasonal basis. The possibility of instantaneous peak flow events that result from several or all water-using appliances or fixtures being used at once also is taken into account.

The number, type, and efficiency of all water-using fixtures and appliances at the source is factored into the estimate (for example, the number and amount of water normally used by faucets, toilets, and washing machines), as is the number of possible users or units that can affect the amount of water used (for example, the number of residents, bedrooms, customers, students, patients, seats, or meals served).

According to studies, water use in many homes is lowest from about midnight to 5 a.m., averaging less than four liters per person per hour, but then rises sharply in the morning around 6 am to a little over twelve liters per person per hour. During the day, water use drops off moderately and rises again in the early evening hours. Weekly peak flows may occur in some homes on weekends, especially when all adults work during the week. Peak flows at stores and other businesses typically occur during business hours and during meal times at restaurants. Rental properties, resorts, and commercial establishments in tourist areas may have extreme flow variations seasonally. Estimating flow volumes for centralized treatment systems is a complicated task, especially when designing a new treatment plant in a community where one has never existed previously. Engineers must allow for additional flows during wet weather due to inflow and infiltration of extra water into sewers. Excess water can enter sewers through leaky manhole covers and cracked pipes and pipe joints, diluting wastewater, which affects its

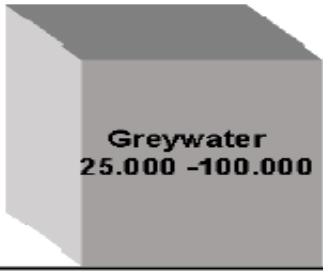


overall characteristics. This can increase flows to treatment plants sometimes by as much as three or four times the original design load.

2.8. Impact of wastewater characteristics on the treatment technology

The understanding of wastewater characteristics is necessary in the design and operation of collection, treatment and disposal facilities and in the engineering management of environmental quality (Metcalf and Eddy, 1991). Therefore, engineers, chemists and biologists have been working for many decades to develop wastewater purification and treatment facilities. As most water treatment processes are chemical reactions in nature, the fundamentals of wastewater chemistry are then necessary in understanding the wastewater characteristics and hence in selecting appropriate treatment technology (Muttamara, 1996).

Design of source control sanitation aims for a high hygienic standard and full reuse of re-sources. This is exactly what can be reached by clever source control. However, design has to be checked to the ability of achieving these goals. It is almost sure that strange concepts will come up from those who do not understand the simple basic principle: "No waste, full reuse". Naturally socioeconomic conditions have to be taken very seriously. The background of the new systems has to be explained to the users. The fundamental step is the identification of the very different characteristics of the main components of household wastewater that are presented in table 2.5. There is a certain variation as conditions are different (Table 2.5 gives a typical range of values) (Otterpohl, 2000).

Table 2.5. Characteristics of the main components of household wastewater (Otterpohl, 2000)

Volume l/(P*year) Yearly Loads kg/(P*year)	 Greywater 25.000 -100.000	Urine ~ 500 	Feeces ~ 50 (option: add biowaste) 
	N ~ 4-5 ~ 3 %	~ 87 %	~ 10 %
P ~ 0.75 ~ 10 %	~ 50 %	~ 40 %	
COD ~ 30 ~ 41 %	~ 12 %	~ 47 %	
Treatment ↓ Reuse / Water Cycle		Treatment ↓ Fertiliser	Biogas-Plant Composting ↓ Soil-Conditioner

Pollution of water by organic and inorganic chemicals is of serious environmental concern. Domestic wastewater differs in characteristics from the industrial wastewater. In domestic wastewater the organic load mainly due to the processes like food processing, washing of floor, cloths, utensils, animals, bathing and sewage. The main components of domestic wastewater are proteins, carbohydrates, detergents, tannins, lignin, humic acid, fulvic acid, melanic acid and many other dissolved organic compounds. The organic content of wastewater is traditionally measured using lumped parameters such as BOD, COD and TOC. These parameters as such do not show any chemical identity of organic matter (Sahu, 2001).

2.9. Wastewater management systems

Wastewater management systems may consist of a decentralized approach using on-site treatment and disposal; a more centralized approach with collection sewers and a wastewater treatment plant and discharges to groundwater or surface water; or, as is more typical, a combination of the two. The decentralized wastewater management system implies collecting, treating and disposing/reusing the wastewater from individual homes and/or clusters of homes at or near the point of wastewater generation. This system has received increased attention from wastewater researchers for solving

the problem of wastewater in small communities along with its potential for delivering several benefits including:

- It is appropriate for areas where water supplies are intermittent and water consumption is low.
- It involves managing wastewater as close as possible to where it is generated.
- It increases wastewater reuse opportunities by keeping wastewater as close as practical to the potential reuse site.
- It results in significant reduction in wastewater transportation and collection.

The probability of simultaneous failure of all small systems is significantly lower than that of failure of one system serving the entire community. The centralized wastewater management system implies collecting the generated wastewater through sewers with a centralized treatment plant where disposal/reuse usually occurs far from the point of generation (ARIJ, 2004).

2.10. Decentralized urban catchment's areas

Conveyance and treatment in sanitation planning have been approached in two ways: on-site sanitation at the household level and off-site sanitation at the city level (Alaerts *et al.*, 1993). Numerous problems exist in providing effective wastewater collection and treatment systems to dense, highly populated urban areas (Giles and Brown, 1997). Many areas inhabited by the urban poor, especially squatter settlements, are found on marginal land, (i.e., marshes, and steep rocky hillsides) that are difficult to excavate for the implementation of water-borne sewage schemes (Giles and Brown, 1997). Several options have recently been proposed and appear feasible, but necessitate further development.

Alaerts *et al.* (1993) have discussed an "intermediate" level wastewater management scheme. Intermediate not referring to the technical level or appropriateness of

technology, but intermediate in terms of conveyance distance between point of waste generation and the point of treatment. This approach would allow for wastewater management to be broken down to the neighborhood-level and to serve disaggregates of the larger urban areas. Selection of technology could be made based upon specific site conditions and financial resources of individual communities. Technology could be more easily matched to segregate and/or recover individual resources of the waste stream including the industrial waste stream (Veenstra and Alaerts, 1996).

Promoting the development of decentralized wastewater treatment and recovery technologies that are linked with urban agriculture systems, at the neighborhood level, appear to be a rational approach to solving the human and environmental health dilemmas that result from under-managed wastewater. Decentralized, small-scale systems must be considered in planning and upgrading urban environments (Chan, 1996; Veenstra and Alaerts, 1996). Gravity flow, small bore sewerage, and water borne conveyance systems offer the potential to decentralize urban environments into catchments systems, each with their own integrated treatment plant and at low costs (Alaerts *et al.*, 1993; Mara, 1996; Chan, 1996). These systems could be based on the topography of the local watershed, opposed to sector or citywide collection and treatment schemes, and would result in small-scale facilities equally dispersed through the urban environment. Pathogen reduction and nutrient recovery would occur through the use of integrated biological processes, which are also low-cost. This approach would allow for independent, self-maintained, and self-sustained facilities that are capable of recovering wastewater resources and immediately reusing them in decentralized urban farms (Chan, 1996).

In many situations, on-site treatment and storage systems (e.g., anaerobic treatment technologies and septic tanks) can be effectively used for the management of wastewater, but they require periodic emptying and the sludge must be transported to agro-production units. In this case, technologies such as the MAPET may be feasible to promote the decentralized treatment scenario. The MAPET (Manual Pit Latrine Emptying Technology) was developed by WASTE Consultants to facilitate the emptying of pit latrines in low-income, unplanned areas of Dar es Salaam (Muller and

Rijnsburger, 1994). The MAPET pump is manufactured locally in Tanzania. The unit is mounted on two pushcarts and is much more hygienic for workers than the previous practice of manually emptying latrine sludge because direct contact between the worker and the sludge is reduced (Muller and Rijnsburger, 1994). Combining this type of innovative sludge removal technology with decentralized, household or neighborhood level treatment systems that can be directly integrated with agriculture is an area that warrants further exploration.

Planning decentralized, intermediate distance treatment facilities in combination with urban agriculture at the corresponding level would allow for the assimilation of wastewater resources and would equally disperse them within urban areas. This strategy would reduce the distance that wastewater is conveyed and would eliminate the need to discharge to receiving bodies. Furthermore, it would reduce the amount of sludge disposed to landfill sites (Strauss, 1996).

Bouwer (1993) has noted that increasingly, small satellite plants are being built to provide reclaimed waste for local use. If small-scale, easily maintained and operated single or multi-residence treatment systems, providing maximum levels of environmental health and public safety, can be developed and easily replicated, then institutional resources can be directed toward education supporting their dissemination and incremental upgrading. National, mid-level, and municipal policies must be action-oriented and support institutional environments that favor the adoption of innovative technologies; otherwise, they are destined to failure.

Bogte *et al.* (1993) reported that in developing countries suffer from the lack of proper wastewater collection and treatment facilities, especially in rural areas. In Egypt, more than 95% of the Egyptian rural area is not provided with wastewater collection and treatment facilities. There are about 4,000 Egyptian rural areas with a population ranging from 1,000 to 20,000 capita. The wastewater produced from houses in these Egyptian rural areas are mainly collected and treated in septic tanks. The high construction, operation and maintenance costs for centralized wastewater collection and treatment represent an obstacle for the Egyptian government to install such systems in

Egyptian rural areas. On the other hand, most of the wastewater produced in developed countries is collected and treated up to tertiary treatment. In The Netherlands about 95% of the produced wastewater is treated in central facilities. The remaining 5% is produced from different sources, like remote houses, farms and recreation facilities for which connection to municipal wastewater is too costly. From 2005, it is forbidden in The Netherlands to discharge municipal wastewater into surface water and soil without adequate treatment.

Decentralized sewage treatment is more and more considered to be a sustainable way of wastewater treatment (Zeeman and Lettinga, 1999). Also, in the USA, on-site treatment (mainly septic tank) for domestic sewage serves about 20% of the US population, more than 20 million homes (Scandura and Sobsey, 1997). Therefore, decentralized treatment can represent a suitable option for the treatment of sewage not only for rural areas in developing countries, but also for unserved areas with wastewater collection and treatment facilities in developed countries (Zeeman and Lettinga, 1999; Elmitwalli *et al.*, 2003; Mahmoud *et al.*, 2003).

Chapter 3

Materials and Methods

3.1. Experimental set-up

This study was conducted on wastewater generated in five houses. Four houses in Anata village which lies about four kilometers north of Jerusalem. Its population is about 9500 inhabitants (PCBS, 1997). And one house in Hizzma village which lies about seven kilometers north east Jerusalem, its population is about 10000 inhabitants (PCBS, 1997). Jerusalem area is located in the central part of the West Bank and considered one of the most important administrative central in Palestine. The out flow wastewater from each of these houses will be separated in order to analyses the elements of which it consists. This will let us consider change to the present technologies used in households, and get knowledge about characteristic of wastewater that through in sewage then we can discuss why wastewater in Middle East and especially in Palestine is described strong wastewater and what causes that led to this position.

3.2. Sampling

The sanitary sewers in five houses have been separated out flow wastewater stream to enable the quantification and characterization of each wastewater stream. Toilet wastewater was separated alone for each house and the same was done for hand basin, kitchen sinks, shower and wastewater from Clothes washing. In this approach the wastewater composition and flow were monitored for a total period of six months for all houses, each sample covered 24 hours for all separated wastewater streams in five houses, the sampling period covered both winter and spring periods. The volume of flow rate variation dictated the time interval for sampling; however, on the average every two hours a sample had been take and the flow volume was measured. Finally, a composite sample was made. The composites samples were preserved by refrigeration

(down to 4 °C) in special isolated boxes during the delay between sampling and transportation. For this composite sample, the amount of each individual sample that was added to the total mixture was proportional to the wastewater flow or volume at the time the sample was taken. For wastewater from Clothes washing that's didn't enter the sewerage system in our research, since people throw this wastewater out of the sewer system e.g., to the garden; it didn't enter the research calculations. In average, the Clothes washed two times in the week for most of houses. Each sample of waste stream was analyzed in single for:

1. Total COD and its fractions (suspended, colloidal and dissolved)
2. Volatile Fatty Acids (VFA)
3. BOD₅
4. Ammonium (NH⁴⁺-N)
5. Total Phosphorus (Total P)
6. Ortho-phosphate (PO₄³⁻)
7. pH
8. Temperature
9. *Fecal Coliform (FC)*

3.3. Analytical methods

3.3.1 Physical and chemical analysis

1. Chemical Oxygen Demand (COD)

COD analysis was carried out using reflux method (acid destruction at 150 °C for 120 minutes). The absorbance was then measured by spectrophotometer at 600 mm wave length according to Standard Methods (APHA, 1995). Total COD (COD_{tot}), paper filtered COD (COD_{filt}) (Schleicher and Schuell 595½ 4.4-µm paper filters), and membrane-filtered (dissolved) COD (COD_{dis}) (Schleicher and Schuell ME 25 0.45-µm

membrane) were determined in the samples. Suspended and colloidal COD (COD_{sus} and COD_{col}) were calculated as $(COD_{tot} - COD_{filt})$ and $(COD_{filt} - COD_{dis})$, respectively.

Calculations:

$$COD_{tot} = COD_{ss} + COD_f$$

$$COD_f = COD_{dis} + COD_{col}$$

Where;

COD_{tot} : amount of total chemical oxygen demand in the tested sample (mg COD/l)

COD_f : amount of filtrated chemical oxygen demand in the tested sample (mg COD/l)

COD_{dis} : amount of dissolved chemical oxygen demand in the tested sample (mg COD/l)

COD_{ss} : amount of dissolved chemical oxygen demand in the tested sample (mg COD/l)

COD_{col} : amount of dissolved chemical oxygen demand in the tested sample (mg COD/l)

The specific production of total COD was calculated for the daily flow of wastewater in each house using this equation:

$$COD_H * Vol_H = COD_{toilet} * Vol_{toilet} + COD_{hand\ basin} * Vol_{hand\ basin} + COD_{kitchen\ sink} * Vol_{kitchen\ sink} + COD_{Shower} * Vol_{Shower}$$

$$COD_H = \frac{COD_{toilet} * Vol_{toilet} + COD_{hand} * Vol_{hand} + COD_{kitchen} * Vol_{kitchen} + COD_{Shower} * Vol_{Shower}}{Vol_H}$$

Where;

COD_H : Total concentration of chemical oxygen demand for each house wastewater along the day

Vol_H : Total volume of wastewater for each house wastewater along the day

COD_{toilet} : concentration of COD in toilet wastewater in sample tested for each house

$COD_{hand\ basin}$: concentration of COD in hand basin wastewater for each house

$COD_{kitchen}$: concentration of COD in kitchen sink wastewater for each house

COD_{Shower} : concentration of COD in shower wastewater in sample tested

Vol_{toilet} : Total volume of toilet wastewater for each house wastewater

Vol_{hand} : Total volume of hand basin wastewater for each house wastewater

$Vol_{kitchen}$: Total volume of kitchen sink wastewater for each house wastewater

Vol_{toilet} : Total volume of shower wastewater for each house wastewater

COD concentration for the sewage wastewater is calculated:

$$COD_{tot} * Vol_{tot} = COD_{H1} * Vol_{H1} + COD_{H2} * Vol_{H2} + COD_{H3} * Vol_{H3} \dots \dots etc$$

$$COD_{tot} = \frac{COD_{H1} * Vol_{H1} + COD_{H2} * Vol_{H2} + COD_{H3} * Vol_{H3} \dots \dots etc}{Vol_{tot}}$$

2. Volatile Fatty Acid

The volatile fatty acid analysis was carried out using titrimetric method according to (Kapp, 1984; Kapp, 1992) (quoted by Buchauer, 1998). This method have simple procedures, which can be conducted with minimum effort, and does not require high investment in technical equipment which is commonly not available in laboratory and WWTP like Gas Chromatograph (GC) (Buchauer, 1998). Analysis description was reported Buchauer (1998) as follows:

- Before analysis the sample is filtered through a 0.45- μ m membrane filter.
- Filtered sample (20 ml) is put into a titration vessel, the size of which is determined by the basic requirement to guarantee that the tip of the pH electrode is always immersed below the liquid surface.
- Initial pH is recorded.
- The sample is titrated slowly with 0.1 N sulphuric acid until pH 5.0 is reached. The added volume of the titrant is recorded.
- More sulfuric acid with 0.02 N is slowly added until pH 4.3 is reached. The total volume of the added titrant is again recorded.
- The latter step is repeated until pH 4.0 is reached and the volume of added titrant recorded once more.
- A constant mixing of sample and added titrant is required right from the start to minimize exchanging of CO_2 with the atmospheric during titration.

Finally, VFA (as acetic acid) can be calculated from the following empirical equations (Eq. 3.1& 3.2) for variable acid normality N and variable sample volume as follows (Buchauer, 1998):

$$\text{VFA} = (131340 * \text{N}) * [\text{VA}_{(5-4, \text{ meas})} / \text{VS}] - (3.08 * \text{Alk}_{\text{meas}}) - 25 \quad (3.1)$$

$$\text{Alk}_{\text{meas}} = (\text{VA}_{(5-4.3, \text{ meas})} * \text{N} * 1000) / \text{VS}$$

Where:

VFA: Volatile Fatty Acid (mg/l), considered to be acetic acid.

$\text{VA}_{(5-4, \text{ meas})}$: measured volume of acid (ml) required for titrate a sample from pH 5.0 to pH 4.0;

VS: volume of a titrated sample (ml);

Alk_{meas} : measured alkalinity (mmol/L);

$\text{VA}_{(5-4.3, \text{ meas})}$: measured volume of acid (ml) required for titrate a sample from pH 5.0 to pH 4.3;

N: normality (mmol/L)

3. Ammonia ($\text{NH}_4^+\text{-N}$)

The amount of $\text{NH}_4^+\text{-N}$ was determined from paper-filtered samples by Nesslerization using spectrophotometer according to Standard Method (APHA, 1995). Sample absorbance was measured at 425 nm wavelength.

4. Total P as PO_4

To determine the amount of total phosphorous, raw wastewater sample was digested by auto-calving at 120°C for 30 minutes to achieve one bar pressure, according to Standard Methods (APH, 1995). Sample Absorbance was measured using spectrophotometer at 880 nm wavelength.

5. Ortho phosphate (PO_4^{3-} as P)

The amount of ortho-phosphate was determined from membrane-filtered samples according to Standard Methods (APHA, 1995). Sample Absorbance was measured using spectrophotometer at 880 nm wavelength.

6. Biological Oxygen Demand (BOD)

BOD_5 was determined in raw samples (before filtration), The BOD test measures the amount of dissolved oxygen organisms are likely to need to degrade wastes in wastewater. This test is important for evaluating both how much treatment wastewater is likely to require and the potential impact that it can have on receiving waters.

To perform the test, wastewater samples are placed in BOD bottles and are diluted with specially prepared water containing dissolved oxygen. The dilution water is also "seeded" with bacteria when treated wastewater is being tested. The amount of dissolved oxygen in the diluted sample is measured, and the samples are then stored at a constant temperature of 20 degrees Celsius (68 degrees Fahrenheit). Common incubation periods are five, seven, or twenty days. Five days (or BOD_5) is the most common. At the end of the incubation period, the dissolved oxygen is measured again. The amount that was used (expressed in milligrams per liter) is an indication of wastewater strength; Measurement was according to Standard Methods (APHA, 1995).

7. pH

It was determined for the total sample by pH meter (HACH). pH meter determined for each sample in the laboratory.

8. Temperature

Wastewater Temperature where determined for each sample when we get the sample, we use alcohol thermometer for that.

3.3.2 Pathogens identification

APHA (1995) methods for *Fecal coliform* identification was adapted the need for uniformity dictates the use of dehydrated media. Media was never prepared from basic ingredients when suitable dehydrated media are available, where the manufacture's direction for dehydration was followed. Commercially prepared media in liquid from solid media already made by rehydrate in water containing 10 ml 1% resolic acid in 0.2 N NaOH. Heat near boiling, promptly remove from heat, and cool to below 50 °C. If agar is used, Dispense 5-7 ml quantities to 50 x 12 mm Petri plate and let solidify. Final pH should be 7.4. Then store finished medium at 4-8 °C, Discard if not used for broth after 96 h or unused agar after 2 weeks. Cultures *Fecal coliform* after adequate sample dilution was made, then filtration by suction and culture for agar or broth and incubation for 45±0.2 °C for 24 h. Finally, the blue colonies are representing the *Fecal coliform* (Figure 3.1).

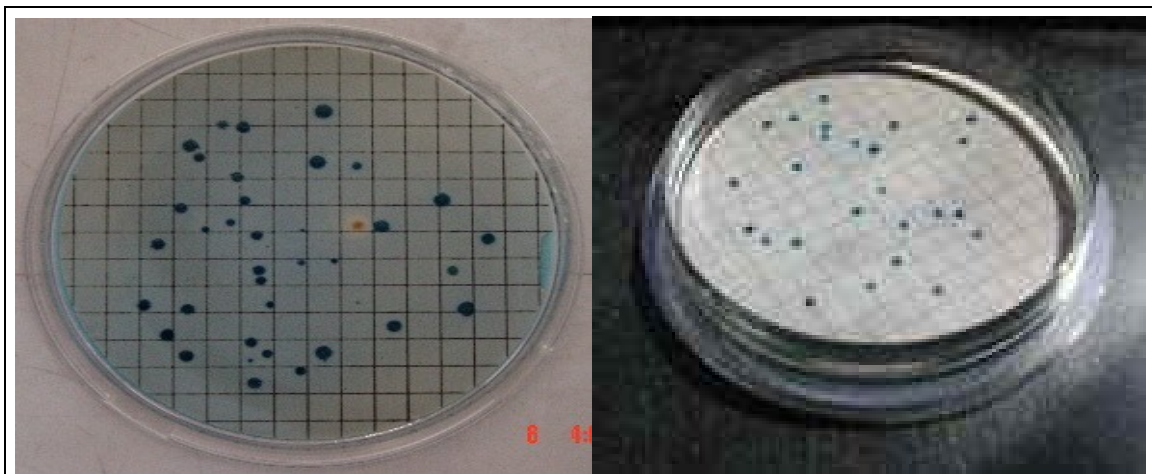


Figure 3.1. *Fecal coliform* after incubation for 24 h at 45±0.2 °C in which the blue colony indicate the *Fecal coliform*, (sample analyzed in two dilution as quality control sample).

3.3.3. Wastewater quantity determination

Wastewater load is different from one house to other depends on the life style, number of persons and enough water sources. Since individual water-using activities occur intermittently and contribute varying quantities of pollutants, the strength of the wastewater generated from a residence fluctuates with time. Accurate quantification of

these fluctuations is impossible. An estimate of the type of fluctuations possible can be derived from the pollutant concentration information. The activities included occur intermittently, we separated the effluent household wastewater such as wastewater from toilet flow in private tube and collected in special container and the same thing for wastewater flow from kitchen sink, hand basin and shower. When we have a volume of wastewater in the containers we get volume sample after mixing from each container separately and record the volume of wastewater in each on. This process covered the 24 hours since we get samples during the day and night. At the last of sampling the total volume of wastewater for each source taken and we get one sample for each source from the mixed samples during the day.

Chapter 4

Results and Discussion

4.1. Influent streams wastewater characteristics

All the experimental results for raw stream wastewater characteristics used in this research are presented in Table 4.1 during the period of the research, which lasted for six months from the first of January 2004 until the end of June 2004. This table shows the detailed information such as sample number and classified the characteristics of domestic household wastewater stream for toilet, kitchen sink, hand basin and shower. Clothes washing didn't enter our calculation where wastewater in the research not enters the sewer system.

The Five houses wastewater streams are classified as "high strength" according to the sewage strength classification proposed by Metcalf and Eddy (1991) in both toilet wastewater and kitchen sink. This also can be seen from the main values of COD_{tot} , BOD_5 , phosphorus and ammonia. Most of literatures refer to that the high strength in the character of household wastewater can be attributed to low water consumption in the region due to the inadequate water resources and low living standard, people's habits and shortage of water supply in most of Palestinian villages where Israel controls 80% of Palestinian Water.

These main values of characteristic household wastewater are in close agreement since the five houses are in the same area and have the same style of life. Despite of that each house has its own specialty. There are many factors that decided the characters of household wastewater quality and quantity like water consumption, numbers of the person in the house, water supply, life style and type of detergent using in the kitchen sink.

Table 4.1. Characteristic of domestic household wastewater streams for five houses located in Anata and Hizma from Palestinian villages

Parameter	# of Samples	Range	AVR	STD
COD Total	120	1329-2143	1802	316.7
Suspended	120	876-1400	1167	191.6
Colloidal	120	76-155	125	34.8
Dissolved	120	378-602	510	107.5
VFA	120	156-287	214	40.3
NH ₄ ⁺ as N	120	295-529	105.4	29.4
Total PO ₄ as P	120	23.4-46.9	33.2	5.4
PO ₄ ³⁻ as P	120	8.4-32.6	17.8	1.5
BOD ₅	120	652-915	809	103
COD/ BOD ₅	120	1.86-2.59	2.23	0.14
pH	120	6.82-8.17	7.49	0.4
T _{ww}	120	16.4-27.7	22.2	3.1
Effluent Wastewater	120	31.2-33.6	32.5	1.5
<i>Fecal Coliform</i>	120	-	1.9x10 ¹¹	0.71

*All parameter are in mg/l except: wastewater temperature (T_{ww}); pH no unit; Effluent wastewater in l/c.d; *fecal coliform*: CFU/100ml.

*Each measurement is calculated from measures the specific parameter for toilet, hand basin, kitchen sink and shower.

4.2. Biochemical parameters and wastewater flow

4.2.1 Chemical Oxygen Demand (COD)

Chemical Oxygen Demand (COD) is a measure of the biochemical degradable content of the organic matter in wastewater. In general, the COD values are higher than the BOD values, this, because more compounds can chemically oxidize than can be biologically degraded. Toilet and kitchen sink wastewaters are much polluted and has high concentration of solids.

Wastewater treatment depends strongly on the size distribution of the pollutants, since the predominant removal mechanisms of most processes -physical, chemical or biological- for treatment of wastewater contaminants are related to particle size distribution (Levine *et al.*, 1985; Qdegaard, 1999). In this research, the size distributions of contaminants were divided into three fractions: suspended (COD_{sus}) which is the large fraction, COD_{col} and COD_{dis} fractions it hasn't been degraded in the sewerage system since the distance is very short between the contaminate source and sampling point, explaining high concentrations observed for these fractions.

The experimental results of COD fractions in toilet and COD fractions in kitchen sink which is the higher COD are summarized in Table 5.1 and Table 5.3 in the appendixes for the five houses. The suspended, the colloidal and dissolved fractions were in the ranges: 62-68%, 6-10% and 24-29% of total COD for toilet, 59-70%, 4-7% and 24-34% of total COD for kitchen sink, respectively. Therefore, the main fraction of COD in the wastewater generated from the studied five locations exists in the particulate form.

From the given results COD_{sus} fraction is the highest percent of COD_{tot} in both toilet and kitchen sink wastewater for all the houses. COD_{sus} percent is close to each other for all houses with some variation and the same thing for COD_{col} and COD_{dis} . This shows the similarity in wastewater characteristics in Palestinian houses that depended on the life styles and the food customs in Palestinian villages; this reflected on the COD of toilet and kitchen sink wastewater.

For COD fraction, the colloidal fraction is the smallest for the five locations this gives an advantage of the wastewater anaerobic treatment, since the colloidal particles in domestic sewage is very difficult to remove and represented up to 60-70% of effluent of the anaerobic fluidized bed reactor according to Yoda *et al.* (1985). The low removal of colloidal particles during the anaerobic treatment of domestic sewage was due to the low adsorption and entrapment and not due to low biodegradability. Therefore, the anaerobic effluent should be further treated in case further reduction of COD is required.

In hand basin and so for shower wastewater which is described to be low pollution, the COD_{sus} fraction is the highest percent of COD_{tot} fractions which summarized in Table 5.2 and Table 5.4 in the appendixes for the five houses. We can see there is low concentration in COD in the two wastewater that related directly to lower pollution in the two wastewater, and there is lower pollution from organic substance which cause higher in COD as shown in toilet and kitchen sink wastewater, this lower concentration in COD help us in putting new planning and strategies to use this wastewater in irrigation with out too treatment since the volume of pollution in this wastewater is low and can be uses in garden of our house.

The suspended, the colloidal and dissolved fractions were in the ranges: 63-71%, 6-13% and 21-25% of total COD for hand basin, 57-77%, 8-12% and 15-31% of total COD for shower, respectively. The percent of COD_{sus} from hand basin and from shower for the five houses is near to each other with some variation and so its for COD_{col} and COD_{dis} . This nearest in the percent of COD fraction for the five houses wastewater from hand basin and shower is usually, since hand basin and shower in general using to wash and its similar for alls, there's no high pollution and at same time there's high dilution (Table 5.2 and Table 5.4). The other reason is that wastewater didn't take much time to be mixed as we take sample directly from the tube of sink and shower. Values of COD fractions express about the empirical COD from sources.

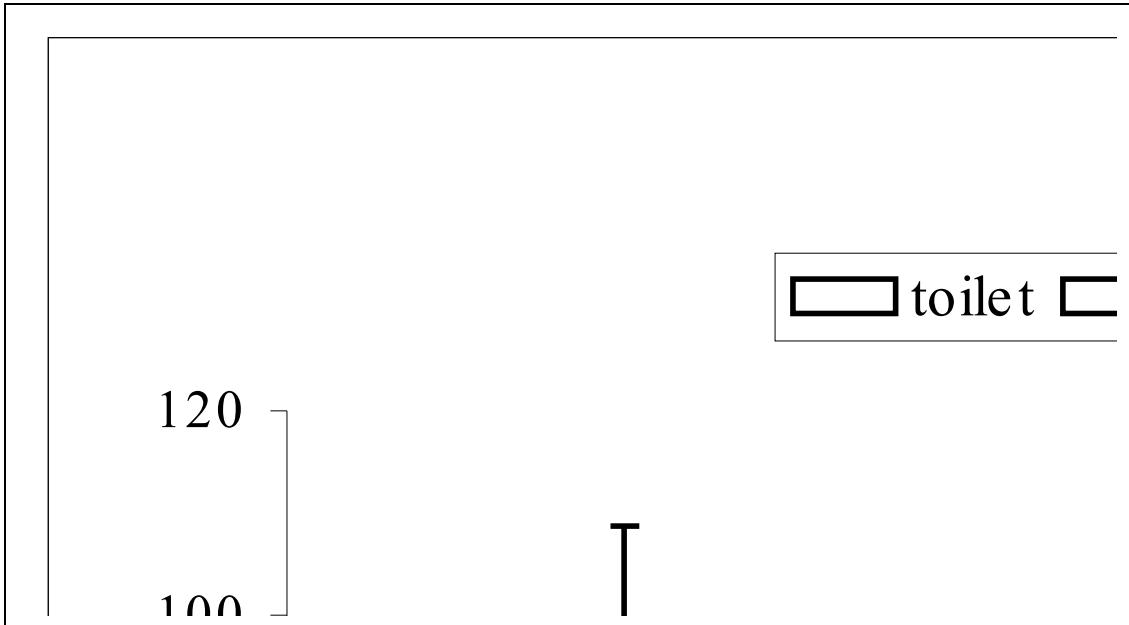


Figure 4.1. COD average for five houses and wastewater quantity assessed over the study period.

Each column represents the effluent total COD from each source of contaminant in domestic wastewater (Figure 4.1). For each house one can see that total COD produced from hand basin and from shower is very small compared with total COD produced from toilet and kitchen sink due to lower organic matter in these sources of pollution. So, we can say the one who responsible about the pollution in domestic wastewater is toilet and kitchen sink in first degree. COD specific production is very high in kitchen sink with an average of 84.9 (22.5) g/c.d and so in toilet wastewater with average of 59.5 (16.8) g/c.d.

COD high in wastewater from toilet in all houses due to the high organic matter in wastes and for the low in the volume of water used for flushing (Table 5.1 in appendix and Figure 4.1). But the question is why it's high in the kitchen sink wastewater in all houses of our experiment? The same thing in all houses in Palestine, this question can be answered by this research; the reason is that kitchen sink used for flushing food wastes, oil and vegetable wastes that make kitchen sink an important pollutant in domestic wastewater. COD from hand basin and shower have the same range for all houses, it didn't play real effect on polluted wastewater, so we can reuse this

wastewater on home like toilet flushing and in irrigation for our garden since it needs a simple treatment and haven't any risk effect.

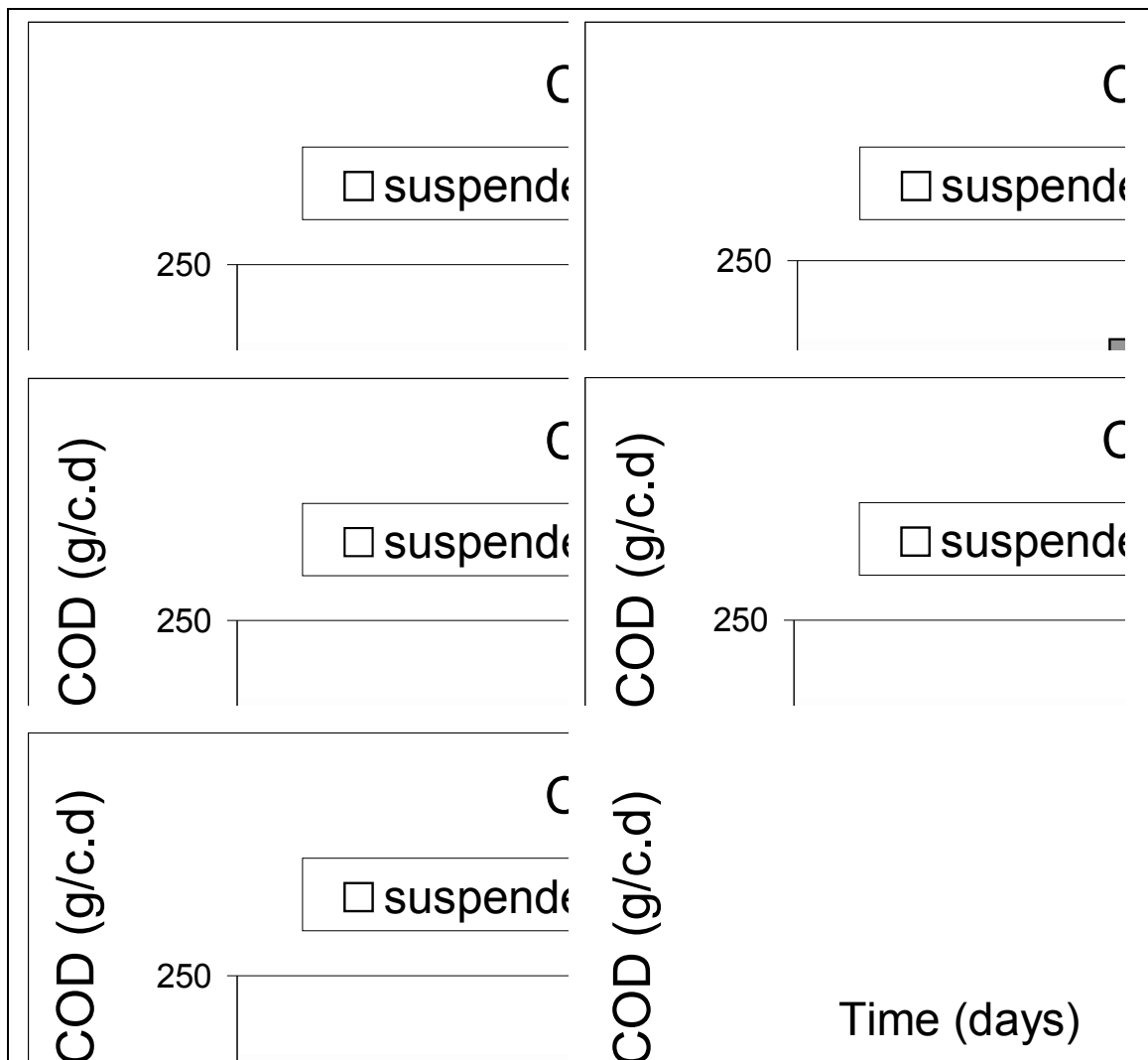


Figure 4.2. Evolutions of the concentrations COD fractions (COD_{ss} , COD_{col} and COD_{dis}) in effluent wastewater for five houses assessed over the study period.

Figure 4.2 shows the effluent sewage of COD specific production per capita per day for the five houses. This figure shows that the COD specific production from H1, H2, H3, H4 and H5 are 166.1(14.9), 182.5(29.1), 178.6(13.6), 154.6(32) and 128.8(17.9) g/c.d, respectively. It's higher for all houses due to life style since there are some through to the food wastes in there kitchen sink that caused the highly in COD produced (show Table 5.5 in appendix).

Time (days)

For the effluent domestic wastewater from the houses we see that COD_{ss} in the raw sewage constitutes a high fraction about 64.9% of the COD_{tot} which is about 1167(191.6) mg/l. This percentage is higher than the values reported in literature for domestic sewage which were found to be in range of 45-55% (Kalogo and Verstraete, 1999; Elmitwalli, 2000) and slightly higher than the 58% proportion found by Mahmoud *et al.* (2003) also for the sewage from Al-Bireh City, and more than the value that was reported by Al-Shayah, (2005) about 53.8% during the summer period and Al-Jamal, (2005) about 43.7%. COD_{col} represent 6.8% of the COD_{tot} in raw sewage, lower than 20-30% proportion cited by Elmitwalli (2000) for the sewage from Bennekom-The Netherlands and slightly lower than the 10% proportion reported by Halalsheh, (2002) for the sewage from Amman City- Jordan. And it's lower than Al-Shayah about 15.3% and Al-Jamal about 14.9%.

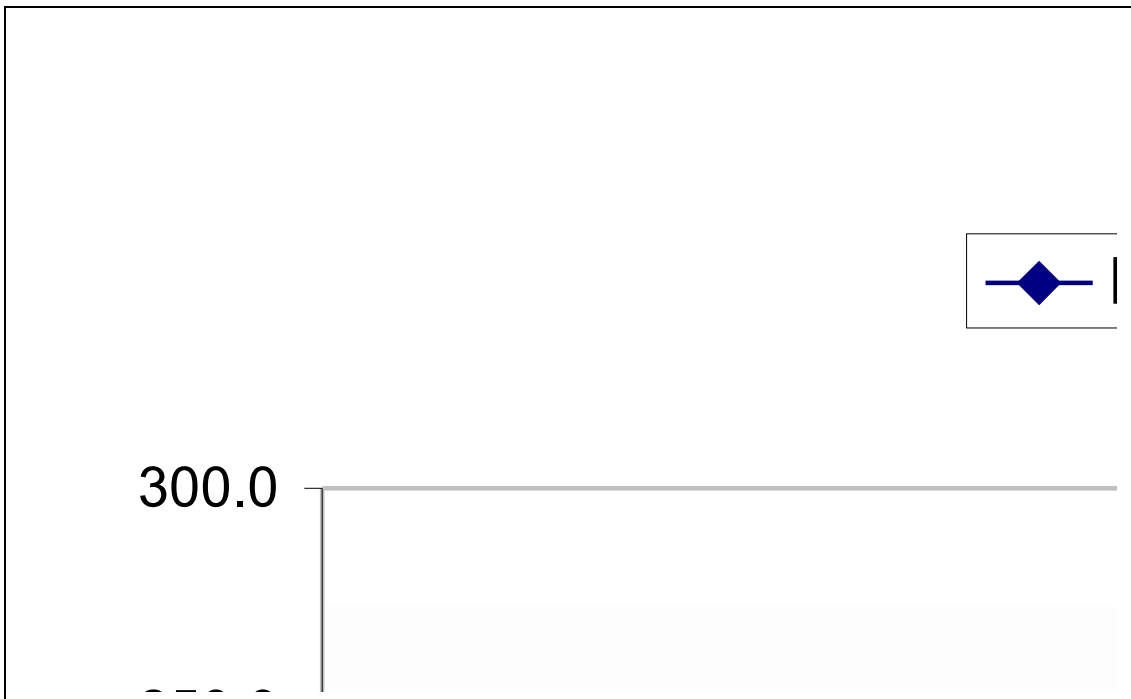


Figure 4.3. Evolutions of the concentrations COD in effluent wastewater and temperature of the air for five houses assessed over the study period.

The results also reveal that main fraction of COD in the raw sewage is particulate (suspended and colloidal), which is represented 71.7% of the total COD and close to the value about 70% that was founded by Wang (1994) in domestic sewage, and close to

CODtot (g/e.d)

the values founded by Mahmoud (2002) for Ramallah, Al-Bireh and Al-Jalazoon which is 65%, 75% and 71%, respectively. And close to the values that was reported by Al-Shayah, (2005) about 69% during the summer period and higher than values reported by Al-Jamal, (2005) about 59% for the influent raw sewage to Al-Bireh WWTP. The percentage of the other fraction of the COD_{tot} was 28.2% for COD_{dis} in raw sewage close to the values founded by Mahmoud (2002) for Al-Bireh and Al-Jalazoon which is 28%, 29%, respectively, but lower than reported for Ramallah which about 35%. Where Al-Shayah, (2005) and Al-Jamal (2005) reported COD_{dis} for the influent raw sewage to Al-Bireh WWTP are about 31% and 39%, respectively.

Figure 4.3 shows the effluent amount of COD_{tot} in terms of g/c.d for all houses during the whole period of the research. The Figure 4.3 gives COD_{tot} concentration in unit g/c.d to give clear picture about the reason for the high pollution in wastewater in Palestine, the variation of COD_{tot} between day and other at community level is high for most of houses. These variations constitute the typical characteristics of wastewater at community level, small system flow rates and wastewater characteristics differ significantly from those of large systems (Metcalf & Eddy, 1991). The average COD_{tot} specific production for all houses is 162.1(21.6) g/c.d. This value in the range of values reported by Mahmoud *et al.* (2002) for Al-Bireh and for Ramallah which about 155-202 g/c.d and 166-418 g/c.d, respectively.

The effluent concentration of COD_{tot} for all houses during the whole period of the research was about 1802(316.7) mg/l. It's slightly larger than measured of COD for sewage wastewater due to high contaminant with organic compound from toilet and kitchen sink with low dilution for wastewater (see table 5.1; table 5.3 in appendixes). Mahmoud *et al.* (2003) found COD for Ramallah, Al-Bireh and Al-Jalazoon to be about 2180 mg/l, 1586 mg/l and 1489 mg/l, respectively. Al-Shayah (2005) reported for the influent raw sewage to Al-Bireh WWTP which about 1189 mg/l during summer and the values found by Al-Jamal (2005) about 905 mg/l during winter time. Samhan (2005) found COD to be 1224 mg/l.

In other way, compared COD produced for the houses didn't show large variation from house to other and the values are close to each others with some variation. This is because we talk about the same region and people have same life style, water consumption and flushing food wastes in kitchen sink; this is nearly similar for all. On other hand, suffering in availability of water where Israel controls 80% of water resources in Palestine, this was reflecting on the wastewater production.

We can't say that pollution with COD for the houses is described to be increased or decreased with time, since this research during the winter and spring time where same condition and no high changed in inhabitant adaptation and life style in consuming water or changed in volume of pollution with COD. We need to continue this research to cover the summer time to show what happen in the pollution of COD in all of wastewater pollution sources. What saying about COD is necessary for other wastewater characteristics, this need to show the full load of wastewater pollution from houses to help us planning and putting strategies for how can we benefit from wastewater that originates from different sources, and the volume of pollution in each; to get real knowledge about our wastewater pollution in Palestine. If we can used some of this wastewater with simple treatment in our houses like toilet flushing or irrigation of our plants in garden and which wastewater needs treated before reused.

The largest sources of COD pollution are toilet and kitchen sink wastewater with 59.5(16.8) g/c.d and 84.9(22.5) g/c.d, respectively (Figure 4.1). We can say it's the source of pollution for COD in the residential wastewater, where we look to treat it in non-central treatment plant, built small plant in villages to treated wastewater comes only from toilet and kitchen sink since other wastewater have low COD concentration and can reuse it at house level in different function like irrigation for garden and for toilet flushing.

4.2.2 Volatile Fatty Acid (VFA)

The average concentration of the Volatile Fatty Acid (VFA) in effluent wastewater for all houses presented in table 4.1 is about 214 (35.1) mg/l. Mahmoud *et al.* (2003) found that average value of the VFA as COD in the raw sewage enters Al-Bireh WWTP was about 160 mg/l. Likewise, Halalsheh (2002) showed the concentration of VFA as COD around 150 mg/l in the influent sewage to Abu-Nusier WWTP in Jordan. The same thing found by Al-Shayah (2005) for the influent raw sewage to Al-Bireh WWTP which about 151 mg/l during summer time but more than values found by Al-Jamal (2005) about 99 mg/l during winter time where the VFA concentration affected by temperature, the production of VFA decreased during the winter period comparing to the results obtained by Al-Shayah (2005).

Table 4.2 Percentage of hydrolysis, acidification of total COD and acidification of dissolved COD effluent wastewater in villages-Palestine, for Al-Bireh WWTP and Abu-Nusier WWTP-Jordan

	Parameter	Palestine ⁽¹⁾ Villages	Palestine ⁽²⁾ Al-Bireh	Palestine ⁽³⁾ Al-Bireh	Jordan ⁽⁴⁾ Amman
Acidified fraction	VFA/COD _{tot}	12.6	12.7	10	9.4
Acidified of dissolved	VFA/COD _{dis}	45	41.1	36	40
Hydrolyzed fraction	COD _{dis} /COD _{tot}	28.2	30.9	28	23.5

(1), this study; (2), Al-Shayah (2005); (3), Mahmoud *et al.* (2003); (4), Halalsheh (2002)

The VFA/COD_{tot} and the VFA/COD_{dis} ratio that found in this research for raw sewage were 12.6(4), 45(14.2), respectively (Table 4.2). These values reported are closed for values reported by Al-Shayah (2005) and the values reported by Mahmoud *et al.* (2003) for the raw sewage enters Al-Bireh WWTP. This also closed for values reported by Halalsheh (2002) for the influent sewage to Abu-Nusier WWTP in Jordan.

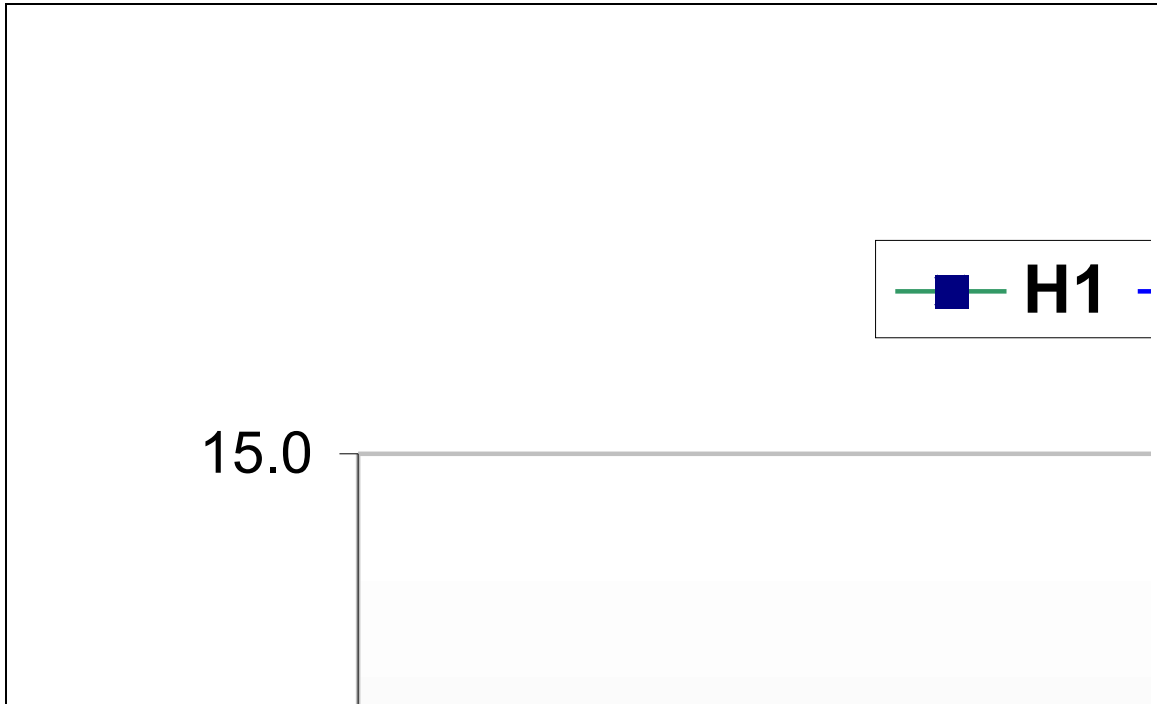


Figure 4.4. The evolution of the concentration VFA for the effluent sewage and temperature of the air for five houses assessed over the study period.

The results of Volatile Fatty Acids (VFA) concentrations for effluent wastewater from the five houses during the whole period of the experiment shown in the Figure 4.4 where the average concentration for VFA at the effluent for H1, H2, H3, H4 and H5 is about 260(20) mg/l, 235(29) mg/l, 209(39) mg/l, 196(24) mg/l and 169(14) mg/l, respectively. The concentration of the VFA represent about 42% from the COD_{dis} so nearly half of the COD_{dis} was in the form of non-acidified COD_{dis} , for some houses there is some variation in VFA concentration since this research was conducted during winter and spring time. There are variations in temperature where the production of VFA decreased during winter period. The lower in VFA concentration for some houses than other might be due to the difference in people habits. The average VFA specific production for H1, H2, H3, H4 and H5 are 8.3(1.3) g/c.d, 7.8(1.1) g/c.d, 6.9(1.4) g/c.d, 6.1(0.9) g/c.d and 5.7(0.6) g/c.d, respectively (Figure 4.5). From this we can see the lower in VFA concentration for the last two houses than other this due to the difference in people habits. From there, we can see stability in VFA concentration along period of the research for each one house. The VFA concentration for raw wastewater for all houses about 7(1.1) g/c.d.

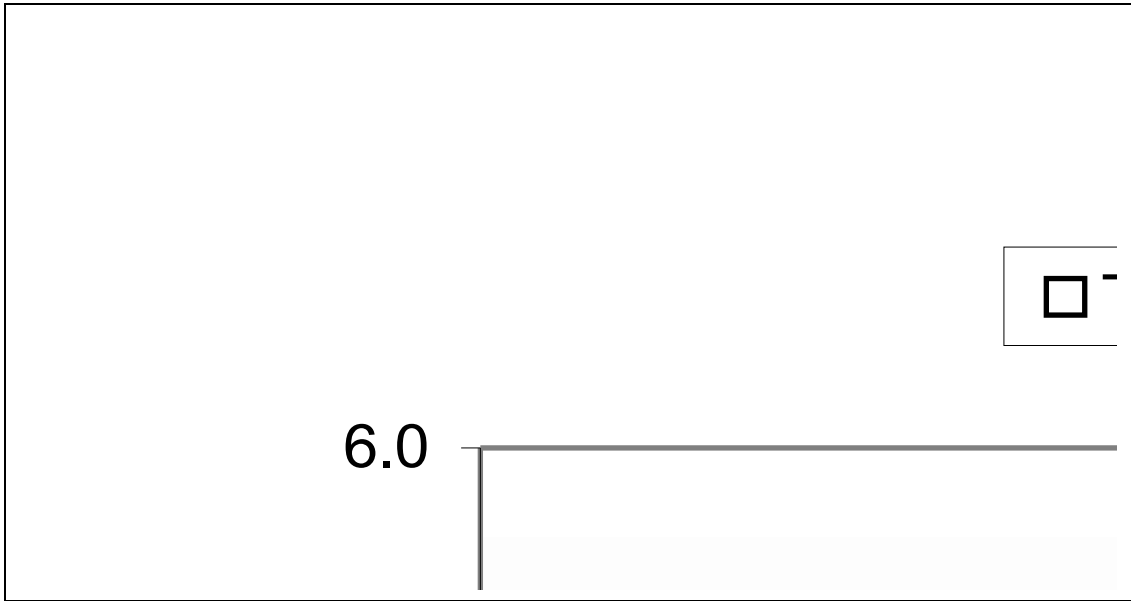


Figure 4.5. Volatile fatty acid effluent concentrations for five houses assessed over the study period.

4.2.3 Ammonia ($\text{NH}_4^+\text{-N}$)

The concentration of ammonia ($\text{NH}_4^+\text{-N}$) for the raw sewage wastewater in five houses is about 105.4(29.4) mg/l (Table 4.1). Where Mahmoud *et al.* (2003) reported that average value of the ammonia in the raw sewage for Ramallah city, Al-Bireh city and Al-Jalazoon camp was about 58 mg/l, 80.1 mg/l and 56.2 mg/l, respectively. The same thing found by Al-Shayah for the influent raw sewage to Al-Bireh WWTP which about 58.9 mg/l during summer time and values founded by Al-Jamal (2005) about 39 mg/l during winter time. This higher in the concentration of ammonia is due to low water consumption in the study area.



Figure 4.6. The NH₄⁺-N effluent concentration for five houses assessed over the study period.

The main source of NH₄⁺-N in domestic wastewater is from toilet, since the wastewater in our research is domestic; it has highest concentration of NH₄⁺-N. Butler *et al.* (1995) found that toilet is particular major contributor of ammonia in domestic wastewater. In this research we reached the same result, the concentration of ammonia comes from toilet is the highest of all, the average ammonia concentration for the five houses that comes from toilet alone is 53.6-120.5 with average 92.7(27.1) mg/l (Figure 4.6). While it's for hand basin, kitchen sink and shower about 0.5-0.7, 0.6(0.1) mg/l; 4.4-13.5, 8.8(3.3) mg/l and 0.5-2.7, 3.2(5.3) mg/l, respectively (Figure 4.6).

The concentration of ammonia in wastewater of hand basin for all the houses is very low, it's usually; since hand basin used only for washing hands and face. The main source for the ammonia is from some chemicals used for cleaning or using soaps. For the ammonia concentration from kitchen sink the concentration is slightly high than hand basin due to using detergents and soaps and there are food waste. The kitchen sink wastewater contributes the highest levels of ammonia to the grey wastewater (concentration range 4.4-13.5, 8.8(3.3) mg/l), its in the range of ammonia concentration for kitchen sink that reported by Eriksson *et al.* (2002) which in range <0.05-25 mg/l that compared to 12-50 mg/l reported by Henze *et al.* (2001).

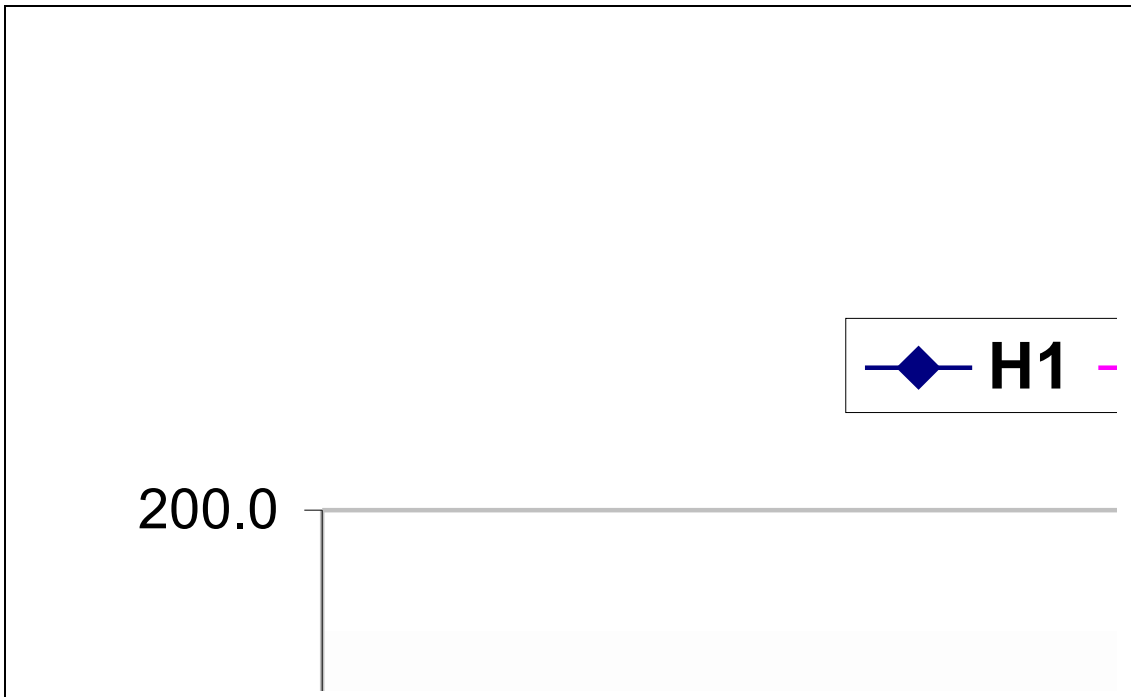


Figure 4.7. The evolution of the concentration $\text{NH}_4^+\text{-N}$ for the effluent sewage and temperature of the air for five houses assessed over the study period.

On the other hand, specific production of ammonia per person per day for H1, H2, H3, H4 and H5 that comes from toilet are 6.7(0.7) g/c.d, 7(2.1) g/c.d, 9(1.3) g/c.d, 10(1) g/c.d and 8.1(1.1) g/c.d, respectively. From these results we show that the main source of ammonia is from faeces and urine. Values of $\text{NH}_4^+\text{-N}$ specific production are close for all houses. Figure 4.7 shows the variation of the $\text{NH}_4^+\text{-N}$ concentration where this research was conducted during winter and spring time with variation in temperature that affect on $\text{NH}_4^+\text{-N}$ concentration.

4.2.4 Total PO_4 as P

Washing detergents are the primary source of total PO_4 as P found in grey wastewater (hand basin, kitchen sink and shower), in countries that have not yet banned phosphorus-containing detergents, concentration between 6 and 23 mg/l. Total PO_4 as P can be found in traditional wastewaters in area where phosphorus detergents are used Eriksson *et al.* (2002).

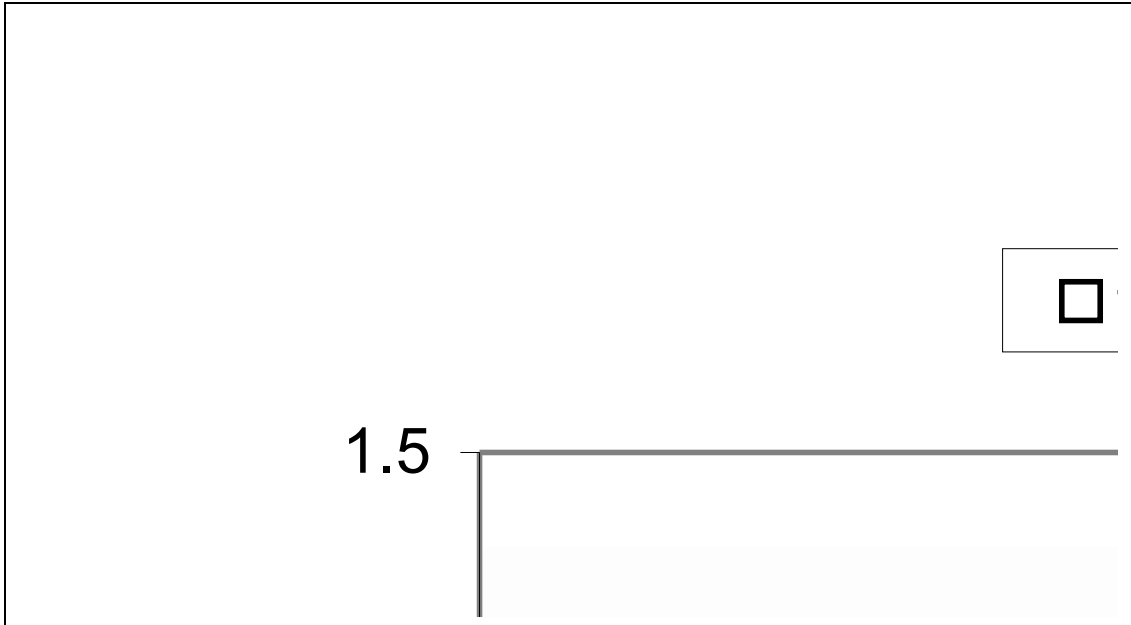


Figure 4.8. Total PO₄ as P effluent concentration for five houses assessed over the study period.

This research shows the main source of total PO₄ as P in household wastewater is effluent from toilet it share about 84.3% of total PO₄ as P. The average concentration of the total PO₄ as P of the effluent wastewater for all houses is about 33.2(5.4) mg/l (Table 4.1). Mahmoud *et al.* (2003) found that average value of the total PO₄ as P in the raw sewage for Ramallah city, Al-Bireh city and Al-Jalazoon camp was about 12.8 mg/l, 13 mg/l and 15 mg/l, respectively. These values near for what Al-Shayah found for the influent raw sewage to Al-Bireh WWTP which about 14 mg/l during summer time and slightly higher than values found by Al-Jamal (2005) about 10 mg/l during winter time. These values are also higher than 18 mg/l reported by Elmitwalli (2000) for raw wastewater in Bennekom village, Netherlands. Orhon *et al.* (1997) reported the concentration total PO₄ as P for rural areas in Egypt about 8.9 mg/l. From these values of concentration total PO₄ as P our result is too high than all where no high dilution for total PO₄ as P in domestic wastewater (see table 5.5 in appendix). Use of chemical household products and the quality of the water supply controls the rising in concentration of total PO₄ as P.

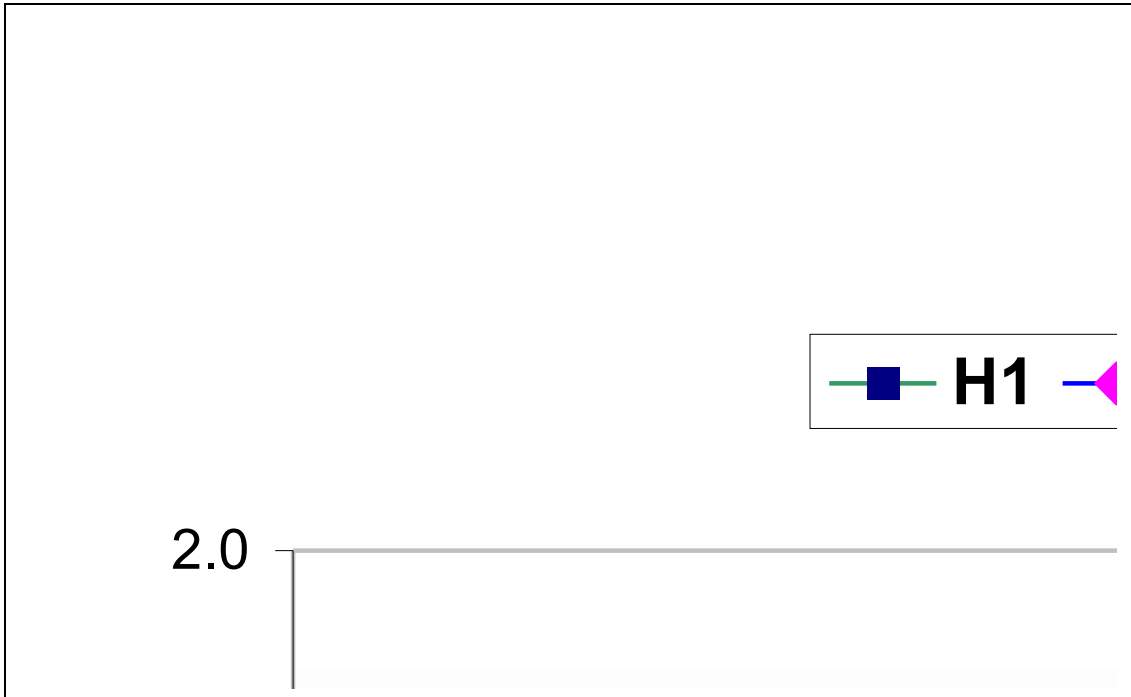
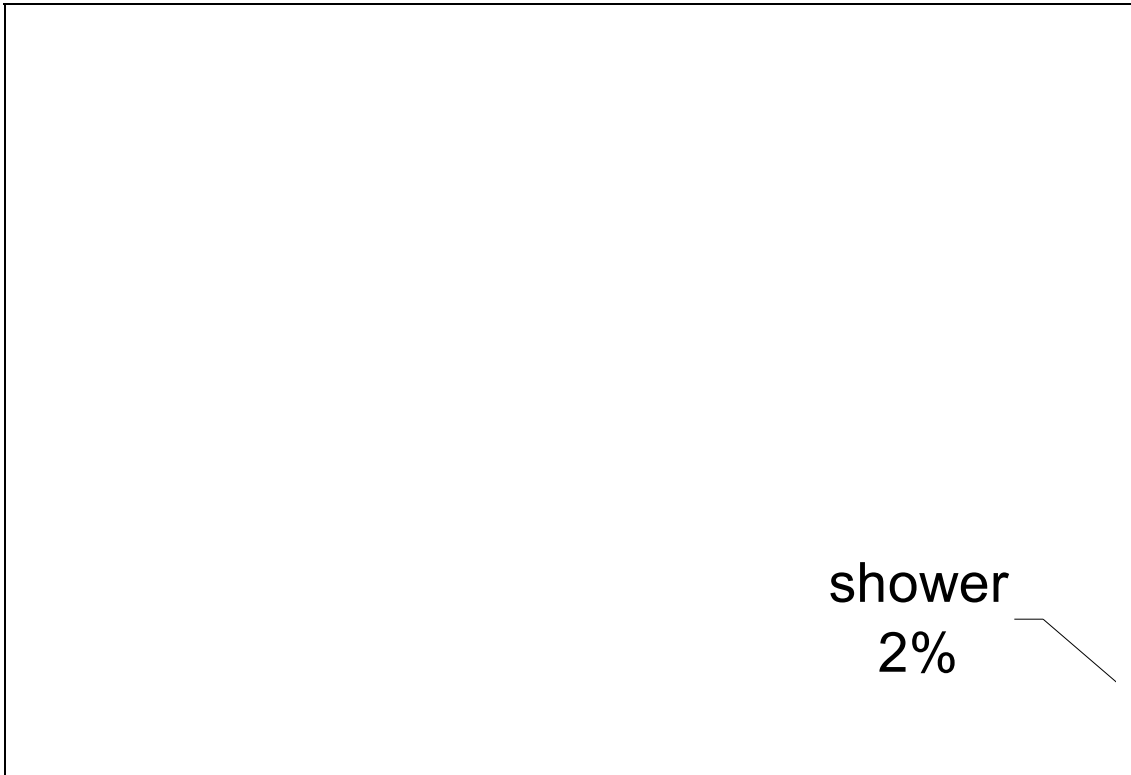


Figure 4.9. The evolution of the concentration total PO_4 as P for the effluent sewage and temperature of the air for five houses assessed over the study period.

The specific production of total PO_4 as P per person per day for H1, H2, H3, H4 and H5 are about 0.9(0.1) g/c.d, 1.2(0.25) g/c.d, 1(0.15) g/c.d, 1(0.05) g/c.d and 1.4(0.15) g/c.d, respectively (Figure 4.8). The average concentration of total PO_4 as P is about 1.1(0.2) g/c.d, its in the range for total PO_4 as P reported by Mahmoud *et al.* (2003) for the raw sewage in Ramallah city and Al-Bireh city, which are in the range 0.7-1.9 (g/c.d) and 0.9-1.6 (g/c.d), respectively. From these results we show that the main source of total PO_4 as P is faces and urine. Figure 4.9 show clearly that grey wastewater in our research has a few concentration of total PO_4 as P. Toilet is the main source for total PO_4 as P it depends on the life (Figure 4.10).



Percent

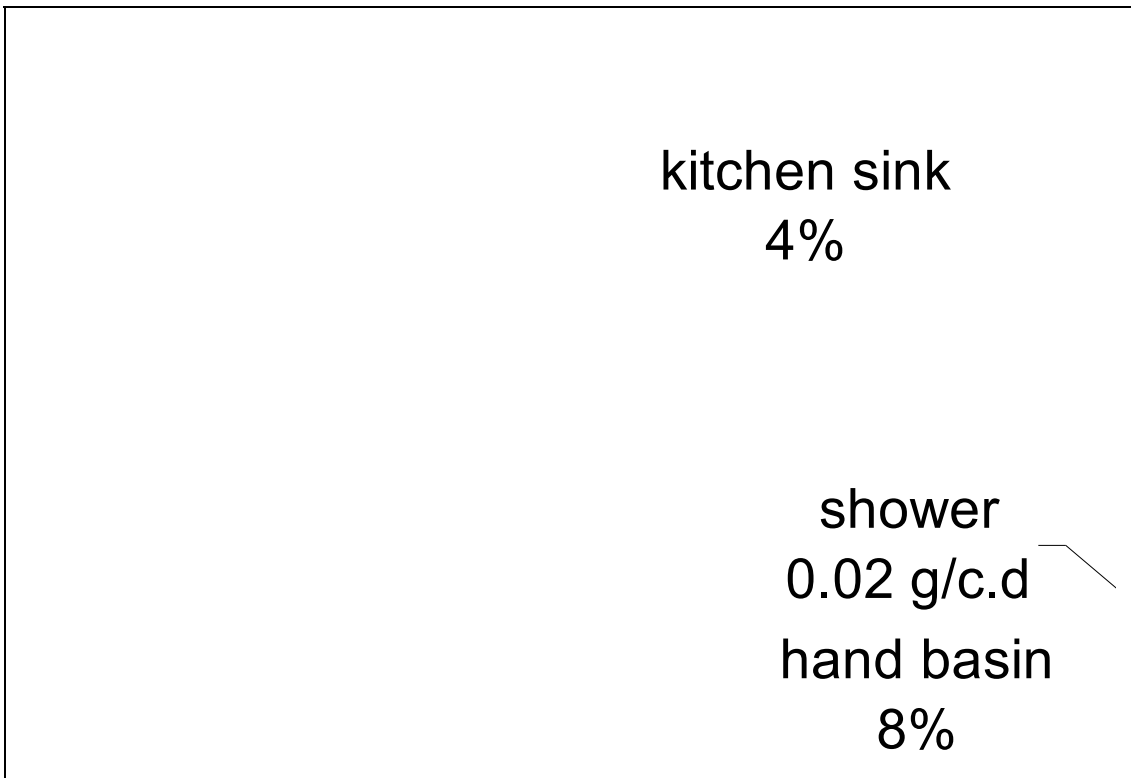


Figure 4.10. (a) The percentage of total PO_4 as P from the various household wastewater streams and (b) The amount of total PO_4 as P in g/c.d from the various household wastewater streams for two houses assessed over the study period.

4.2.5 Ortho phosphate (PO_4^{3-} as P)

kitchen sink
0.07 g/c.d

From table 4.1 ortho phosphate is lower than total PO_4 as P, this result didn't conformity with Mahmoud *et al.* (2003) who reported that total PO_4 as P are approximately equal the values of ortho-phosphate. It can explain that most portion of total phosphate is in soluble, since this wastewater is domestic wastewater and mainly comes from feces and urine which are rich in phosphorus compounds.

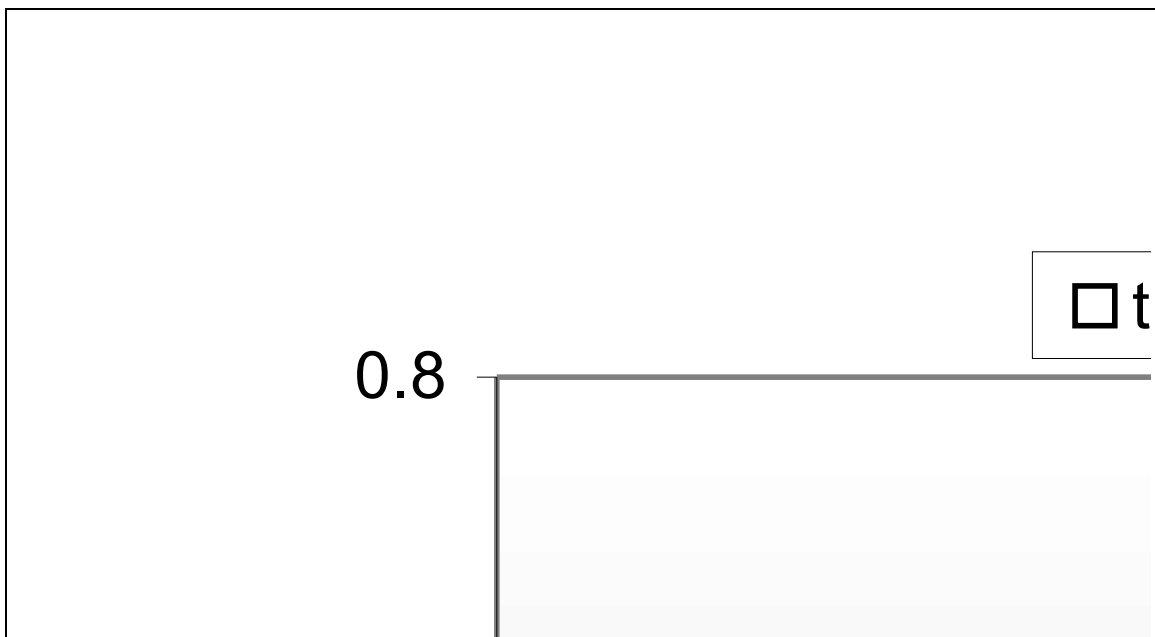


Figure 4.11. The PO_4^{3-} as P effluent concentration for five houses assessed over the study period.

The average concentration of the ortho-phosphate (PO_4^{3-} as P) of the effluent wastewater for the all houses presented in table 4.1 is about 17.8(5.6) mg/l. This value is slightly higher than values reported by Mahmoud *et al.* (2003) for Ramallah city, Al-Bireh city and Al-Palazoon camp which about 12.4(3.8) mg/l, 12.9(2.6) mg/l and 11.9(2.4) mg/l, respectively. Al-Shayah (2005) found the concentration of ortho-phosphate to be 12.6(1.14) mg/l during the summer time, but Al-Jamal found the concentration of ortho-phosphate during winter time to be 8.4(4) mg/l. For the neighbor countries; Orhon *et al.* (1997) reported the concentration of ortho-phosphate about 3.87 mg/l for rural areas in Egypt, while Tawfik (1988) reported about 4.5 mg/l for Istanbul in Turkey. From these values the wastewater in Palestine is rich with ortho-phosphate than other neighbor's countries. It's slightly higher than Elmitwalli (2000) who reported

about 14 mg/l for Bennekom village-Netherlands. This rising in the ortho-phosphate concentration in our research may be due to lower in dilution factor in addition to the life style.

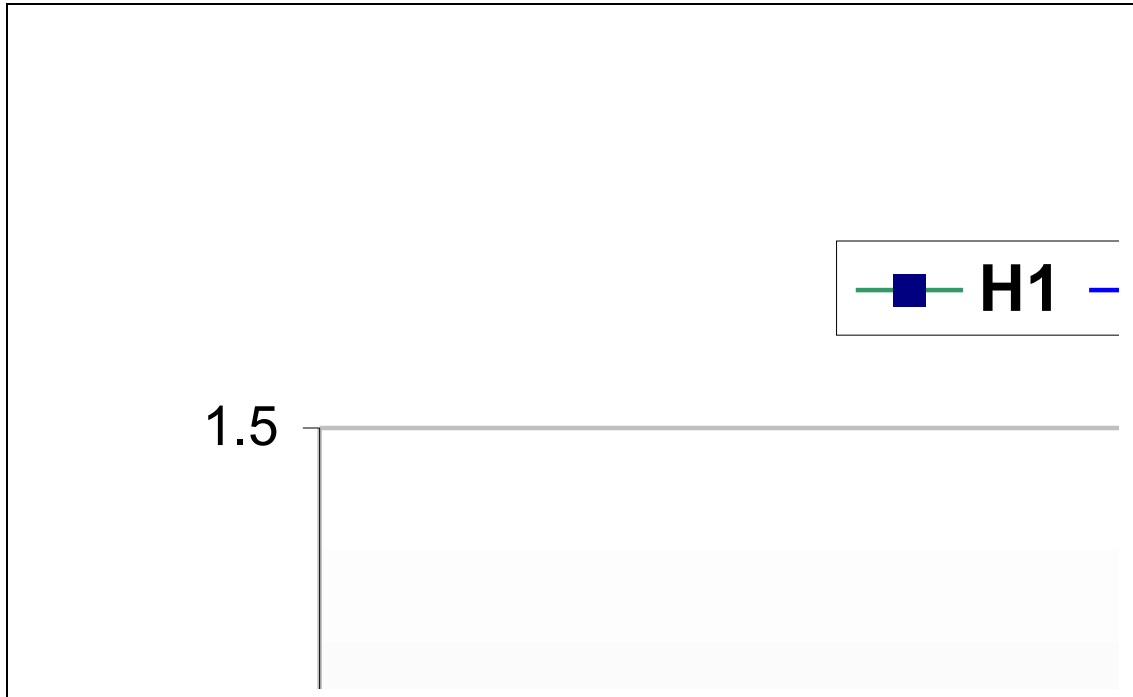


Figure 4.12. The evolution of the concentration PO_4^{3-} as P for the effluent sewage and average temperature of the air for five houses assessed over the study period.

Figure 4.13 shows some variation in concentration of ortho-phosphate during the research period due to variation in water consumption (dilution factor) and life style in foods and using detergents containing phosphorus. The unusually high values may refer to the using high detergent in the day of sample for cleaning the house, like, what shown after 28 days of research period for H4 and after 95 days for H3 and H5.

Ortho-phosphate specific productions for H1, H2, H3, H4 and H5 are 0.6(0.08) g/c.d, 0.5(0.22) g/c.d, 0.6(0.25) g/c.d, 0.5(0.19) g/c.d and 0.7(0.14) g/c.d, respectively. Like total PO_4 as P; ortho-phosphate main concentration source is from faeces and urine. The average ortho-phosphate concentration is about 0.6(0.08) g/c.d.

4.2.6. BOD₅

BOD₅ specific production in the research for community wastewater is slightly high. There is enough organic matter in household wastewater especially from faeces in toilet wastewater streams and from kitchen sink wastewater streams. Throwing food wastes, oils and vegetable wastes in kitchen sink produce this highly in BOD₅. These make kitchen sink to be described as the rubbish for food wastes in several houses.

Measurements of biological oxygen demand (BOD₅) specific production for community wastewater are in a range of (652-915) mg/l. For wastewater from toilet is between 187-422 mg/l. There are differences between the various grey wastewater fractions; the hand basin is about (54-87) mg/l, the kitchen sink is between (286-478) mg/l and shower is between (24-38) mg/l. Where the mixed grey wastewaters are ranges between (373-571) mg/l. These findings illustrate that the different types of grey wastewater could be suitable for different types of reuse, and there will be different needs for pre-treatment depending on both the types of grey wastewater and the intended use of the water.

The concentration of biological oxygen demand (BOD₅) for the raw sewage wastewater is about 809(103) mg/l. Where Al-Shayah reported BOD₅ for the influent raw sewage to Al-Bireh WWTP is about 616(81.3) mg/l during summer time and values found by Al-Jamal (2005) is about 502(133) mg/l during winter time.

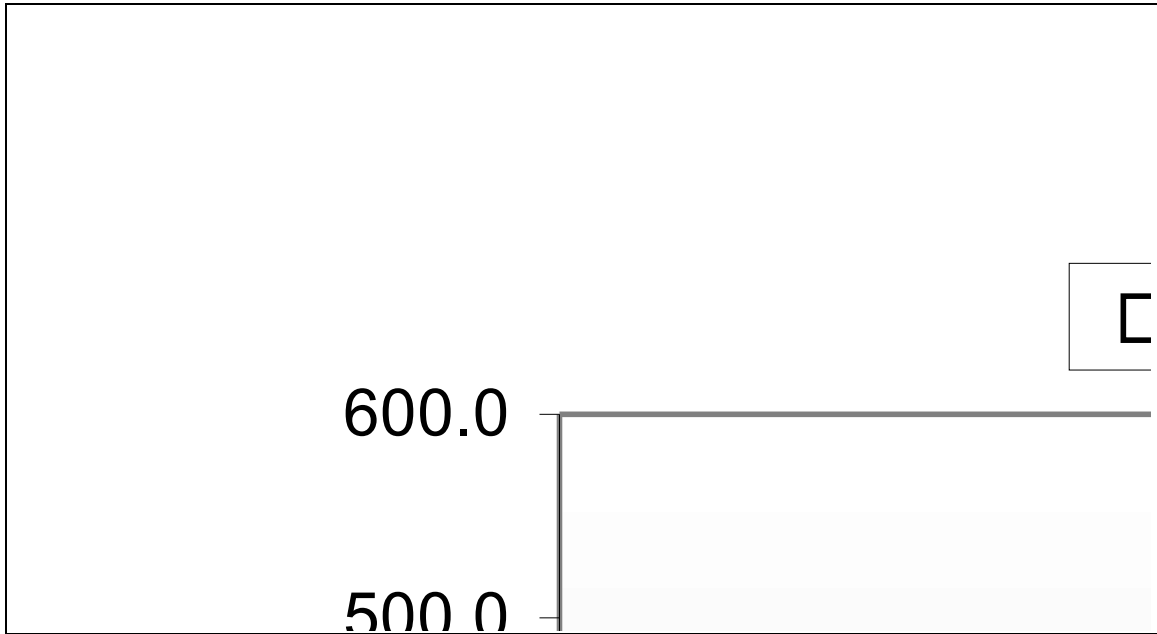


Figure 4.13. Biological oxygen demand (BOD₅) effluent concentrations for five houses assessed over the study period.

Figure 4.13 shows high specific BOD₅ production from kitchen sink and toilet wastewater; there are low specific production BOD₅ values in hand basin wastewater and in shower wastewater due to lower organic matter. The BOD₅ in hand basin and in shower wastewater comes from hairs, skin died cell, chemical products and some times from urine in shower wastewater. Biological oxygen demand (BOD₅) specific production for H1, H2, H3, H4 and H5 are 81.4(5.7) g/c.d, 80.6(9) g/c.d, 76.2(7) g/c.d, 66.2(9.3) g/c.d and 61.4(6.5) g/c.d, respectively (Figure 4.13). The average Biological oxygen demand (BOD₅) specific productions are about 73.2(8.9) g/c.d. Toilet and kitchen sink share about 88% from BOD₅ mass production. For all houses the concentration of BOD₅ is slightly closed to each other (see Figure 4.14), that does refer to the similarity in people habits.

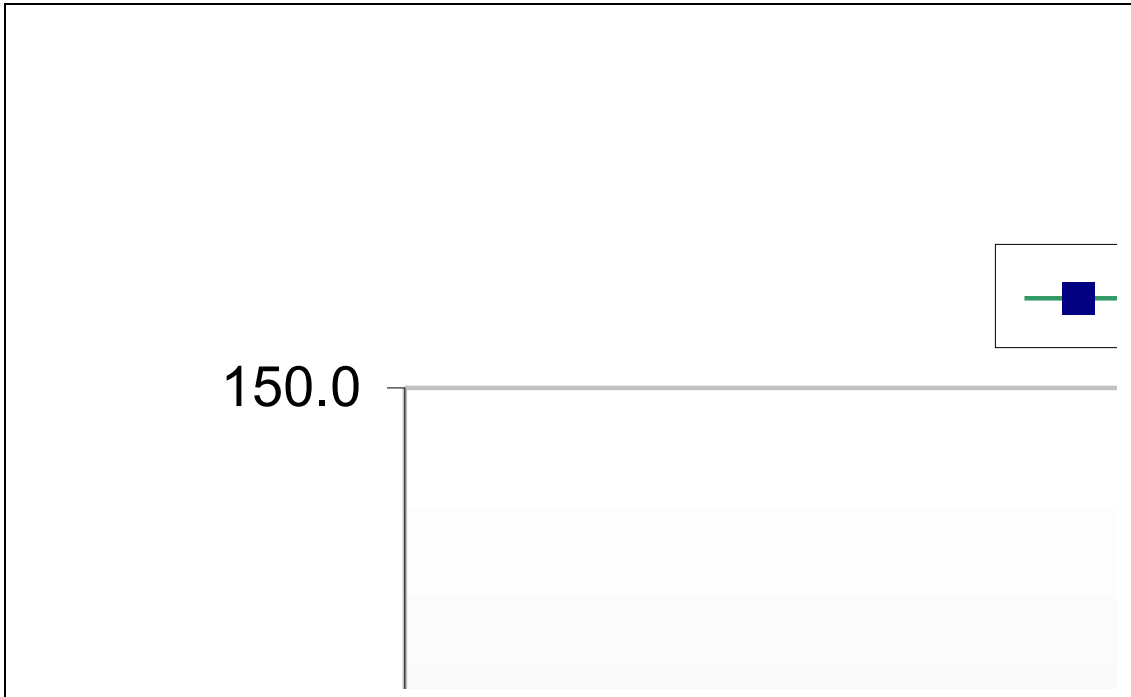


Figure 4.14. The evolution of the specific production of BOD₅ for the effluent sewage and average temperature of the air for five houses assessed over the study period.

The average ratio COD: BOD₅ found for the wastewater at the research area is about 2.23 (0.14). This ratio is within the range of the typical untreated domestic wastewater that varies from 1.25-2.5 (Metcalf and Eddy, 1991). However since the ratio is close to the upper bound of 2.5, it indicates that the wastewater in the research area is lowly biodegradable, which is expected of the wastewater quality at community level. This result shows that raw sewage in community contains a high percentage of non-biodegradable organic matter, compared with sewage in industrial or more temperate regions (Metcalf and Eddy, 1991). This result is higher compared what Samhan (2005), Al-Shayah (2005) and Al-Jamal (2005) reported for the influent raw sewage to Al-Bireh WWTP which about 2.03, 2.0 and 1.97, respectively.

It is important to develop correlation between COD and BOD concentration, which must define for each individual wastewater. There is generally no correlation between COD and BOD when organic suspended solids that are present in the wastewater are only slowly biodegradable. Ideally, for wastewater that is composing of biodegradable organic substance. Moreover, simple relationship rarely substantiate when testing

municipal wastewaters, many organic compounds can oxidize chemically that are only partly biodegradable (Viessman and Hammer, 1985).

There is generally also no correlation between BOD and COD in complex effluent containing refractory substance for this reason, treated effluent may exert virtually no BOD and yet exhibit a high COD. Since the COD will report virtually all organic compounds, many of which are either partially degradable or non-biodegradable, it is proportional to the BOD only for readily assailable substance such as sugars (Eckenfelder, 1989).

4.2.7. pH Value

Measurement of pH is one of the most important and frequently used tests in water chemistry. Practically every phase of water supply and wastewater treatment, i.e., acid-base neutralization, water softening, precipitation, coagulation, disinfection, and corrosion control, is pH-dependent; pH also is important for microorganism growth and control the removal of pollutant (COD, BOD, solids and pathogens).

Black wastewater from the toilet is neutral to alkaline and has generally pH-values in the range 7.54-9.08, the pH in the black wastewater can be affected by pH and alkalinity in the water supply where's no much chemical products are using in toilet. The reason for higher pH is the urea that rise pH to be alkaline. It can be noticed that pH for the five houses are in agreement and close to each other, using chemicals in house (H3) for washing affect on the pH of the black wastewater and bit it lower than the range where in this day they do washing for there house (Table 5.3 in appendix).

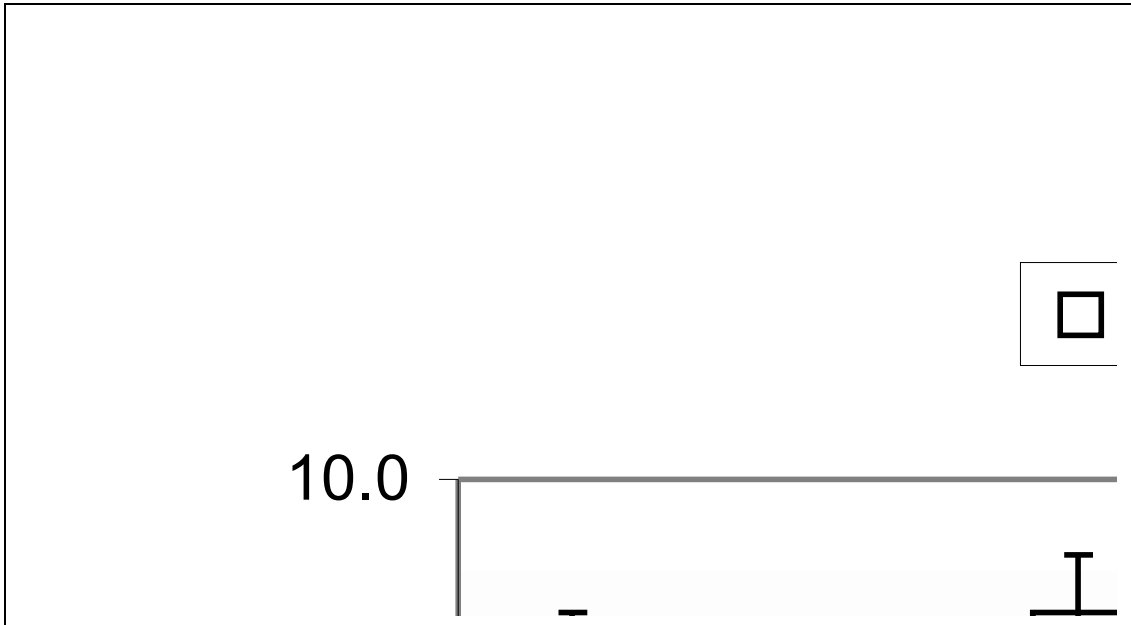


Figure 4.15. The pH value for wastewater stream for five houses assessed over the study period.

Grey wastewater that originates from hand basin and shower is in neutral range 7.15-8.25; 7.23-8.01 respectively (Figure 4.15). While it is bit lower for kitchen sink which is slightly acidic 5.88-7.24, and with some variation for all pH-values. Generally, the low pH-value observed in kitchen sink refers to the type of chemicals using in the jelly of washing dishes (Table 5.3 in appendix). This is also valid for kitchen sink as result show that using chemical products in washing dishes is of importance as well. It shows that life style and the chemical products using in the washing is nearly similar in its components and so its pH-values is near each other.

It can be noticed that pH-values for grey wastewater for the five houses are in agreement and close to each other and in the alkaline range while it is bit lower in grey wastewater from kitchen sink, this refer to the similarity in life style and may in chemicals using in washing for the five houses.

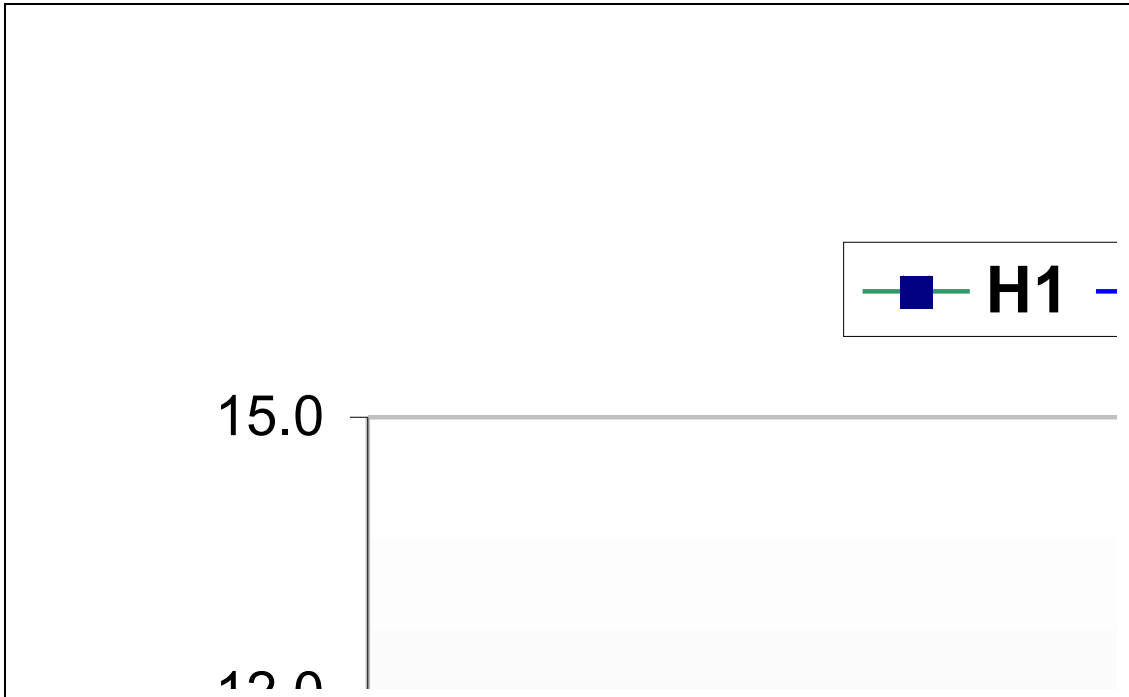


Figure 4.16. pH values and average of temperature for five houses assessed over the study period.

pH values for all houses during the research period is slightly alkaline while its bits slightly acidic for H3 that caused by using chemicals product like detergent, but there are stability in pH value for most houses.

The average pH-value in wastewater for all houses is 7.49(0.40) which is in the neutral range, where the concentration suitable for the existence of most biological life is typically 6 to 9 (Tamimi, 2004). This value close to pH reported by Mahmoud (2002) 7.45(0.39) for Ramallah, 7.26(0.13) for Al-Bireh and 7.31(0.2) for AL-Jalazoon, and so close to pH reported by Al-Shayah (2005), Al-Jamal (2005) and Samhan (2005) which about 7.5(0.22), 7.6(0.28) and 7.43(0.21) respectively for Al-Bireh WWTP.

4.2.8. Sewage temperature

Temperature is an important parameter for wastewater plant, the main temperature of raw sewage during the period of experiment was 22.2(3.1) °C (Table 4.1). There is great variation in the temperature of wastewater, this great variation in temperature due to

different in temperature using in house, usually, we use water with ambient temperature in toilet, hand basin and kitchen sink. Some times in winter people use warm water in hand basin and kitchen sink to enable them to use it. So we can see variation in water temperature in these sources while wastewater from toilet has temperature near to ambient temperature. In shower wastewater the position is different; we need always to warm water for washing so there highly in temperature, in warm days some people washing with water with ambient temperature (see the values of temperature for all wastewater sources in Table 5.1, Table 5.2, Table 5.3 and Table 5.4 in appendix)

4.2.9. *Fecal coliform*

Pathogenic viruses, bacteria, protozoa and helminthes escape from the bodies of infected persons in their excreta and may be passed onto others via exposure of wastewater. These *micro-organisms* can be introduced into grey wastewater by hand washing after toilet use, washing of babies and small children connected with diaper changes and diaper washing, as well as from uncooked vegetables and raw meat. Knowledge about the introduction, survival and transformation of micro-organisms in a grey wastewater system is a highly relevant issue to evaluate.

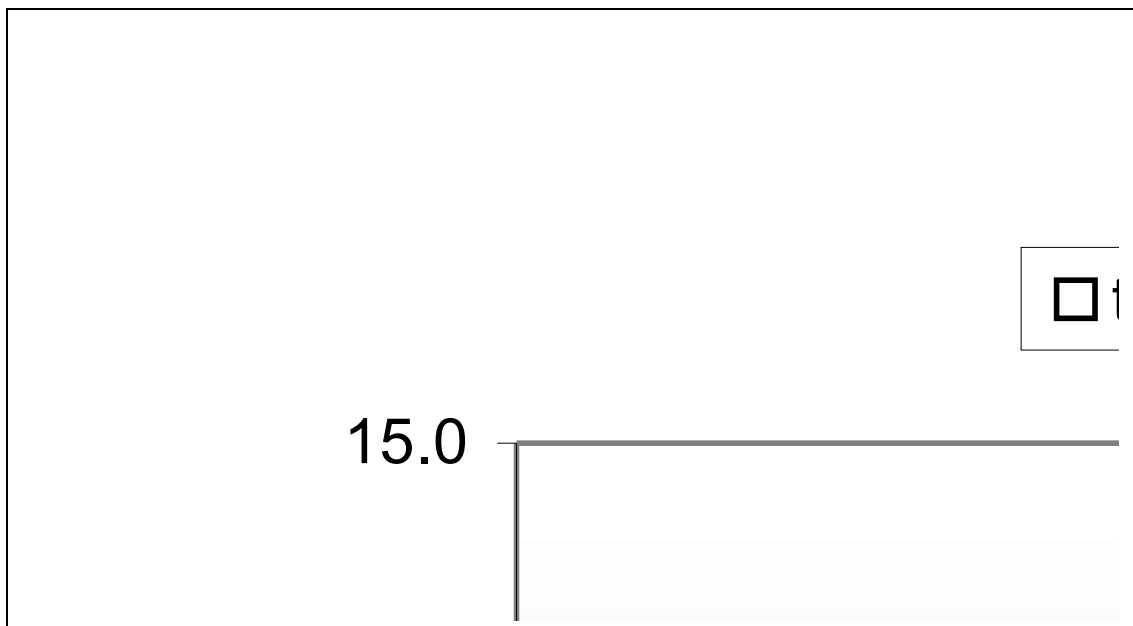


Figure 4.17. *Fecal coliform* of each household wastewater stream for five houses assessed over the study period.



Figure 4.17 show that toilet form the main source of *Fecal coliform*. The high values in toilet refer to that concentrated wastewater has few dilution. Since the water used for flushing faeces is low. There is enough *Fecal coliform* in wastewater from the hand basin due to washing hands after using toilet, some people wash for there babies in the hand basin where most of houses in our research have a small babies.

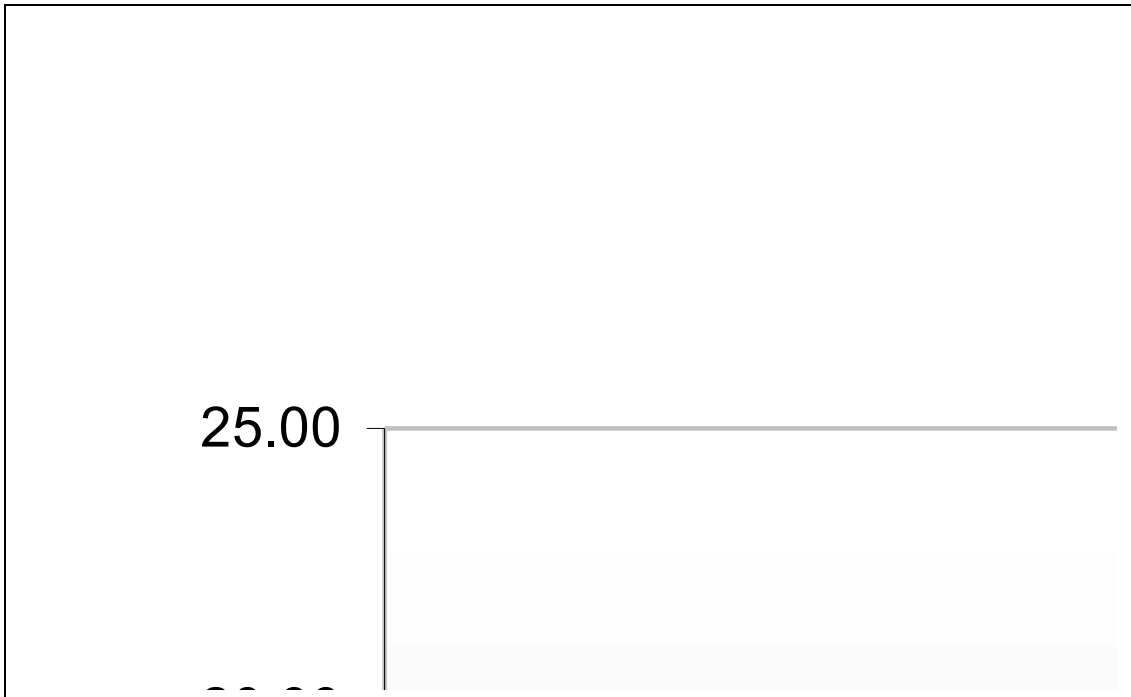


Figure 4.18. The evolution of Log *Fecal coliform* for the effluent sewage of five houses assessed over the study period.

Fecal coliform in household wastewater is effluent from toilet in large quantity. Wastewater from toilet carries what's about 65% of the all *Fecal Coliform* produced from house. The specific production for *Fecal Coliform* in effluent wastewater is about 1.9×10^{11} (0.71) CFU/100 ml (table 4.1). It's higher than Al-Shayah (2005) reported for the influent raw sewage to Al-Bireh WWTP during summer time which about 2.1×10^7 (0.9) CFU/100 ml. there are variation in *Fecal coliform* in the effluent wastewater

4.2.10. Wastewater quantity

In Palestine houses, black and grey wastewaters are normally mixed and piped together into one sewer that's finally thrown in Wadis or in septic tanks. The total volume of wastewater used in household is about 365 (63) l/d; While the average water that was provide about 537.6(69) l/d (see table 5.5 in appendix). This difference between water provide and wastewater produce go to several other uses like clothes washing, cleaning the house and for irrigation our garden. Where this water uses didn't enter the sewer system especially for houses under our study. For example: wastewater from clothes washing thrown in garden not in the sewer system. There is variation in daily wastewater flow from houses, due to several factors like people habits, life style, the number of person and there ages. Variation in wastewater flow can occurred due to the time in day and due to the ambient temperature.

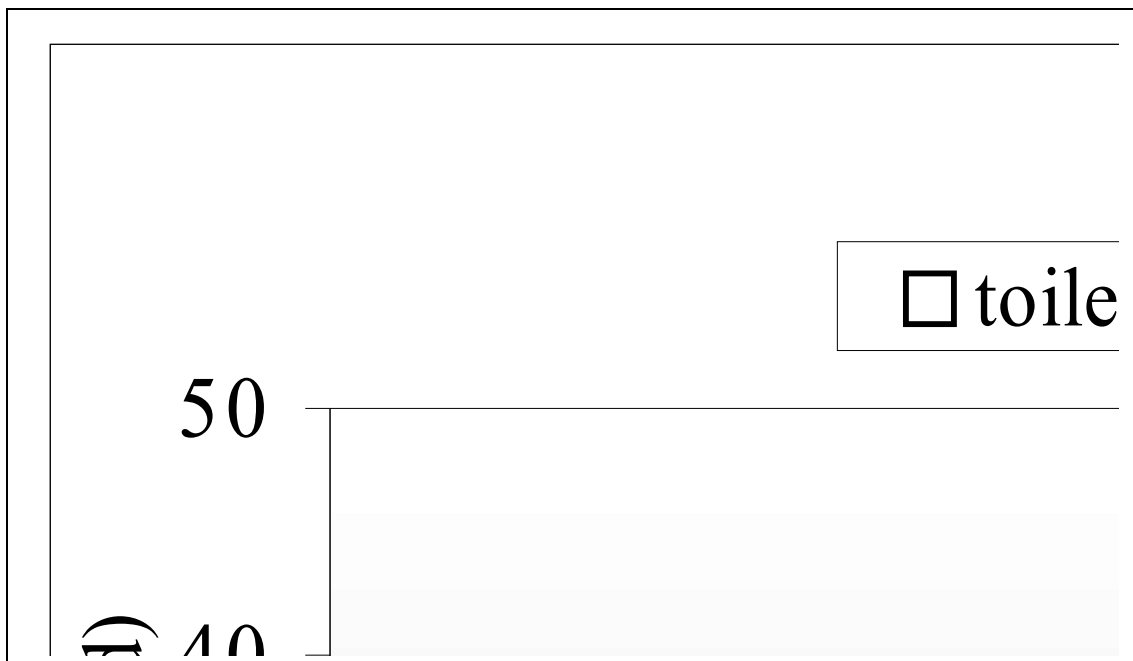


Figure 4.19. Wastewater quantity of each household wastewater stream for five houses assessed over the study period (see table 5.5 in appendix).

The average of wastewater was 32.5(1) l/c.d; While the average water that was provide about 48.4(3.5) l/c.d. Approximately 24.8(1.6) l/c.d from grey wastewater, i.e. wastewater from hand basin, kitchen sink and in the shower. The grey wastewater

represents the major part of domestic sewage (60-70%) and remaining 7.7(1.4) l/c.d is from toilet wastewater. Palmquist and Hanæus (2005) reported the specific average black wastewater flow was 28.5 L per person and day. The total water for toilet flushing about 15 to 55 l/c.d can be substituted with service water without a hygienic risk or comfort loss (Nolde, 1999). Palmquist and Hanæus (2005) reported that grey wastewater flow fluctuated, with a specific average flow of 66 l/c.d. The composition of black wastewater also fluctuated, with shifting proportions of urine, faeces and flush water.

4.2.11 Wastewater characteristics for clothes washing

Clothes washing as a type of grey wastewater share in the pollution of wastewater. We have two sample for each type of clothes wastewater (traditional and laundry washing). We reach the result of average COD concentration of both samples to be about 1229(72.8) mg/l. Where Eriksson (2002) reported COD for clothes washing in the range of 725-1815 mg/l. Surendran and Wheatley (1998) found COD about 725 mg/l. The suspended, the colloidal and dissolved fractions percent are 38.6%, 28.6% and 33% of total COD, respectively (Figure 4.20). COD_{ss} , COD_{col} and COD_{dis} are about 474(44.5) mg/l, 405(12) mg/l and 351(129.4) mg/l, respectively.



Figure 4.20. COD fraction of traditional and laundry clothes washing for two samples measured during a week.

Volatile fatty acid (VFA) reported for clothes washing is about 21.6(2.7) mg/l which represented about 0.27(0.14) g/c.d. Ammonia (NH_4^+ -N) concentration about 25(13) mg/l represents 0.3(0.2) g/c.d. Total PO_4 as P concentration about 12.6(8.4) mg/l represents 0.13(0.09) g/c.d and ortho phosphate (PO_4^{3-} as P) concentration about 10.2(7.6) mg/l. BOD_5 specific production was 558(39) mg/l represents 9.1(4.5) g/c.d where COD/BOD ratio 2.2(0.02) this ratio is within the range of the typical untreated domestic wastewater that varies from 1.25-2.5 (Metcalf and Eddy, 1991). However since the ratio is close to the upper bound of 2.5, it indicates that the wastewater in the research area is lowly biodegradable, this result shows that clothes washing contains a high percentage of non-biodegradable organic matter.

Fecal coliform in clothes washing is about 3.04×10^5 it's slightly high due to some faeces in clothes of small babies since we have small babies in both houses as shown in table 1.4 in chapter 1. Wastewater production from clothes washing is slightly high compared with other sources of wastewater in household wastewater it's about 109(22) l/d represents 15.5(8.5) l/c.d.

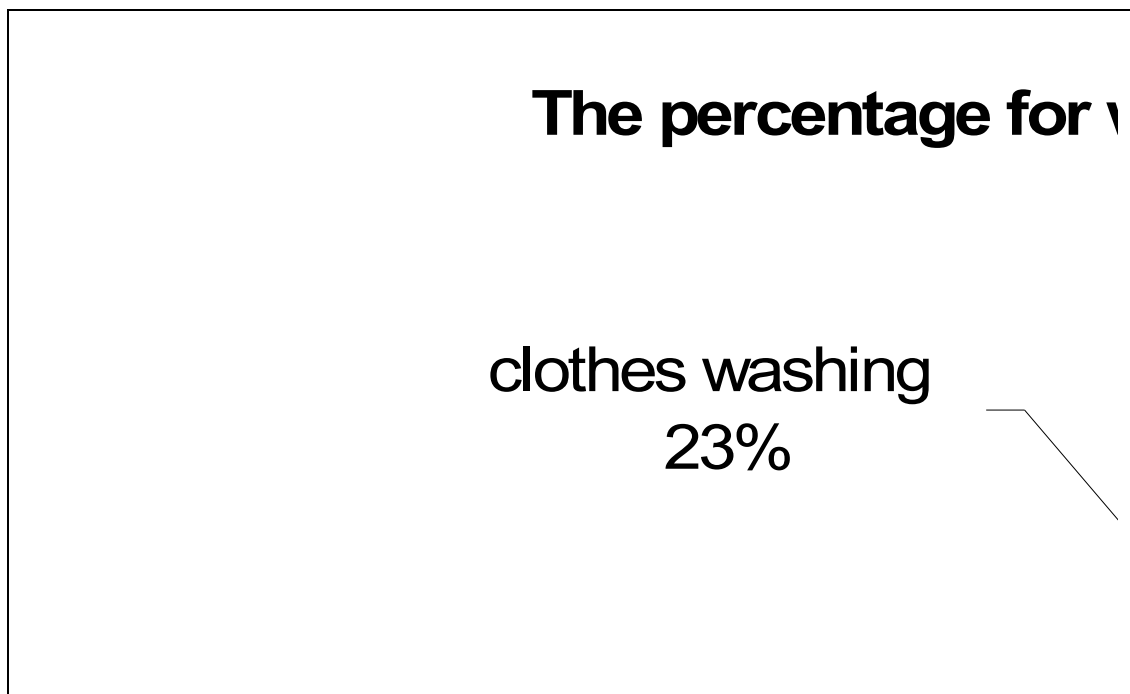


Figure 4.21. .

In average, the Clothes washed two times in the week for most of houses. The selected two houses different in the way of clothes wash, one house use traditional way of clothes wash, while the other use the laundry way. This difference in the washing has reflected on both wastewater quantity and quality. We can see that laundry washing of clothes produce more wastewater quantity and more pollution than traditional washing; we can see that in the concentration of COD, ammonia ($\text{NH}_4^+\text{-N}$), BOD_5 , and phosphorus.

Chapter 5

Conclusions and Recommendations

5.1. Conclusions

The following conclusions are drawn from the results of the research carried out in this work:

1. Raw sewage from the five houses of Palestine villages can be considered as high strength domestic sewage, with a COD_{tot} concentration of 1802(316.7) mg/L about 162.1(21.6) g/c.d, and a high percentage of COD_{sus} (64.9%) around 1167(191.6) mg/L about 105(11.9) g/c.d.
2. COD_{col} is the smallest COD fraction for the five locations; it's about 125.3 (34.8) mg/L form 6.8% of total COD with 11.2(2.5) g/c.d. COD_{dis} about 28.2% of total COD its concentration about 509.5(107.5) mg/l represents 46(8.7) g/c.d.
3. Toilet and kitchen sink wastewaters are the highest contributions of COD in domestic wastewater which about 59.5(16.8) g/c.d and 84.9(22.5) g/c.d, respectively.
4. VFA for raw wastewater is about 214 (40.3) mg/l. The VFA/ COD_{tot} and the VFA/ COD_{dis} ratio are about 12.6(4) mg/l, 45(14.2) mg/l, respectively.
5. The main source of NH_4^+-N in domestic wastewater is feces and urine. The specific production of ammonia in five houses is about 105.4(29.4) mg/l. From toilet alone 92.7(27.1) mg/l. Kitchen sink can be another source of ammonia that's come from using detergent and soaps; food waste causes some ammonia in wastewater.
6. The concentration of total PO_4 as P in wastewater is high, it's about 33.2(5.4) mg/l, each person produce 1.1(0.2) g/c.d. the high concentration of total PO_4 as P in wastewater is from toilet wastewater about 0.91(0.15) g/c.d, and from using chemical products (detergent and soaps) in kitchen sink.

7. It can be explained that most portion of total phosphorus is soluble, and mainly comes from faeces and urine that are rich with phosphorus compounds. Orthophosphate is the high percentage total PO_4 as P about 53.6%. PO_4^{3-} as P specific production is about 17.8(1.5) mg/l.

8. Biological oxygen demand (BOD_5) was somewhat in range 652-915 mg/l for sewage wastewater. For wastewater from toilet are between 187-422 mg/l. COD / BOD_5 ratios found in our study for the effluent wastewater from houses as an average 2.23(. However, since the ratio is close to the upper bound of 2.23 (0.14).

9. In terms of bacterial analysis for raw wastewater, *Fecal coliform (FC)* reported to be 1.9×10^{11} (0.71) CFU/100 ml. *Fecal Coliform* in household wastewater that effluent from toilet alone form about 65% of *Fecal Coliform*, while there is some *Fecal coliform* in hand basin wastewater due to wash hands after using toilet and sometimes from washing of babies.

10. The main temperature of raw sewage during the period of experiment about 22.2(3.1)°C. While the main temperature of air about 15(4.5) °C. There is great variation temperature between sources of wastewater in the house, since some uses of water needs to warm especially in shower and some time during winter time for several uses.

11. Each person produces about 32.5(1.5) l/d of wastewater; where the average water consumption are 48.4(3.5) l/c.d the remained volume of water used in other objectives. wastewater produce from toilet were about 7.7(1.4) l/d (faeces and urine using large water for flushing). Grey water represents the major part of domestic sewage 75.7%. This quantity of household wastewater production in Palestine is low comparing with other results for household wastewater production for other countries.

12. pH of black wastewater is alkaline due to the urea that raises pH to be alkaline. Grey wastewater that originates from hand basin and shower is in neutral range, while it is bit lower for kitchen sink that's slightly acidic due to using chemical products.

13. There are a number of problems related to the reuse of untreated grey wastewater. The risk of spreading of diseases, due to exposure to *micro-organisms* in the water, will be a crucial point if the water is to be reused for e.g. toilet flushing or irrigation. There is a risk that micro-organisms in the water will be spread in the form of aerosols that are generated as the toilets are flushed.

14. The compounds present in the wastewater vary from source of pollution to other, where the lifestyles and customs (e.g. using kitchen sink for flushing food wastes and oil, still using old type of toilet that didn't need large volume of water for flushing, many times of taking shower, washing babies in hand basin or shower and others) installations and use of chemical household products will be of importance. The composition will vary significantly in terms of both place and time due to the variations in water consumption in relation to the discharged amounts of substances. Furthermore, there could be chemical and biological degradation of the chemical compounds, within the transportation network and during storage.

5.2. Recommendations

1. The application of decentralized "community onsite and/or one house or cluster onsite" in Palestine is recommended for the following major reasons: (a) enabling the urban agricultural reuse of treated effluent as the majority of the agricultural land in Palestine is scattered as small agricultural lots; (b) reducing the sewerage work cost and consequently proper environmental protection; (c) solving the problem of effluent discharge.

2. We recommended separating black wastewater from grey wastewater in household wastewater in order to reduce the volume of pollution in sewerage. Furthermore, toilet wastewater rich in *fecal coliform*, so, it's dangerous on human health.

3. Use of grey wastewater for urinal and toilet flushing is one of the possibilities since the water that is used for toilet flushing in many countries today is of drinking water quality. Prior treatment for grey wastewater before reuse in toilet flushing or in irrigation has an economic benefits for water resources preservation. Reuse of grey wastewater from bathrooms has been successfully used in Germany where it has been shown that it is technically feasible and health requirements can be met (Nolde, 1999).

4. It should be possible in the future to have a dual water system in households with two water quantities. The first a high quantity drinking water originating primarily from natural water resources, and a second water quality for all other uses. This should bring with it an environmental relief on both the water and energy sectors.

5. At this point in time, it is difficult to give general recommendations regarding planning and design of a grey wastewater plant, since the user behavior, volume and concentration of grey wastewater can vary widely as for example in a one-family household and in a hotel. As such it is still difficult to give precise details on the investment costs of such systems, to which a second pipe system and additional space are also needed.

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Appendixes

Appendixes

Appendix 1: Tables

Table 5.1. Quality of toilet wastewater concentration of five houses in Anata (House No:2,3,4&5) and Hizzma (House No:1) Villages in Palestine assessed over the study period. Standard deviations are presented between brackets.

Parameters	#Samples	House No 1		House No 2		House No 3		House No 4		House No 5	
		Range	Average (SD)	Range	Average (SD)	Range	Average (SD)	Range	Average (SD)	Range	Average (SD)
COD Total	120	1439-2745	1921(523)	1621-3909	2874(919)	1621-3909	3244(804)	1889-4419	3438(915)	1889-3098	2394(483)
Suspended Colloidal	120	956-1804	1307(315)	1107-2619	1924(590)	1186-2725	2099(564)	1169-3065	2124(618)	1357-1934	1606(251)
Dissolved	120	55-213	123(66)	110-394	253(112)	139-444	313(115)	172-588	310(160)	59-228	148(60)
VFA as COD	120	354-729	491(162)	405-990	697(240)	663-1041	832(143)	548-1262	1005(328)	410-991	640(222)
BOD ₅	120	188-235	211(20)	158-232	180(31)	121-204	165(38)	115-176	153(24)	99-143	114(16)
COD _{Tot} /BOD ₅	120	869-1560	1124(277)	1043-1791	1385(247)	989-1890	1496(321)	1088-1834	1465(257)	1220-1429	1353(78)
NH ₄ ⁺ as N	120	1.52-1.84	1.70(0.13)	1.55-2.57	2.04(0.39)	1.87-2.41	2.16(0.24)	1.74-2.70	2.32(0.39)	1.55-2.21	1.76(0.28)
Total PO ₄ as P	120	282-347	319(26)	246-424	341(83)	368-468	433(44)	392-458	421(31)	350-450	408(38)
Ortho PO ₄ ³⁻ as P	120	20.4-26.8	23.8(2.4)	19.7-39.3	28.7(7.6)	19.4-31.4	25.3(4.7)	24.8-31.6	28(2.6)	27.1-39.3	34.4(4.1)
pH	120	12.7-19.6	15.7(2.6)	6.4-26.1	12.5(7.8)	9.7-30	15.1(7.5)	6.8-25.2	14.6(6.6)	10.4-20.4	16.2(4.3)
<i>Fecal coliform</i>	120	7.25-9.16	8.34(0.87)	8.44-9.09	8.84(0.26)	7.16-8.85	7.54(0.65)	8.21-9.45	9.08(0.46)	7.64-8.95	8.32(0.5)
Temperature	120	8.2E+05-		1.2E+08-		7.1E+08-		2.8E+08-		4.7E+07-	
		4.5E+09	1.10E+09	7.1E+11	1.90E+11	9.2E+10	2.50E+10	3.8E+12	7.20E+12	6.8E+09	1.40E+09
		10.8-24.2	17.3(6.1)	10.4-24.1	17.8(6.2)	9.7-23.7	16.5(6.1)	11.1-24.6	16.9(5.6)	10.2-23.4	16.5(5.6)

All parameters are in mg/l except: pH no unit; *Fecal Coliform*: CFU/100 ml.

Table 5.2. Quality of hand basin wastewater concentration of five houses in Anata (House No:2,3,4&5) and Hizzma (House No:1) Villages in Palestine assessed over the study period. Standard deviations are presented between brackets.

Parameters	#Samples	House No 1		House No 2		House No 3		House No 4		House No 5	
		Range	Average (SD)	Range	Average (SD)	Range	Average (SD)	Range	Average (SD)	Range	Average (SD)
COD Total	120	485-533	506(18)	338-380	354(16)	359-408	377(17)	328-441	369(46)	485-619	553(54)
Suspended	120	335-388	358(23)	212-254	233(15)	216-251	239(13)	203-307	249(41)	339-460	395(44)
Colloidal	120	24-57	45(13)	31-56	41(9)	29-72	48(14)	14-41	29(10)	25-48	33(8)
Dissolved	120	71-123	104(25)	72-90	80(6)	76-117	91(14)	76-113	91(14)	104-158	124(18)
VFA as COD	120	14-22	16(3)	17-35	21(7)	13-16	15(1)	13-15	14(1)	15-22	19(3)
BOD ₅	120	198-254	222(25)	189-222	209(12)	152-219	191(24)	176-215	195(15)	275-333	309(22)
COD _{Tot} /BOD ₅	120	1.99-2.54	2.31(0.24)	1.59-1.86	1.7(0.1)	1.75-2.41	2.0(0.24)	1.65-2.37	1.90(0.26)	1.57-2.03	1.8(0.18)
NH ₄ ⁺ as N	120	1-3.2	1.9(0.8)	0.8-3.6	2.2(1.1)	1.5-2.6	2(0.4)	1.3-2.6	1.8(0.5)	1.6-3.6	2.4(0.7)
Total PO ₄ as P	120	0.88-2.19	1.56(0.54)	3.94-5.24	4.59(0.47)	0.88-2.51	1.68(0.68)	1.01-2.1	1.58(0.44)	1.74-2.32	1.99(0.22)
Ortho PO ₄ ³⁻ as P	120	0.2-1	0.7(0.3)	2-3.5	2.6(0.5)	0.4-1.4	0.8(0.4)	0.4-1	0.8(0.3)	0.9-1.9	1.3(0.4)
pH	120	7.69-9.03	8.25(0.59)	6.44-8.95	7.63(0.91)	6.96-7.29	7.18(0.12)	7.36-8.42	7.81(0.43)	6.66-7.31	7.15(0.31)
	120	4.5E+02-		6.1E+02-		1.1E+03-		9.1E+02-		8.8E+02-	
<i>Fecal coliform</i>		8.2E+03	3.30E+03	2.8E+03	1.90E+03	2.2E+03	1.60E+03	3.3E+03	1.80E+03	4.7E+03	3.40E+03
Temperature	120	11.2-24.3	17.6(6)	12.2-23.8	17.9(5.2)	10.2-24.1	16.8(6.1)	12.1-24.8	19.6(5.3)	10.3-23.8	17.9(5.3)

All parameters are in mg/l except: pH no unit; *Fecal Coliform*: CFU/ 100ml.

Table 5.3. Quality of kitchen sinks wastewater concentration of five houses in Anata (House No:2,3,4&5) and Hizzma (House No:1) Villages in Palestine assessed over the study period. Standard deviations are presented between brackets.

Parameters	#Samples	House No 1		House No 2		House No 3		House No 4		House No 5	
		Range	Average (SD)	Range	Average (SD)	Range	Average (SD)	Range	Average (SD)	Range	Average (SD)
COD Total	120	1899-2549	2189(232)	2713-3845	3211(426)	2822-3751	3305(384)	1790-2884	2331(412)	1846-2898	2409(424)
Suspended	120	1033-1719	1419(226)	1642-2160	1891(230)	1750-2501	2179(299)	1059-1850	1433(330)	1265-1973	1687(348)
Colloidal	120	44-129	93(41)	100-282	219(67)	83-238	155(56)	52-204	117(50)	77-190	145(47)
Dissolved	120	569-774	677(77)	822-1489	1100(219)	792-1125	972(114)	624-1020	782(152)	485-632	577(66)
VFA as COD	120	14.1-16.3	14.5(1.3)	12.8-17.7	14.2(1.9)	11.5-12.8	12.1(0.5)	7.7-14.8	11.4(2.8)	9.7-14.1	11.2(1.5)
BOD ₅	120	954-1035	1003(29)	1139-1590	1310(157)	1110-1473	1298(134)	731-1269	949(209)	675-1208	958(198)
COD _{Tot} /BOD ₅	120	1.84-2.53	2.19(0.26)	2.12-2.59	2.45(0.17)	2.47-2.72	2.55(0.1)	2.26-2.81	2.48(0.23)	2.17-2.78	2.54(0.26)
NH ₄ ⁺ as N	120	16-28	21(4)	12-40	24(12)	14-59	38(20)	11-18	15(3)	20-43	30(8)
Total PO ₄ as P	120	1-2	1.4(0.4)	0.9-2.7	1.6(0.6)	1.3-3	2.2(0.7)	1.2-3.5	2.3(0.8)	2.9-5.2	3.9(0.9)
Ortho PO ₄ ³⁻ as P	120	0.6-1.3	1(0.3)	0.6-1.6	0.8(0.4)	1-2.1	1.5(0.4)	1-2.4	1.7(0.5)	1.2-3.5	2(0.8)
pH	120	5.98-6.44	6.22(0.17)	5.03-8.95	7.24(1.39)	5.33-6.45	5.88(0.44)	5.6-7.45	6.93(0.7)	5.51-6.83	6.19(0.58)
<i>Fecal coliform</i>	120	0-2	1	1-3	1.7	2-6	3	1-8	3	0-3	1
Temperature	120	15.6-25.1	21.2(4)	19.8-31.2	24.3(4)	15.4-24.1	20.4(3.4)	15.1-27	19.7(5.6)	11.4-23.5	17.2(5.2)

All parameters are in mg/l except: pH no unit; *Fecal Coliform*: CFU/ 100ml.

Table 5.4. Quality of shower wastewater concentration of five houses in Anata (House No:2,3,4&5) and Hizzma (House No:1) Villages in Palestine assessed over the study period. Standard deviations are presented between brackets.

Parameters	#Samples	House No 1	House No 2	House No 3	House No 4	House No 5
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		Range	Average (SD)	Range	Average (SD)	Range	Average (SD)	Range	Average (SD)	Range	Average (SD)
COD Total	120	322-410	362(35)	577-724	629(50)	301-642	481(144)	377-574	462(72)	553-937	705(163)
Suspended	120	173-261	205(37)	377-479	410(37)	204-425	314(97)	216-374	289(56)	435-740	544(115)
Colloidal	120	38-49	45(5)	41-56	48(6)	32-67	51(13)	37-59	46(9)	30-93	53(26)
Dissolved	120	87-128	112(19)	151-195	171(18)	65-154	116(39)	88-159	128(24)	79-178	108(37)
VFA as COD	120	14-25	18(4)	18-21	19(1)	15-20	18(2)	16-19	17(2)	22-30	25(3)
BOD ₅	120	186-204	193(6)	254-312	282(25)	156-278	228(57)	189-335	237(51)	257-383	317(51)
COD _{Tot} /BOD ₅	120	1.69-2.14	1.88(0.18)	2.05-2.44	2.24(0.14)	1.89-2.34	2.09(0.18)	1.72-2.18	1.97(0.19)	1.99-2.45	2.21(0.19)
NH ₄ ⁺ as N	120	2.2-5.2	4.2(1.1)	11.3-17.3	13.1(2.2)	2.1-9.4	5.3(2.9)	2.2-12.9	6.3(4.1)	7-12.8	10.5(2)
Total PO ₄ as P	120	0.3-0.7	0.4(0.2)	0.4-0.8	0.6(0.1)	0.3-0.7	0.5(0.1)	0.4-0.9	0.7(0.2)	0.6-1.0	0.8(0.1)
Ortho PO ₄ ³⁻ as P	120	0.1-0.6	0.3(0.2)	0.1-0.5	0.3(0.2)	0.1-0.5	0.2(0.1)	0.2-0.6	0.3(0.2)	0.4-0.6	0.5(0.1)
pH	120	7.45-8.59	8.03(0.4)	7.06-7.35	7.2(0.1)	7.03-7.41	7.25(0.13)	7.34-7.82	7.59(0.18)	7.48-7.82	7.63(0.14)
<i>Fecal coliform</i>	120	45-124	90	22-108	80	4-35	20	10-39	14	41-88	67
Temperature	120	23.4-38.2	31.7(6.4)	32.1-38.9	34.8(2.5)	23-38.7	31.7(6.2)	31.2-38.8	35(2.8)	21.5-38.8	32.5(7.6)

All parameters are in mg/l except: pH no unit; *Fecal Coliform*: CFU/ 100ml.

Table 5.5. Quantity of wastewater for five houses in Anata (House No:2,3,4&5) and Hizzma (House No:1) Villages in Palestine assessed over the study period. Standard deviations are presented between brackets.

	H1(8 inhabitants)			H2(11 inhabitants)			H3(12 inhabitants)			H4(12 inhabitants)			H5(13 inhabitants)		
	Range	Average	l/c.d	Range	Average	l/c.d	Range	Average	l/c.d	Range	Average	l/c.d	Range	Average	l/c.d
Toilet	36-55	43(7)	5.4	72-94	82(8)	7.5	88-112	98(9)	8.2	100-117	107(7)	8.9	102-124	113(9)	8.7
Sink	78-100	88(9)	11	96-110	106(6)	9.6	100-122	110(8)	9.2	102-125	113(9)	9.4	116-134	124(7)	9.5

Kitchen	72-107	92(13)	11.5	110-152	135(16)	12.3	118-155	139(14)	11.6	98-131	112(13)	9.3	132-162	148(11)	11.4
Shower	21-45	32(9)	4	29-55	43(10)	3.9	32-61	46(12)	3.8	32-56	42(9)	3.5	38-65	53(10)	4.1
Laundry															
clothes	17.7-18.6	18.2(0.5)	2.3	93-104	99(6)	9	-	-	-	-	-	-	-	-	-
Total	17.7-107	273.2(33.5)	34.2(4.7)	29-152	465(33.9)	42.3(3.5)	32-155	393(38.9)	32.8(4)	32-131	374(34.4)	31.1(3.4)	38-162	438(40.4)	33.7(3.8)

All parameters are in l/d except: Rate in l/c.d

Table 5.6. COD fraction concentration of five houses in Anata (House No:2,3,4&5) and Hizzma (House No:1) Villages in Palestine assessed over the study period. Standard deviations are presented between brackets.

	(H1(8 inhabitants	(H2(11 inhabitants	(H3(12 inhabitants	(H4(12 inhabitants	(H5(13 inhabitants	Average
COD _{tot}	166.1	182.5	178.6	154.6	128.8	162.1
COD _{sus}	109.4	113.7	116.7	95.4	89.5	104.9
%	65.9	62.3	65.3	61.7	69.5	64.9
COD _{col}	9.4	14.1	12.7	11.7	7.9	11.2
%	5.7	7.7	7.1	7.6	6.1	6.8
COD _{dis}	47.3	54.7	49.2	47.5	31.4	46.0
%	28.5	30.0	27.5	30.7	24.4	28.2

Table 5.7. Characteristic of domestic household wastewater streams of five houses in Anata (House No:2,3,4&5) and Hizzma (House No:1) Villages in Palestine assessed over the study period. Standard deviations are presented between brackets.

	# of samples	pH	COD	BOD ₅	VFA as COD	NH ₄ ⁺ -N	Total PO ₄ as P	PO ₄ ³⁻ as P	Temperature	FC	Wastewater product
Toilet	120	8.42(0.59)	59.5(16.8)	29.1(4.4)	2.3(0.4)	8.2(1.39)	0.91(0.15)	0.48(0.05)	17(0.6)	1.48x10 ¹²	7.7(1.4)
Hand basin	120	7.6(0.46)	12.3(5.5)	6.2(2.1)	3.5(0.8)	0.10(0.01)	0.08(0.04)	0.04(0.03)	18(1)	63.6(28.1)	9.7(0.7)
Kitchen sink	120	6.37(0.41)	84.9(22.5)	35.2(10.2)	0.5(0.2)	0.80(0.28)	0.07(0.03)	0.05(0.02)	20.6(2.6)	1.93(1.01)	11.2(1.1)
Shower	120	7.54(0.34)	5.5(1)	2.7(0.4)	0.4(0.2)	0.3(0.4)	0.02(0.01)	0.01(0.01)	33.1(1.7)	74.3(62.05)	3.9(0.2)
Laundry	4	9.2(0.32)	14.1(0.5)	2.20(0.02)	0.27(0.14)	0.3(0.2)	0.13(0.09)	0.11(0.07)	19(2.2)	3.04x10 ⁵	15.5(8.5)

All parameters are in g/c.d except: wastewater temperature (T_{ww}) in °C; pH no unit; effluent wastewater in l/c.d; *fecal coliform*: CFU/100ml.

Appendix 2: Photos



Photo 1. The sampling boxes

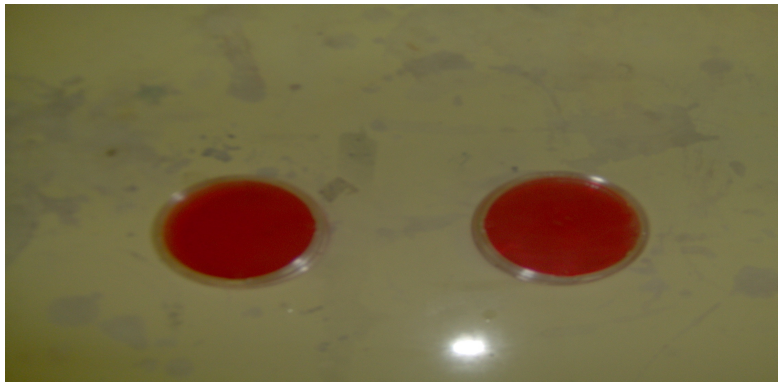


Photo 2. *Fecal coliform* media

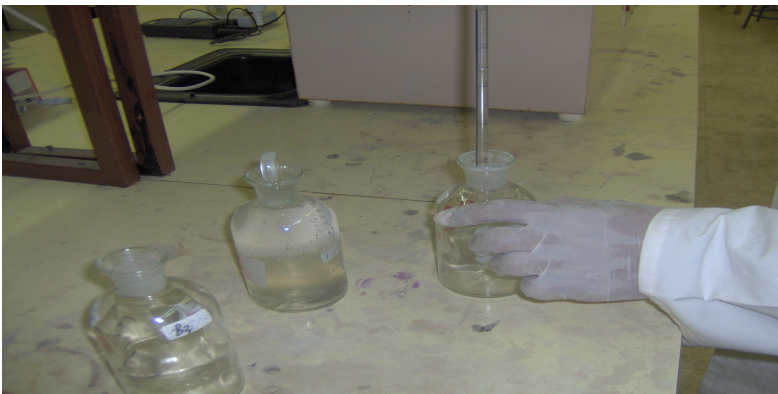


Photo 3. BOD bottles



Photo 4. Digestion process for analysis of ammonia in wastewater



Photo 5. Membrane-filtered process for total coliform in
Wastewater using 4.4- μm paper filters



Photo 6. Separation system for toilet, kitchen sink and shower +hand basin
effluent domestic household Wastewater for several houses



Photo 7. Separation system for kitchen sink

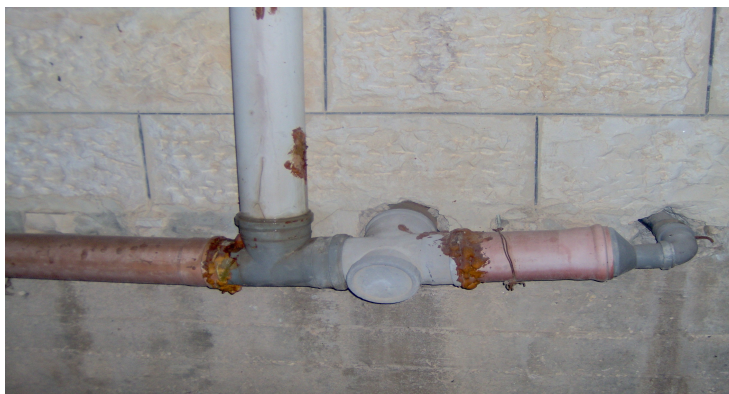


Photo 8. Separation system for toilet and hand basin



Photo 9. Separation system for kitchen sink

Arabic Summary

الخلاصة

إن المياه العادمة غير المعالجة من أهم مصادر تلوث المياه في فلسطين ذلك لأنها تتدفق عبر قنوات مكشوفة عبر المناطق الأهلة بالسكان و المناطق الزراعية و تعتبر عملية تصريف المياه العادمة و معالجتها في فلسطين من الأمور الهامة لسلامة البيئة. إذ تقدر نسبة المياه العادمة الغير معالجة بحوالي 90 % من جملة كمية المياه العادمة. وفلسطين من بلدان ذات المناخ الجاف أو شبه الجاف تعاني هي الأخرى من ندرة المياه التي يمكن أن تكون المحور الرئيسي في تطوير البلد مستقبلا.

الكلام عن نقص المياه بلا معنى طالما هناك تلوينا لمصادر المياه العالية الجودة, حيث أن رمي المياه العادمة غير المعالجة تشكل التهديد الرئيسي بالنسبة لتلويث المياه الجوفية التي تشكل المصدر الرئيسي لمياه الشرب في فلسطين. من الناحية الأخرى, تركيز النفايات الصادرة عن الإنسان (1.5 لتر من الغائط والبول يوميا لكل شخص) مخففة بكميات كبيرة من المياه الصالحة للشرب لكي تنقل هذه النفايات من موقع الإنتاج إلى موقع المعالجة أو الرمي. في العديد من القرى الفلسطينية والمخيمات والمناطق الريفية لا يوجد شبكة صرف صحي للمياه العادمة وبالتالي فإن إمكانية فصل المياه العادمة السوداء عن المياه العادمة الرمادية على مستوى البيوت ومعالجتها في محطات محلية يعد خيار منطقي لهذه المشكلة. إلا أن هذه الآلية لم تجرب بعد خصوصا في الظروف الحالية الموجودة في فلسطين, حيث أن المياه العادمة المحلية مميزة بالقوة والتقلب العالي في درجات الحرارة الموسمية كما أن الارتفاع في تركيز COD للمياه العادية حيث وصل إلى ما يقرب (1802 ملغم/لتر) ليس فقط بسبب استهلاك الماء القليل, لكن بسبب عادات الناس وسلوكهم كإلقاء بواقي الطعام وزيت الطبخ المستعمل في مغسلة المطبخ, يعتقد أنها تلعب دور مركزي في زيادة التلوث في المياه العادمة المنزلية.

إن الهدف الرئيسي من هذا البحث هو زيادة المعرفة عن الكمية والنوعية للمياه العادمة البيئية المختلفة المصادر, ومعرفة سبب التركيز العالي في حجم للمياه العادمة في فلسطين الذي لم يعرف بعد. صياغة المفاهيم الإبداعية لتصريف مجاري الموقع التي يمكن أن تحقق الحد الأقصى من إعادة استعمال المياه العادمة مثال إعادة استعمال المياه العادمة في الزراعة, أيضا مصدر للطاقة والمواد المغذية للنبات. هذه المفاهيم ستكون في المستقبل قاعدة لتعديل مثالي لتصريف المياه العادمة البيئية في فلسطين للوصول للاستغلال المثالي والمستمر للمياه العادمة. وأخيرا, صياغة المفاهيم التي يمكن تخفيض استعمال الماء الصافي وذلك بإعادة استعمال المياه العادمة المعالجة.

لأجل ذلك قمنا بفصل مصادر المياه البيئية كل على حدة لخمسة بيوت ودراسة خصائص هذه المياه على مدى ستة أشهر تقريبا حيث يتم من خلالها معرفة خواص المياه العادمة وكمية التدفق المتذبذب الذي يعبر عن كمية المياه العادمة البيئية الناتجة وسلوكيات الأفراد في استخدام المياه داخل البيوت.

إن نتائج هذا البحث تظهر ان درجة التلوث توصف بأنها عالية للمياه العادمة البيئية وفي نفس الوقت هناك استهلاك ليس بالكبير بالنسبة للمياه الصالحة بمعنى أن التلوث العالي في المياه العادمة لا يرجع فقط للاستخدام المنخفض للمياه وإنما لأسباب أخرى نعللها بسلوكيات الأفراد في استخدام المياه مثل رمي وطرح بواقي الطعام والزيت المستخدمة في المطابخ من خلال المياه العادمة الخارجة منه. وكذلك وجود هذا الانخفاض في استهلاك المياه الذي يعود إلى النقص في توفر المياه الصالحة في فلسطين والاقتصاد في استهلاكها حيث أن كميات المياه الصالحة المخصصة للفلسطينيين هي محدودة وذلك بسبب سيطرة الاحتلال على معظم هذه المصادر وتخصيص حصص محدودة منها للفلسطينيين, كما أن العادات والتقاليد وتعاليم الدين عند الفلسطينيين لا تسمح بالاستهلاك المفرط للمياه الصالحة.

بناء على نتائج البحث الذي اظهر درجة التلوث العالية في المياه العادمة البيئية والذي يعود بنسب متفاوتة لجميع مصادر المياه العادمة في المنزل. حيث اظهر البحث أن المياه العادمة الخارجة من استخدام المراض والمياه العادمة الناتجة من استخدامات المطبخ تعد الأكثر تلوثا وعليه يمكن أن نفصل هذه المياه عن باقي المياه العادمة المنزلية والتي توصف بأنها أقل تلوثا ومن ثم بعث هذه المياه العادمة إلى محطات تقوم بمعالجتها في حين يمكن أن نستغل المياه العادمة الأقل تلوثا في استخدامات أخرى لا تضر بصحة الأفراد كعمليات الري للمزروعات سواء على مستوى حديقة البيت أو المزارع الكبيرة وذلك بتجميع هذه المياه للبيوت على مستوى القرية أو المخيم عبر قنوات صرف صحي خاصة ومعزولة. وكذلك يمكن إعادة استخدامها في المراض بغرض الشطف.

انه من الملائم استخدام نظام ادارة فعال للمياه العادمة المنزلية لمجموعة من البيوت بدلا من تركيب نظام معالجة واحد لكل بيت على حدى. في مثل هذه الحالة هناك حاجة لتركيب نظام تصريف ومعالجة لمجموعة من البيوت ذات انايبب مناسبة وبالوعات ضغط معينة للجاليات الصغيرة قليلة التكلفة. فيمكن استخدام نظام معالجة مثل UASB مثلا ليطبق في مثل هذه الحالات بالرغم من ان الجاليات الصغيرة عادة ما تكون ذات كثافة سكانية كبيرة مثل القرى او المخيمات كما هو الحال في فلسطين - مثل نظام UASB لكل شارع- اكثر ما يقال ان نظام UASB هو الاكثر رخصا للجاليات التي تكون فيها المياه العادمة سيئة بمعنى ان نسبة التلوث في المياه العادمة مرتفع, حيث ان هذا النظام من المعالجة يمتاز بانه لا يحتاج للكثير من الخبرة لادارته كما انه لا يتطلب تجهيز خارجي من الطاقة خصوصا اذا كان النمط العام للمياه العادمة المتدفقة متذبذب.