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Assessing the Palestinian Experience in Using Household Water Treatment Systems: Hebron Governorate as a case study

تقييم خبرة فلسطين في استخدام وحدات معالجة مياه الشرب المنزلية:محافظة الخليل كحالة دراسية

Student:

Alaa Othman (1175433)

Supervisor:

Dr. Maher Abu-Madi

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Master's Thesis Submitted By

Alaa Othman (1175433)

Supervisor:

Dr. Maher Abu-Madi

This Thesis was successfully defended and approved on 5/12/2019

Examining Committee Signature

Dr. Maher Abu-Madi (Supervisor) ……………………………

Prof. Rashed Al- Sa'ed (Member) ……………………………

Dr.Ghassan Barghouthi (Member) ……………………………

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List of Abbreviation

AA	Activated Alumina
AC	Activated Carbon
ANSI	American National Standard Institute
AX	Anion Exchange
CFU	Colony - forming Units
CX	Cation Exchange
DBPs	Disinfection By-products
DO	Dissolved Oxygen
EPA	Environmental Protection Agency
FC	Fecal Coliform
GAC	Granular Activated Carbon
HWT	Home/ Household Water Treatment
IX	Ion Exchange
MCL	Maximum Concentration Level
MOH	Ministry of Health
NSF	National Sanitation Foundation
NTU	Nephelometric turbidity unit
^{O}C	Celsius
PCBS	Palestinian Central Bureau of Statistics
POE	Point of Entry
POU	Point of Use
PSI	Palestinian Standards Institution
PWA	Palestinian Water Authority
RO	Reverse Osmosis
SPSS	Statistical Package for Social Sciences

TC	Total Coliform
TCU	Total Coliform Unit
TDS	Total Dissolved Solids
THMs	Trihalomethanes
UV	Ultraviolet
VOCs	Volatile Organic Carbons
WDS	Water Distribution System
WHO	World Health Organization
WSRC	Water Sector Regulatory Council

Abstract

In the West Bank especially in Hebron Governorate, in the recent years the number of used household water treatment systems increased rapidly with about 5806 units (PCBs, 2017). This raises the need to study the application of these systems, and to assess their performance compared with the quality standards of the PSI and WHO guidelines.

In this study a structured questionnaire targeted a sample of users of these systems and water samples at the inlet and outlet of the most common used water filters (RO and three stages) were taken from different locations in Hebron Governorate; Hebron city, BeitUlla, Sourif and Yatta. The microbial tests included total and fecal coliform and physical chemical analysis included total dissolved solid, pH, electrical conductivity, chloride, carbonate, nitrate and sulfate (WHO, 2011).

It is found that the adaption of these systems is not related to a single feature as a reason for this adaption but there are many factors affect the adaption of these systems include negative perception about tap water quality with the availability of the willingness to pay (Daniel et al., 2018). From the questionnaire It is found the about 40% of the users in Hebron Governorate adapt these systems as they think that municipal water quality is poor due to aesthetical properties like color, taste and odor . Also there is a strong linear relationship between the type of the filter its capital and maintenance cost. And between the satisfaction about water quality produced with the occurrence of the periodic maintenance and between the satisfaction about provider performance with respect to filter maintenance.

Based on physiochemical results of this study, it is found that the tap water from municipal water system is clean and safe according to PSI standards. While drinking water quality at the outlet of water filters lacks for beneficial elements to human body as it produces water with TDS concentration less than 100 mg/l which conflicts with PSI recommendations and might lead to health problems with long term consumption for bones, nervous system and cardiovascular system. Besides, these systems produce soft water with the concentration of $CaCo_3$less than 90 mg/l which may causes

leaching of metals like iron and may affect skeletal and cardiovascular health. Re-mineralization is essential for water from these systems but many efforts are required for finding systems that produce safe and clean drinking water that meet PSI and WHO standards without additional need for re-mineralization. From biological and physical tests it is found that these systems are subject to biological fouling and scaling so frequent maintenance is essential to ensure obtain water with the same quality over consumption time. Additional attention must be made by the regularity authority to monitor marketing of these systems and raise public awareness about tap water quality, also safety measures that are required to keep obtaining safe and clean drinking water from taps.

الخلاصة

في الضفة الغربية وخصوصا" محافظة الخليل, لوحظ في السنوات الأخيرة زيادة مستمرة في عدد وحدات معالجة المياه المنزلية والذي بلغ 5806 وحدة في عام 2017. ما أدى الى زيادة الحاجة الى دراسة تطبيقات هذه الأنظمة وتقييم أدائها مقارنة" بمعايير نوعية المياه حسب المواصفات الفلسطينية ومواصفات منظمة الصحة العالمية. لقد وجد بأن أكثر مستخدمي هذه الأنظمة يستخدموها لاعتقادهم بأن مياه الشبكة العامة رديئة وذلك استنادا" الى الصفات الجمالية كاللون والطعم والرائحة.

في هذه الدراسة تم عمل استبيان يستهدف عينة من مستخدمي هذه الأنظمة وأخذ عينات المياه عند مدخل ومخرج أكثر هذه الأنظمة استخداما" (نظام التناضح العكسي ونظام الترشيح الثلاثي), تم أخذ هذه العينات من أماكن مختلفة في محافظة الخليل وتشمل مدينة الخليل وبيت أولا وصوريف ويطا. وذلك لاجراء الفحوصات الميكروبيولوجية والتي تشمل القولونيات الكلية والبرازية والفحوصات الفيزيائية و الكيميائية التي تشمل الأملاح الذائبة و درجة الحوضة والتوصيل الكهربائي و الكلورايد و الكربونات و النيترات و الكبريتات.

لوحظ بأن استخدام هذه الانظمة لا يعود لسبب واحد وانما الى اسباب وعوامل عدة تتضمن الاعتقاد بأن المياه المزودة من الشبكة العامة ملوثة وايضا قابلية المستخدم للانفاق على مثل هذه الأنظمة. كذلك فقد وجد من الاستبيان بأن 40% من مستخدمي هذه الأنظمة بمحافظة الخليل يستخدمونها لاعتقادهم بـأن نوعية المياه المزودة من الشبكة العادمة متردية وذلك اعتمادا" على الخصائص الحسية كاللون والطعم والرائحة. كذلك فقد وجد بأن هناك علاقة خطية قوية بين الثقة بنوعية المياهالناتجة وبين الثقة بأداء المزود وخاصة الصيانة.

استنادا" لهذه الدراسة فقد وجد بأن المياه من الشبكة العامة امنة ونظيفة حسب المواصفات الفلسطينية. بينما وجد بأن المياه الناتجة من وحدات معالجة المياه المنزلية تخلو من عناصر مهمة وضرورية لجسم الانسان, حيث أن تركيز الأملاح الذائبة فيها أقل من من 100 ملغم/لتر, وهو ما يتعارض مع المواصفات الفلسطينية لمياه الشرب. بالاضافة الى أنه من الممكن أن يؤدي الى مشاكل صحية للعظام والجهاز العصبي والقلب والأوعية الدموية مع الاستخدام طويل الأمد. بالاضافة الى أن هذه الأنظمة تنتج مياه عذبة تركيز كربونات الكالسيوم فيها أقل من 90 ملغم/لتر ما يؤدي الى ترشيح بعض المعادن مثل الحديد ويمكن أن يؤثر على صحة الهيكل العظمي والقلب و الأوعية الدموية. لذلك فان عملية اضافة المعادن ضرورية للمياه الناتجة من هذه الأنظمة ولكن يجب العمل على ايجاد أنظمة تنتج مياه شرب أمنة ونظيفة وتتطابق مع مواصفات مياه الشرب الفلسطينية ومواصفات منظمة الصحة العالمية دون الحاجة الى اضافة المعادن . ومن الفحوصاتالبيولوجيية والفيزيائية تبين ايضا تعرض النظام الى تلوث بيولوجي وتراكم للاملاح وبالتالي هناك حاجة ماسة الى الصيانة الدورية لضمان الحصول على نفس نوعسة المياه طوال مدة الاستخدام . كذلك فانه تقع على عاتق الجهات المختصة مسؤولية مراقبة تسويق هذه الأنظمة, وزيادة وعي الناس حول نوعية المياه المزودة من الشبكة العامة واجراءات السلامة التي يجب بذلها من قبل المستهلكلضمان الحصول على مياه أمنة ونظيفة من الشيكة العامة.

Dedication

To my beloved husband Ammar,

To my little daughters Bessan and Zaina,

To my wonderful parents, sisters, brother, parents in law and family,

To all who support me in my life.

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Great thanks to Birzeit University, Institute of Environmental and Water Studies and especially for my best supervisor who support me in all stages of this work, who provide me with all technical and scientific issues in this study Dr-Maher Abu-Madi.

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Chapter One - Introduction

1.1 Background

Water is a basic need for humanity; about 60% of human body is from water. About 70% of the earth is water, 97% is sea water with only 3% is fresh water but only 1% available for human consumption (Singh, 2015).Rapid population growth and human activities such as industries, agriculture and other human activities cause incremental demand and deterioration of water quality. Microbial contaminant is a major concern that threatens public health as it may cause serious health problems that vary from diarrhea to death. About 60% of the diseases in the world are due to polluted water and absence of wastewater treatment (Singh, 2015). In Palestine, deterioration in water quality occurred in many groundwater wells due to human activities, aged network and leakage of about 60% or more (WSRC, 2017). Also penetration of wastewater to the groundwater wells; that cause increase in the concentration of some chemicals such as nitrate to more than 50 ppm in many ground water wells. Nitrate above this level become carcinogenic and it is converted to nitrite that cause infant methemoglobinemia (Blue baby syndrome).Another element of health concern is chlorine that is used as a disinfectant in water network but the presence of organic matter cause the formation of Trihalomenthanes (THMs) which is also carcinogenic. Also seepage of wastewater that contains endocrine disrupter is carcinogenic even in trace amount. As most of our water is from ground water source it may contain some metals with high concentration such as calcium, magnesium and other elements such as iron and manganese that are undesirable for the consumer as it cause health and aesthetical problems(Singh, 2015).

Palestine faces an increasing shortage in water supply for domestic use and lack of access to clean, safe and adequate water. In addition to restricted access to water resources to level that does not meet the needs; as less than 14% of the total West Bank water resources are available for the Palestinians or allowed to use. All previous reasons lead citizen to rely on other water resources that have unguaranteed water quality(PWA, 2013).

About 93% of household in Gaza and West Bank are connected to piped water supply (World Bank, 2018). Water quality is dependent on the availability of the water from municipal network, which is uneven distributed in West Bank cities that varies widely seasonally and daily which cause deterioration in supplied water quality (World Bank, 2018).According to the Ministry of Health (MOH) and Palestinian Water Authority (PWA), water quality of the municipal network is safe and clean and there is no need for the use of any household water treatment systems. On the other hand, the distributers of these units claim that there is a real deterioration of the tap water quality at the consumer. With these controversial opinions the need to study this phenomena rise. Although water provided by PWA is clean and safe; deterioration in water quality can occur not only from the source but also from treatment and during transportation or storage at households. In West Bank water have many problems include daily and seasonal variation in water supply, low water pressure, bad color, bad taste, bad smell and high water cost. About 47% of the population in West Bank has access to network water supply for less than ten days which cause also deterioration in water quality provided (World Bank, 2018).

One or more of the previous reasons result on the usage of Palestinian household for home water treatment systems that people use to improve drinking water quality, which include aesthetic issue to preserve amenities and health issue in order to improve public health and reduce water contamination (Eftekhar et al., 2015).

In market there are many types of the water filters that are wildly used. Here, the most common types of water filters that are used in West Bank are studied from technical, economical, health and public issues. Tap water quality is followed from the source; through the network to the storage tank of the consumer till it reach the consumer tap. Also water quality at the inlet and outlet of water filter will be to determine their efficiency.

1.2 Problem Statement

Home water filters are used widely in Palestine with a big portion in Hebron of about (5,806) water filters (PCBS, 2017). Therefore, there is real need for studying whether these units provide water with the quality recommended by the Palestinian standards or not.

Households' main source of drinking water in 2017 in Hebron was piped into dwellings, tanker truck/cart with small tank, rainwater, protected dug well/protected spring, bottled water, unprotected dug well/unprotected spring and public tap which are arranged respectively (PCBs, 2017). So there is a need to determine whether tap water is polluted or not and to determine the pollution source; whether it from the source, network or water storage tank.

Water from municipal water network provided from Palestinian Water Authority (PWA) are usually tested regularly by Ministry of Health twice a year (every six months), these tests include chemical and biological tests for the source, and biological tests for network and selected Household storage tanks.

In this work quality of drinking water will be checked before it enters water filter and after to determine the efficiency of these systems and whether they provide healthy water within the standards or not. As it is known that the easiest and most personal place to improve and protect water quality is at home (Vigil, 2003).

In Palestine about (44,979) water filters are used, about (33,333) water filters in West Bank and (11,646) in Gaza. The highest number of household water filters in West Bank is found in Hebron Governorate with about (5,806) water filters (PCBs, 2017). Many types of water filters are widely used in Hebron include Reverse Osmosis (RO), Three-stage water filters (Sediment-Carbon-Carbon), and two-stages (Sediment-Carbon), Ceramic filter which is with limited usage in Hebron and UV units for disinfection. With the incremental use of household water filter, this increases the need for determining the efficiency of these units.

1.3Aim and Objectives

The main aim of this research is to assess the Palestinian experience in using household water treatment systems. The specific objectives are:

- To assess the technical feasibility of household water filters.
- To assess the economic feasibility of household water filters.
- To assess the health impacts associated with these systems.
- To study the public perceptions regarding the household water filters.

1.4 Thesis Outline

This thesis consists of five chapters: Chapter one includes an introduction, problem statement and objectives. Chapter two provides a description of the study area and, literature review. Chapter three describes the methodology. Chapter four presents the results and discussion and Chapter five summarizes the conclusions and recommendations.

Chapter Two - Literature Review

2.1 Study Area Description

2.1.1 Geographical Location

Study area is Hebron Governorate in Southern West Bank with about (711,223) citizens, about (88.5%) of them use safe drinking water (PCBs, 2017).

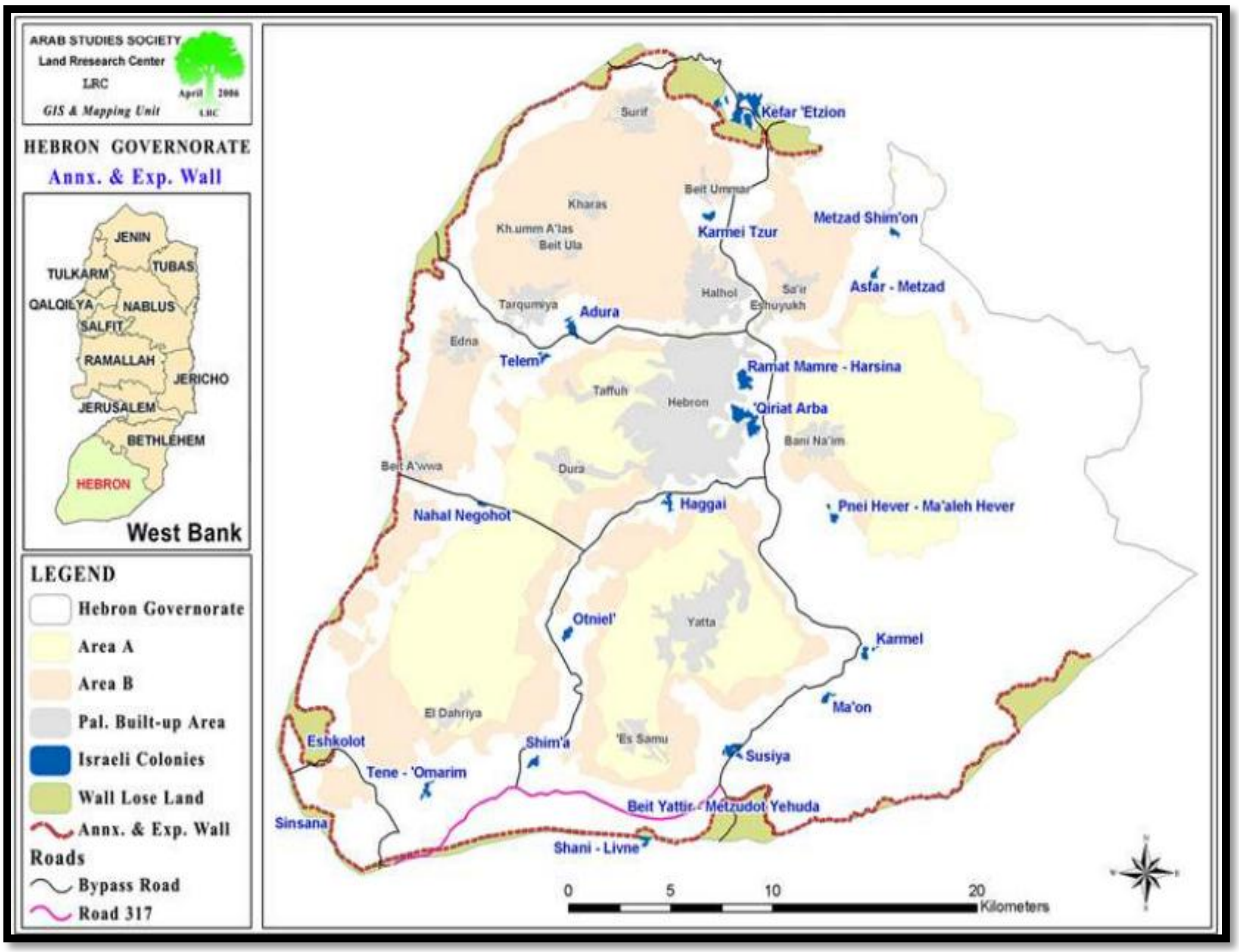

Figure 1 Hebron Governorate (Source: LRC, 2006)

Most of households in Hebron are connected to water network since 1936. Water provided from PWA is from ground water wells or purchased from Israel Water Company (Mekorot). Water problems in Hebron include; frequent intermittent, water pollution, water loss and supply that don't meet the current level of demand (ARIJ, 2009).

2.1.2 Water Resources in Hebron

Water resources in Hebron governorate differ between cities due to the availability of local wells and springs; these resources include Purchased from Israel Water Company as shown in Table 1.

Table 1 Available water resources in Hebron and Bethlehem Governorate in MCM in 2013 (Source: ARIJ, 2015)

Pumped Quantity from Wells		**Spring discharge**	**Purchased from Mekorot**	**Total Available Water**
Domestic	**Agriculture**			
11.4 MCM	0.00	0.5	21.4	33.3

2.1.3 Water Quantity

Average household size for Palestinian family was found in 2016 about 5.2 (Wafa, 2017). Water network connections nearly reach every household; about 93% of household in Gaza and West Bank are connected to piped water supply. In spite of high network coverage, the delivery of the service is intermittent with great variation in per capita supply between cities and villages (World Bank, 2018). Main source of drinking water in households in Palestine is from the municipal network. Out of (135,614) households in Hebron about (109,231) Households are connected to public water network in Hebron from. About (15,294) households in Hebron use Tanker Truck and (6,261) households use rain water harvesting of which protected cisterns are about (4,277) households. Others use bottled water and public taps as a source of drinking water (PCBS, 2017).

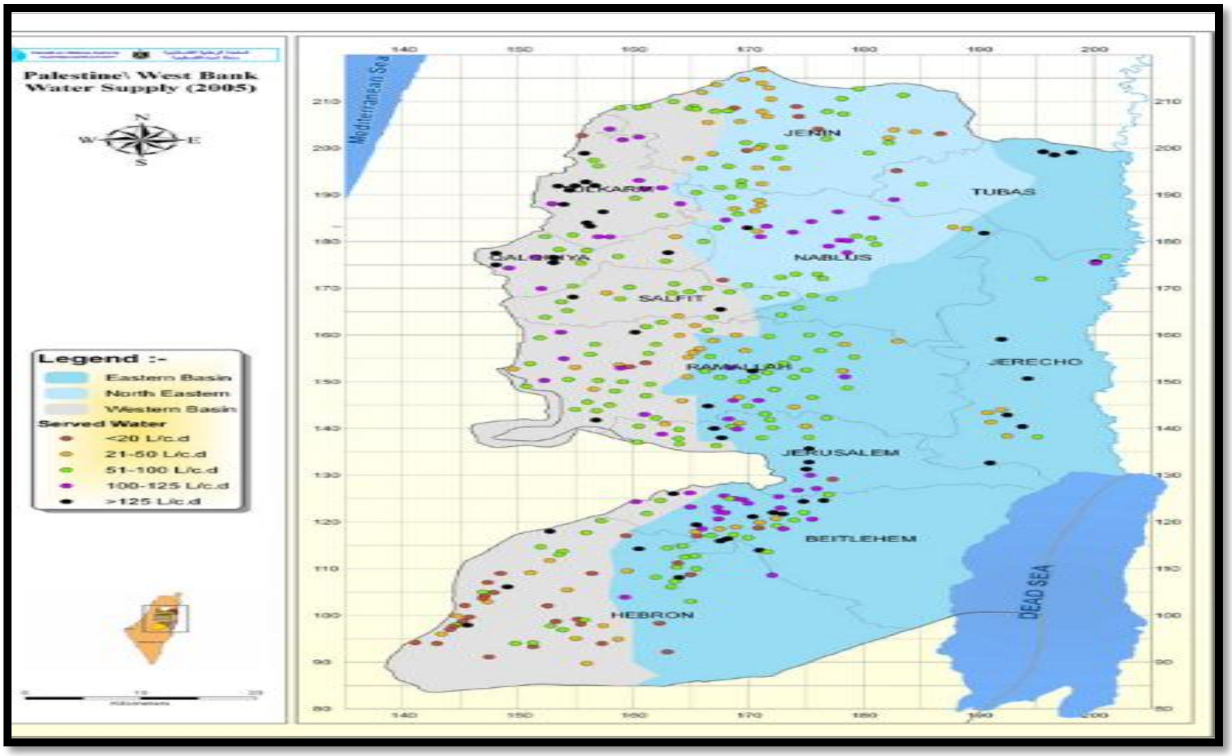

Figure 2 Palestine/ West Bank water supply (Source: PWA, 2017)

2.1.4 Water Quality

Intermittent Water Supply Service

In spite of high network coverage, the delivery service is intermittent with great variation in per capita supply between cities and villages. Great portion of the Palestinian households have a storage tank on roof or in courtyard to meet the frequent intermittent of the water supply. This problem makes the consumer forced to find other alternatives. Other problems results such as high amount of non-revenue water that includes leakage due to old pipes and unaccounted for water from illegal connection increase the problem. Degradation of supply water quality either from the source due to inflow of wastewater and intensive use of agricultural pesticides, during transportation or storage (ARIJ, 2015). MOH make regular biological and chemical tests of water quality for the source, network and storage tanks of the consumers as shown in Table 2.

Table 2 Tested water samples in Hebron from the source (MOH, 2018)

District	All Tested Water Samples*		
	No. of Samples	No. of Contaminated Samples	Percentage of the Contaminated Samples
North Hebron	791	74	9.4%
Hebron	839	200	23.8%
South Hebron	802	143	17.8%
Yatta	828	96	11.6%

**All tested water sample include: Source, Networks, Cisterns, Rainwater Cisterns*

Table 3 shows water quality tests of households' water storage tank that was done by MOH which shows that water quality at household storage tanks was much greater than that at the source.

Table 3 biological test results of households water storage tanks (MOH, 2018).

District	Storage Tanks		
	Number	Polluted	Percent (%)
North Hebron	453	43	9.5
Hebron	413	119	28.8
South Hebron	292	128	43.8
Yatta	207	66	31.9

It is recommended to use tap water after at least three minutes flush as the total number of bacteria was found to be much greater in the first flush than that in the municipal distribution network. After 3- minutes flushing, the number of the microbial pathogen decrease to the number in the distribution system. That decreases the concentration of inorganic chemicals (Bitton, 2014).

Appendix 2, 3, 4 shows water quality analysis in Western, Eastern and North Eastern basin in West Bank. Appendix5 and 6 shows water quality indicators by Water Sector Regulatory Council for Hebron Governorate. While Appendix 7 shows Chemical Analysis Report for Source of Water in North Hebron from MOH.

2.2 Household Water Treatment Technology

2.2.1 Concerns about water quality

According to Vigil (2003), the main concerns for water quality include:

- Source related concern.
- Treatment related concern

- Distribution related concern.

Presence of contaminant in WDS will lead to many problems such as:

- Bio-corrosion
- Microbial Growth
- Pathogen growth and survival
- Nitrification Problems (Ahuja et al., 2014).

2.2.2 Types of Contaminants in Water

Microbial pollutants include: bacteria, viruses and protozoa. It is found that cover water container help to reduce fecal and total contamination about 50% (Wright et al., 2004).

Inorganic chemicals result from the corrosion of metallic pipes. Producing copper, iron or lead depending on the type of the pipe used**.**

Organic chemicals: natural and synthetic expressed as total organic carbon (TOC). That enters the sewer system from animal feed lot, pesticides, herbicides, pharmaceutical and microbes.

Disinfection By-products (DBPs) as disinfectant are reactive material they interact with organic compound to form (DBPs) such as Trihalomethanes (THMs).

Taste, odor and color; Taste of water result from compounds that are produced during algae bloom. Also Chlorine that is used as disinfectant produces undesirable odor to consumer. Color results from corrosion of pipes while taste result in the presence of iron and manganese.

Hardness results from calcium and magnesium carbonate forming a scale that is difficult to remove and cause stains plumbing fixture, laundry and cooking utensil. Consumer of soft water that is of very low concentration of dissolved solid must be aware of sufficient dietary mineral consumption (Vigil, 2003).

2.2.3 Point of Use and Point of Entry

Point of Use (POU) and Point of Entry (POE) technologies become widely used to ensure that drinking water quality is clean and safe for human consumption. POU is cost effective as it is only used for treating water for drinking and cooking as it is usually attached to one tap or limited number of taps. While POE is used where problems like hardness found that will affect laundry and cooking utensils to treat all water entering the house or facility (Ahuja et al., 2014).

Point of Use (POU) and point of Entry (POE) are used to:

- Achieve the maximum concentration level (MCL) of chemicals,
- Removal of the pathogenic microorganism,
- Achieve the aesthetic properties such as color, taste and odor recommended by regularity authority for drinking water (Bitton, 2014).

The most common types of home water treatment systems used recently in the POU and POE systems that provide final barrier to the contaminant before use include the following techniques:

- ➢ Personal water bottle;
- ➢ Pour-through;
- ➢ Counter-top manual fill;
- ➢ Counter-top connected to sink faucet or faucet-connected counter-top units;
- ➢ plumbed-in units;
- ➢ Faucet-attached units; and
- ➢ Under sink units with separate faucets (Wange et al., 2011).

Under sink units with separate faucets allow for the use of treated water for drinking and cooking while untreated water used for cleaning and washing. Separate faucet units help to reduce the operating cost of the unit (EPA, 2006).

POU treatment technologies include:

- Distillation
- Granular Activated Carbon(GAC)
- Ion Exchange (IX)
- Anion Exchange (AX)
- Cation Exchange (CX)
- Reverse Osmosis (RO)

- Adsorptive Media like Activated Aluminum (AA) and others (EPA, 2006; Molloyet al., 2008)

2.3 Technical Feasibility of Household Water Filters

Water filters consist of cartridges that must be economic, not toxic material, long lasting and efficient (Evangelista et al., 2019). Following some of the Technical properties of household water treatment systems include (Hamouda et al., 2010):

- Removal efficiency
- Microbial Re-growth
- Service life and maintenance frequency
- System footprint
- Operation skill

Steps for finding appropriate water treatment system:

Testing of water quality at household tap:

Test of the water quality at the consumers tap is the most important step to determine whether they need to install water treatment system or not and which type of these system is effective, economically feasible and safe. It is recommended to visit the environmental health department to obtain information about the quality of the water and the problems related in the local area (NSF, 2019).

2.3.1 Removal Efficiency

Performance standard and certification (ANSI/NSF Certified devices):

National Sanitation Foundation (NSF)/ American National Standard Institute (ANSI) establish the standard for Drinking Water Treatment Units. These standards include testing the safety of the material in contact with drinking water, structural integrity and the contaminant reduction performance. These standards adopted 1972-1991 with continuous updating.

HWT technologies like filtration, chlorination, boiling have greatly improve microbial water quality, POU technologies is the most efficient way to reduce recontamination of water (Brown & Clasen, 2012). Removal efficiency must achieve the maximum concentration level recommended by the regulatory authority noticing that it will be decreased with the saturation of the filter material (Deshommes et al., 2010). US EPA identifies small scale compliance technologies; POU and POE that are recommended for the removal of certain contaminant (EPA, 2006). GAC able to remove DBP (disinfection by products) like thrihalomethane, herbicides, pesticides, chlorine, triazines and other substances (Evangelista et al., 2019). AC able to remove taste, odor, natural and synthetic compounds; while powdered AC adsorb only microbial, radiological and organic chemical compounds but not the compounds that are essential to human bodies (Ling et al., 2019). RO have greater removal efficiency than GAC of organic compound as it has a smaller pour size (size exclusion) (Yoon & Lueptow, 2005). Removal efficiency of RO will be reduced by membrane age, $CaCO_3$precipitation and PH; it is also affected by initial concentration at water inlet (Lothrop et al., 2015). Adding silver nitrate or silver nano particle within the recommendation for ceramic filters is essential to enhance microbiological efficiency, keep filtered water away from recontamination, reduction of fouling formation (Lyon-Marion et al., 2018).

Table 4 shows typical technologies and contaminant reduction performance claims certified under NSF/ANSI.

Table 4 Typical technologies and contaminant reduction performance claims certified under NSF/ANSI (Ahuja et al., 2014)

NSF/ANSI Standard	Water Treatment Technology	Typical Claims
42	Activated Carbon, Other Adsorptive or Absorptive medias, Mechanical Filtration,	Chlorine reduction, nominal particulate reduction and chloramines reduction.
44	Ion Exchange Softeners	Softening performance, rated softening capacity, and accuracy of brine system.
53	Activated Carbon, Other Adsorptive and Absorptive Medias and Mechanical Filtration.	Lead reduction, Cyst reduction, volatile organic compound reduction, turbidity reduction and lindane reduction.
55	Ultraviolet	Disinfection
58	Reverse osmosis	Total dissolved solid reduction, lead reduction and Cyst reduction.
62	Distillation	Total dissolved solids reduction, lead reduction and Cyst reduction.

2.3.2 Fouling

There are four fouling categories include scaling, colloidal, organic and biological fouling. Fouling process is the accumulation of the particle, colloids and ions in the membrane surface or within the membrane due to its ability for the rejection of these contaminants that results in the deterioration of the membrane performance over the time. In order to avoid mechanical and chemical damage of the membrane due to fouling periodic cleaning is needed (Wange et al., 2011).

Biological fouling is growth of bacteria in the presence of nutrient which lead to deterioration in water quality. Post disinfection is needed after RO system as bio-film accumulate at this membrane (Park & Hu, 2010). Back washing and chemical cleaning are used to remove bio-fouling and scaling (Pooi & Ng, 2018).

2.3.3 Service Life and Maintenance Frequency

Service life is the life time of the filter until it is expired in liter (Hamouda et al., 2010). Service life depend on the type of this filter, quality of filter material, water quality at the inlet as clogging of the filter cause increase of the head loss thus result in reduction of life cycle of the cartridges (Evangelista et al., 2019). Also frequent maintenance must be done in accordance to the manufacturer instruction but some of these systems have a built in monitor that is used to indicate the level of TDS and make a sign if the system is not working properly. Generally the volume of untreated water that enters RO system and the inlet water quality control the replacement of pre-filters and post-filters (Wang et al., 2011).Some filters come with transparent case to know if membrane needs to change. Some filter with alert like LED light that indicates that RO systems require little maintenance (Water Filter Mag, 2019). During the life time removal of the contaminants like lead will be reduced from 80-60% (Deshommes et al., 2010). Frequent maintenance help to produce filtered water with the same quality over filter life time (Pooi& Ng, 2018).

2.3.3 System Footprint

Environmental foot print includes solid residual and liquid residual (Hamouda et al., 2010). Recovery rate for RO system is the ratio between the volume of the treated water at the outlet of water filter to the volume of untreated water at water filter inlet. Low recovery rate produce larger amount of rejected water cause wasting larger amount of water to produce clean water (Altaee & Hilal, 2015).

2.3.4 Operation and Maintenance Skills

Water treatment operator must be able to operate and control these systems like watching gauges and other indicators to make sure that the system working properly (Mymajors, 2019).

Sustained use of home water treatment systems is important to maximize health benefits from these systems; this can be achieved by improvement in these systems that reduce necessity to frequent change and water quality monitoring tools (Brown & Clasen, 2012).

Reverse osmosis have a great removal efficiency but it requires high operating pressure (Ling et al., 2019).

2.4 Economic Feasibility of Household Water Filters

Three options for improving drinking water quality are improving public network water quality, using of water purification systems or use of bottled water. High monthly income encourages purchase bottled water while household size with the presence of children and length of residence encourage the adoption of HWT systems (Johnstone & Serret, 2011).

It is recommended that 5% is the maximum expenditure in water from households monthly income according to World Bank but this percent may reach 10%- 55% in some countries due to water accessibility, availability of water throughout the year and water vendor that sell water (Behailu et al., 2012).

Better water quality can be measured by consumer willingness to pay (WTP) for improved service level and willingness to pay for improvement in water quality. Household in urban areas and those who have their own source of water have higher WTP than whom live in rural areas or who use tap water. Education level and income level affect improvement of water quality, also Public awareness affect household perception for the opportunity cost of not drinking safe water (Haq et al., 2007).

Economic criteria for choosing specific type include capital cost for purchasing and installation such systems, operation and maintenance (Hamouda et al., 2010). According to EPA cost estimation of water filters include capital cost, operation and maintenance cost. Capital cost that is paid in the first year only includes the cost to purchase water filter, installation and educational material and water quality test. While operation and maintenance cost that occur annually like annual replacement of filter cartridges include of maintenance of the device, residual disposal, insurance coverage, annual water quality monitoring and public education (EPA, 2007).

New type of water filter developed recently that treat water without causing drop in head loss that result from frequent clogging which reduce the need to change the cartridges in short time as its life time vary from 5-6 years depending on inlet water quality reducing maintenance cost making it economical(Evangelista et al., 2019).

Membrane filtration require electrical pumping that act as external force, these system have higher capital cost than other water treatment technologies but due to its high efficiency it has a lower cost per liter of treated water and providing the highest removal of pathogens (Pooi & Ng, 2018).

The availability of adequate technical and financial support limits the success of water filter usage (Johnston et al., 2010). Pitcher filter and tap mounted filter are most used in US whileunder sink filters are not easy to install and expensive (Deshommes et al., 2010).

2.5 Health Impacts

Home water treatment systems reduce concentration of some contaminant while others are not; contaminant testing and treatment help to protect public health. Chemical and microbial guideline must be monitored by the regularity authority for municipal water network; while drinking water quality from other sources is the responsibility of the consumer. Consumer will not think that their water quality is unsafe if there is no change in aesthetic properties or there is disease spread by water (Lothrop et al., 2015).

Unsafe drinking water lead to serious health problem such as diarrhea which is the most common water born disease that cause weight loss through liquid loss which lead to dehydration, gastroenteritis and others (Pooi & Ng, 2018). Diarrheal disease is the second cause of death for children bellow five years worldwide (UNICEF, 2009).

Household health can be improved effectively using HWT systems more than treating water at the source (Daniel et al., 2018).

RO provides a great removal efficiency of the contaminants which depend on the concentration at the inlet, soft water with $CaCo_3$ concentration less than 90mg/l may not protect against cancer risk and affect skeletal and cardiovascular health also soft water cause leaching of metals like iron. Therefore, re-mineralization is essential for this type of systems to prevent corrosion and increase their daily intake of calcium and magnesium. AC provides water with components within the guidelines. Hard water with the concentration of $CaCo_3$ more than 300 mg/l produces undesirable taste and scaling of water heaters and pipes (Lothrop et al., 2015).

Optimum concentration of calcium and magnesium is from 40 to 80 mg/l for Calcium and from 20 to 30 mg/l of magnesium; higher concentration of these elements indicate higher concentration of other dissolved solid that may be of health concern for human body (Kožíšek, 2003). Also Ca is essential for bone health, blood clotting and transmission of nerve impulses (Ling et al., 2019).

Many studies show that hard water with high magnesium content help to protect from cardiovascular diseases (CVD). Low concentration of Ca and Mg in drinking water lead to increase in triglyceride, total cholesterol, and LDL-cholesterol levels, diastolic blood pressure and systolic which increase the opportunity of Ischemic Heart Disease. The protective amount of Ca that must be taken daily from water is 75.7 mg while for Mg is about 6.87 mg to prevent heart diseases (Stevanovic et al., 2017).

Sodium-potassium is essential elements for renal health and for nervous system for the generation of electrical potential in nerve cell to conduct nerve impulses which generate heart beat and muscle contraction(Ling et al., 2019).Concentration above 2.5 g/l of Sodium chloride cause hypertension related to the concentration of sodium ions not chloride(WHO, 2003).

In a study in India it is found that there is no relationship between kidney stone occurrence and water quality (Mitra, Pal & Das, 2018). Another study shows that hard water increase urinary calcium concentration which increase formation of kidney stone (Bellizzi et al., 1998).

Sodium leads to high blood pressure or hypertension while calcium and magnesium and potassium has effects in lowering blood pressure and reduce cardiovascular problems. Human body adsorbs minerals from water better than that from food(Paddock, 2019

,Naser et al., 2019).Food and Agricultural Organization of the United Nations identify EC categories as (Naser et al., 2019):

- Fresh water (EC <0.7 mS/cm),

- Mild salinity (EC ≥0.7 and <2 mS/cm), and

-Moderate salinity (EC ≥2 and <10 mS/cm).

National Academy of Medicine (NAM) recommend for adult male the average total daily water intake about 3.7 liters (15 cups) while for adult female the average total daily water intake is recommended of about 2.7 liters (11 cup) (One Medical, 2017).

2.6 Public Perceptions

Public Perception that water is a public good and basic right; and it should be provided clean and for free (Behailu et al., 2012). The adaption of HWT systems or bottled water are due to lake of confidence in tap water quality from aesthetical properties like color taste and odor (Johnstone & Serret, 2011).

In a study of families with young children’s using private wells; educate mothers usually treat their drinking water. Household income and education level widely affect positively the adoption of home water treatment systems and are not related to drinking water quality at the source (Lothrop et al., 2015).

The adoption of household water treatment systems related to socio economic conditions include household water treatment systems promotions, educational level, wealth level and access to technology (Daniel et al., 2018).

The decision of the consumer to adopt bottled water or home water treatment system to maintain better drinking water quality is affected by the negative perception at the consumer about tap water quality and the knowledge that the use of bottled water as it produces solid waste has a negative impact on the environment. The wealth is the most important factor that affects the decision of consumers at household to use water treatment systems (Fotueet al., 2012). No single feature can be alone the reason for the adoption of HWT systems as many factors affect the adaption such as negative perception about tap water quality and unavailability of prior experience in using HWT systems encourage the adoption of these system in households connected to piped network. The negative perceptions about tap water quality with the availability of the willingness to pay have a high influence in the adoption of HWT systems (Daniel et al., 2018).

Most of water filter users judge the safety and water quality produced based on aesthetic properties include taste, color, odor and suspended solid not focus on water quality chemically and biologically as these systems mostly used by rich people in some countries like Egypt and it is the opposite in few countries like Indonesia as it usage decrease within wealth people (Rosa & Clasen, 2010). Also high adherence in using HWT is necessary to maximize health protection from microbial risk by improve monitoring techniques of these systems (Brown & Clasen, 2012).

Sustainable use of HWT systems which is the long term use of these systems that require little effort and time for producing sufficient quantity of drinking water required for households, purchase for one time only and provide high removal efficiency of the contaminant after long term use this result in high and large scale adoption of these systems (Sobsey et al., 2008).

According to previous studies home water treatment systems reduce exposure to diarrheal diseases but with high adherence especially when water quality of the source is deteriorated which is more important than microbial removal efficiency to optimize health gain (Brown & Clasen, 2012).

2.7 Drinking Water Quality Parameters

Safe drinking water quality is water that will not cause any significant health risk during lifetime of consumption. Guidelines of drinking water quality are mandatory limits that represent the minimum requirement to protect public health during the consumption (WHO, 2004).

- Microbial aspects (Bacteriological analysis)

- Chemical and Radiological aspects (Physicochemical analysis)
- Acceptability aspects (Aesthetic parameters)

2.7.1 Microbial Contamination

Microbial contamination is one of the major concerns of water quality. Many types of microorganisms can be present in water such as Protozoan, Bacteria, Viruses and Helminthes.

2.7.1.1 Indicator Organism

Escherichia coli usually found where there is a human and animal feces pollution that is found in sewage and treated effluent, and so it is an index of fecal contamination of water and indicator for the effectiveness of disinfection process. These organisms are difficult to test, so indicators are used to indicate the presence of these organisms that may be harmful and cause illness to human. E-coli are measured in 100 ml sample of drinking water. Process includes membrane filtration and incubation at 44-45 ^{o}C, then after 24 hour counting of colonies (WHO, 2011).

2.7.7.2 Thermotolerant Coliform Bacteria

Include E-Coli and other types of bacteria that originate from soil, industrial effluent or decaying of plants. Re-growth of bacteria in water distribution system will not be present without the presence of the following condition:

1. The presence of adequate quantity of nutrient.
2. Temperature of water above 13^{o}C.
3. Low concentration or no residual chlorine.

2.7.1.3 Coliform organism (Total Coliform Bacteria)

Total Coliform group include all organism that could grow and live in water like fecal contaminants and environmental species. Total Coliform can’t be used as indicator for the presence of pathogenic microorganism but it can be used as indicator for the effectiveness of disinfection process and the potential presence of bio-film in water distribution system. Total Coliform is measured in 100 ml of water sample. Total

Coliform counting includes membrane filtration then incubation at 35-37 ^{o}C and then counting of colonies after 24 hours (WHO, 2008). According to WHO and PSI specification Total Coliform must be less than 3 in 100 ml of water. After disinfection process Total Coliform should be absent in water; their presence indicates inadequate treatment (PSI, 2010; WHO, 2011).

2.7.2 Physicochemical Analysis

2.7.2.1 Chemical Analysis

Chemical contaminants can be found in water either from natural resources or from pollution source such as human activities like industries, agriculture and human dwellings. Some of these chemicals are essential to human body but other even at a low concentration cause a serious health problem.

- **Guideline value:** concentration of the constituent in water that doesn't cause health risk to human over life time of consumption that doesn't exceed tolerable risk (WHO, 2011).
- **Maximum Concentration level:** the highest concentration of the contaminant in water that will not cause serious health problem like cancer to consumer over life time of consumption; it enforceable standards (EPA, 2018).
- **PH:** it is operational water quality parameter; for example if you want to have efficient disinfection process it is recommended to keep PH less than 8, on the other hand PH less than 7 is corrosive making water with unprofitable taste and color. But there is no guideline value for PH (WHO, 2011).
- **Chlorine:** it is used as a disinfectant, have special odor that all consumer can smell. **Total Dissolved Solid (TDS):** TDS in water of less than 600 mg/l is acceptable, above this level produce undesirable taste and cause formation of scale in water pipes and household appliances.
- **Turbidity:** it is caused by the presence of colloidal and suspended solid that obstruct light transmission in water. These elements include organics, inorganic and microorganisms. Turbidity will reduce the efficiency of disinfectant as it protect microorganism and change the appearance of water; this make turbidity an indicator

for the presence of the contaminant that may include microorganism which may cause gastrointestinal infections.

- Turbidity is measured by Nephelometric turbidity unit (NTU) and it must be less than 1 NTU to ensure occurrence of efficient disinfection.
- **Dissolved Oxygen (DO):** is the amount of DO that is affected by the source of water, its temperature and other factors. Lack of oxygen enhances microbial reduction of nitrate to nitrite and sulfate to sulfide. Excessive DO accelerate corrosion of pipes. DO have no health based guideline.
- **Heavy Metals:** heavy metals in water such as Mercury (Hg), Chromium(Cr), Copper(Cu) and others can be found in water from many sources; these elements are of a high density and toxic effect even at low concentration or they become carcinogenic with long term exposure or lead to death. On other hand some of these elements are necessary to human body metabolism but in small concentrations.

2.7.2.2 Physical analysis

Physical properties of water include Taste, Odor, Color, Temperature and others. These properties can be recognized by our senses such as smell, taste or sight.

- **Color:** Drinking water should be with no color. Color of water is due to the presence of impurities such as organic chemicals that is either naturally occurring from soil or from corrosion of pipes or even from industrial effluent. Color result from oxidation by iron bacteria or exposure to air causing rust-colored deposition in drinking water.
- Unit of measuring color is True Color Unit (TCU); it is recommended to be less than 15 TCU were consumer can detect color above this.
- **Hardness:** is a measure for the ability of water to react with soap; it usually expressed by concentration of Calcium Carbonate.
- Less than 60 mg/l called soft water.
- 60-120 mg/l considered moderately hard.
- More than 120 mg/l considered hard.
- **Temperature:** High temperatures increase the growth rate of microorganism; increasing corrosion thus changes color, Taste and odor of water. Low water temperature is more desirable.

- **Taste and Odor**: the first indicator for the safety of water for consumption is color, taste and odor. Guide line values established for the substances that cause change in these properties at a concentration much lower than guide line value. For example chloramination with a high concentration lead to the formation of trichloramines that causes undesirable taste and odor**.** Taste and odor usually result from natural organic, inorganic pollutants and biological process during storage and distribution (WHO, 2011).

Chapter Three -Methodology

3.1 Data Collection and Questionnaire Survey

Based on the data collected from the Palestinian Water Authority and Ministry of Health reports it is found that water quality of some wells in the West Bank suffers from incremental deterioration. The Ministry of Health in Ramallah provided the number of tests conducted for water resources, network and some household storage tanks. These tests showed that there is pollution in some cities in West Bank. The Environmental Department at primary health care and public health of north Hebron provided the chemical analysis results of water resources in North Hebron, after the permission was taken from Ministry of Health that make regular test of total and fecal coliform for water resources and network twice a year.

With the highest portion for the number of water filter that are used in Palestine is found in Hebron; it was decided to study this phenomena at this area. After searching for a distributer for these units a Company called National Marketing Company agreed to cooperate to find what the most used units are and provide a list with names and location of beneficiary households. From these names selection was made in areas known with high pollution in drinking water and that with good drinking water quality for two types of most used water filters.

In order to determine the efficiency of the common used water purification system in Palestine particularly in West Bank which include RO-System that consist of6 stages (Sediment, Carbon, Carbon, RO, Carbon, UV unit); notice that UV filter in this company just used with RO, Two Stage Water Filter that consist of sediment filter followed by Activated Carbon Filter, or 3 stages that contain sediment filter followed by two carbon filter. Many factors affect the consumer selection of these units that are going to study as illustrated bellow. Our study includes quantitative and qualitative study. We designed a survey for consumer to determine the reason for the use of home water filter and the efficiency of these units. Whether there is a real need for these systems or they are only aesthetically used and what are the limitations.

This study is based on questionnaire that is shown in appendix 1 and experimental method; depending on a certified laboratory water quality tests were done using standard method to determine the efficiency of these systems. Water Quality parameters for inlet and outlet of water filter include chemical and bacteriological tests. Using the Palestinian Standard Institution (PSI) for drinking water instructions for drinking water and comparing alternative of home water filter option used to determine the most efficient option technically and economically. With corporation of National Marketing Company structured survey were conducted for the user of water filters that include many questions about the reason why they use these units and whether they make water quality test before they choose the type of water filter used and their impression about water quality resulted. Table 5 shows how to determine the sample size (Singh & Masuku, 2014).

Table 5 Sample Size Determination (Singh & Masuku, 2014)

Size of Population	Sample Size (n) for precision (e)	
	±5%	±10%
500	222	83
1,000	286	91
2,000	333	95
3,000	353	97
4,000	364	98
5,000	370	98
7,000	378	99
9,000	383	99
10,000	385	99
15,000	390	99
20,000	392	100
25,000	394	100
50,000	397	100
100,000	398	100
>100,000	400	100

Table 5 by Glenn (1992), Sample size for ±5% and ±10% precision levels where confidence level is 95% and P= 0.5 (Singh & Masuku, 2014).

The number of used water filter in Hebron Governorate was (5,806) filters (PCBs, 2017); according to Table 5, the sample size is100 households.

Survey analysis was conducted using SPSS software version 19 to analyze and produce relationship between the different variables in the questionnaire and perform the output graphically to understand the results.

3.2 Data and Questionnaire Analysis

Questionnaire analysis is done using SPSS program (Statistical Package for Social Sciences) which is used to perform statistical analysis to obtain relationship between variables. Questionnaire include of 18 questions. And each question result was analyzed.

3.3 Field Visits and Drinking Water Sample Collection

Three types of water filters are widely used in Hebron; Three-Stages, Two Stages and RO water filter. As the Two-Stages water filter now become rarely used in Hebron so it is neglected. For each type of water filter three consumers were chosen and three samples of water inlet and outlet for each filter were taken for chemical physical tests and three samples of water at the inlet and outlet for each filter were taken for biological tests as shown in table (7).Household were chosen for water sample from Hebron city, Yatta city, Beit Ulla and Sourif.

3.4Water Sampling and Analysis

After taking samples from selected households and locations, samples were sent to water and environment department laboratory in BZU within few hours.

3.4.1 Sampling

Selection of households was based on location of household and the type of water filter used. For each type of water filter three houses were chosen in locations that are known of a good water quality and of deteriorated water quality.

Storage of samples for microbiological analysis

Analysis of samples for microbiological tests should be done within less than 24 hours after collection of samples, and should be kept in sterilized containers in dark, cool conditions.

Sampling method for physiochemical analysis

Sampling must be done using clean (not necessary sterilized) glass or polyethylene bottles; collected and stored properly at a low temperature (4^oC) in dark conditions.

3.4.2 Analytical Techniques

Indicator organisms are isolated from water using many techniques such as membrane filtration techniques (MF) and others.

3.4.2.1 Bacteriological analysis - Filtration techniques (MF)

Using dilution of the sample of minimum volume of 10 ml at a sterile filtration contain a membrane filter of a pore size 0.2-0.45 μm. indicator organisms are isolated within the filter which are then transported to petri dish where bacteria acclimatize to new condition, then petri dish is transferred to incubator at a selective temperature for a period of time. Identified colony are recognized visually and counted to obtain “Colony - forming Units” (CFU) per 100 ml of original sample.

3.4.2.2 Physiochemical Analysis - Titration Principles

Using of test kits for measuring some of health–related parameters based on conventional titration, photometers or comparators (WHO, 2011).

Chapter Four - Results and Discussion

4.1 Technical Performance of Households Water Filters

4.1.1 Removal Efficiency

Figure 3 illustrates percentage for most common used water filter in West Bank; Two stages water filter (Sediment-Carbon) are the most used type for the users who answer the questioner with about 35% of sample size, then Reverse Osmosis are used by 30%. Three stages water filters (Sediment-Carbon-Carbon) are used by about 27% while UV disinfection is used by only 1% of the consumer for each type. Both types have Performance standard and certification (ANSI/NSF Certified devices).

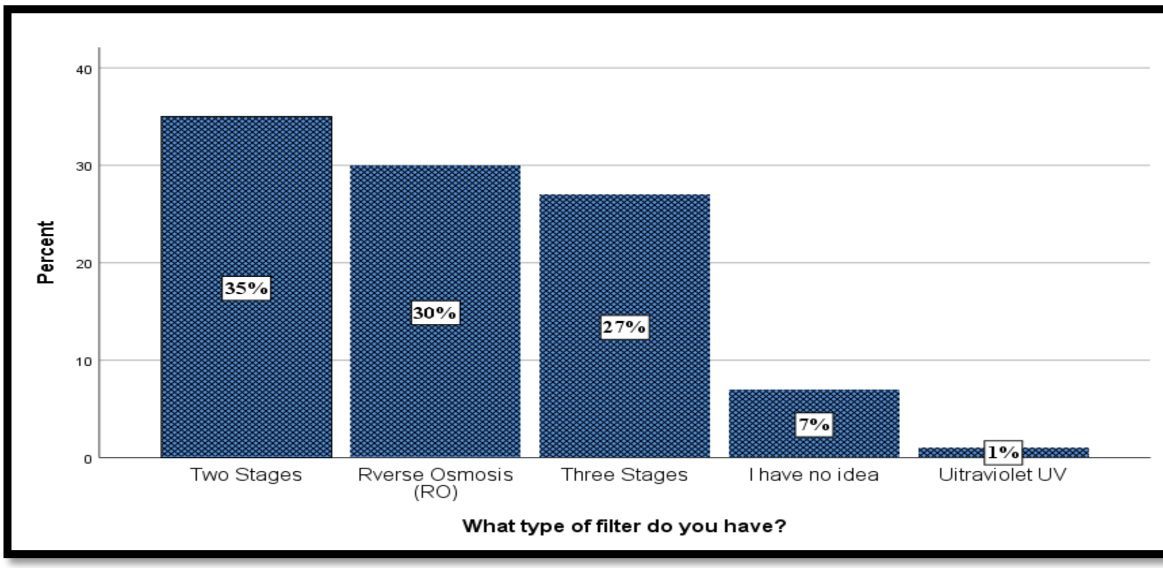

Figure 3 Types of water filters used according to Questionnaire

4.1.1.1 Water Quality Analysis

In this study we carried out water quality analysis for two types of water filters that are most widely used in Hebron; Three-stage water filters and RO water filters. For each type of water filter we took samples from three different users. From each user three samples at the inlet of water filter for microbial test and three samples for chemical tests were taken and the same at the outlet of water filter. Microbial tests include Total and fecal coliform while physiochemical analysis include total dissolved solid, pH, electrical conductivity, chloride, carbonate, nitrate and sulfate.

Drinking water physiochemical and microbiological properties standards according to PSI and WHO are shown in Table6.Note that chloride, hardness, pH, sulfate, total dissolved solid are naturally occurring chemicals that are usually not of health concern and just affect acceptability of water so they have no guide line value (WHO, 2011).

Table 6 Drinking water physiochemical and microbiological properties standards according to PSI and WHO (PSI, 2010; WHO, 2011; Khalil, 2019; Aish, 2013)

Parameter	***pH***	***TDS***	***E.C***	***Cl^-***	***HCO_3***	***NO_3^-***	***SO_4^{-2}***	***T.C***	***F.C***
Standard value PSI 2010*	6.5-9.5	1500 mg/l	2500 µS/cm	250 mg/l	200 mg/l	70 mg/l	250 mg/l	3/100 ml	0/100 ml
Standard value WHO 2011*	6.5-8.5	1000 mg/l	Up to 2000 µS/cm	250 mg/l	200 mg/l	50 mg/l	250 mg/l	3/100 ml	0/100 ml

Table 7 shows drinking water quality parameter for water samples taken at the inlet and outlet of water filters.

Table 7 Drinking water quality parameter for water filters samples

Location	***Type water filter***	***PH***	***TDS***	***E.C***	***Cl^-***	***HCO_3***	***NO_3^-***	***SO_4^{-2}***	***T.C*** CFU	***F.C*** CFU
	Standard value PSI	6.5-9.5	1500 mg/l	2500 µS/cm	250 mg/l	200 mg/l	70 mg/l	250 mg/l	3/100 ml	0/100 ml
Beit Ulla	**S.C.C_1 in**	7.99	259	529	42	158.9	0	16	Nil	Nil
	S.C.C_1 out	7.42	50.1	99.7	26.2	23.2	0	10.7	5	Nil
Hebron	**S.C.C_2 in**	8.02	296	590	44.2	210	0	16.9	Nil	Nil
	S.C.C_2 out	7.99	267	534	32.1	190	0	13.2	Nil	Nil
Hebron	**S.C.C_3 in**	8.26	289	578	47	225.2	0	18.8	Nil	Nil
	S.C.C_3 out	8.13	83.6	168.1	26.8	55	0	12.1	7	Nil
Sourif	**RO_1 in**	7.88	272	544	46.4	180	0	18.1	Nil	Nil
	RO_1 out	7.39	34.1	69.5	28.3	15	0	11.2	Nil	Nil
Yatta(rain water)	**RO_2 in**	8.01	297	595	40.4	160.8	0	17.1	Nil	Nil
	RO_2 out	7.67	72.4	147.3	29.9	13.2	0	12.1	2	Nil
Yatta	**RO_3 in**	8.05	173	346	46	115.2	0	22	Nil	Nil
	RO_3 out	7.92	26	51.9	32.4	13.4	0	14.2	Nil	Nil

pH Value

pH values for all samples at the inlet of filters are between 7.88 to 8.26. Using Three-Stage filter produce water with pH from 7.42 to 8.13 while RO filters produce water with pH varies from 7.39 to 7.92. Notice that pH values at the inlet and outlet of both types of filters are within the acceptable limit of PSI and WHO. pH less than 8 and not less than 7 help to have efficient disinfection process and keep water not corrosive with acceptable taste and color (WHO, 2011).

Total dissolved solid (TDS)

Total dissolved solid include many beneficial constituents like calcium, sodium, potassium, magnesium cations, hydrogencarbonate, carbonate, sulfate, chloride and nitrate anions. Concentration of the total dissolved solid at the inlet of filters is less than 300 mg/l which are less than the WHO guideline. At the outlet of three stages filters decrease to less than 100 mg/l which is not acceptable by PSI standards, except for one sample for filter that need to be changed. For RO water filter concentration of TDS is less than 100 mg/l which is undesirable and may affect the acceptability of water producing flat taste and become corrosive to water supply system (WHO, 2004). According to PSI TDS must be not less than 100 mg/l with not less than 10 mg/l of magnesium and 30 mg/l of calcium. With concentration of less than 100 mg/l for water at the outlet of the filters it will lack of these essential elements for human bodies and this cause health problem. Optimum concentration of calcium and magnesium is from 40 to 80 mg/l for Calcium and from 20 to 30 mg/l of magnesium; higher concentration of these elements indicate higher concentration of other dissolved solid that may be of health concern for human body (Kožíšek, 2003). Also Ca is essential for bone health, blood clotting and transmission of nerve impulses (Ling et al., 2019).

Notice that Sellers of water filter claim that tap water is contaminated using electrode method (electric precipitation) that contains electrodes which is made of iron and connected to electric power source. Pure water is a weak conductor of electricity while in the presence of dissolved solid electrical conductivity of water increase. While these electrodes are connected to electricity this causes dissolution of electrodes producing iron dioxide that change color of water. In case of tap water with high concentration of TDS the amount of iron dioxide produced is greater this mean that the color change where they claim that this change is a result of contaminants in water. In pure water with small amount of TDS the color will not change so it will appear clear. Water Quality Association (WQA) declare that electronic precipitator test is misleading as this test indicate the level of TDS in water that aren't of health concern and doesn't provide any information about the contaminant of health effect (eSpring, 2005;Yaheea, 2015).

Electrical conductivity

Electrical conductivity or salinity is related to the concentration of TDS; increase of TDS concentration will increase electrical conductivity of water. For the inlet of water filter EC values are less than 600 µS/cm or 0.6 mS/cm; they are still within the acceptable limit provided by PSI and WHO. For outlet of these filters, as they provide water with low concentration of TDS their EC will be decreased after using water filters. According to Food and Agricultural Organization of the United Nations identify fresh water with (EC <0.7 mS/cm) (Naser et al., 2019).

Chloride concentration

Chloride concentration at the inlet and outlet are less than 250 mg/l. Increase in concentration of chloride will change water taste that becomes salty, which depend on the available cations like sodium, calcium and potassium (WHO, 2017).

Carbonate concentration

High carbonate concentration with the presence of calcium and magnesium ions cause formation of hardness problem. All of samples that are taken at the inlet and outlet of water filter have a concentration less than 200 mg/l which are acceptable according to PSI and WHO recommendations except one sample in Hebron city. Notice that at outlet of AC water filter Carbonate concentration varies from (23.2-55) mg/l while for RO water filters (13.2- 15) mg/l. Taste threshold for Ca ions from 100-300 mg/l while less than for magnesium (WHO, 2017). Soft water with $CaCo_3$ concentration less than 90mg/l may not protect against cancer risk and affect skeletal and cardiovascular health also soft water cause leaching of metals like iron; so re-mineralization is essential for this type of systems to prevent corrosion and increase their daily intake of calcium and magnesium (Lothrop et al., 2015) and water become more corrosive (WHO, 2017).

Nitrate Concentration

For all water samples at the inlet and outlet of water filter water is clean from nitrate.

Sulfate Concentration

For all water samples at the inlet sulfate concentration varies from 16- 22 mg/l and at the outlet of water filters varies from 10.7- 14.2 mg/l which are less than 250 mg/l of sodium sulfate and 1000 mg/l for calcium sulfate. Effect of high concentration of sulfate varies from changing taste of water to causing laxative effects (WHO, 2017).

Microbial Contaminants

Microbial testing is used to determine the presence of fecal pathogens like viruses, bacteria, protozoa and helminthes. Also it measures the effectiveness of disinfection process.

Total Coliform Bacteria

In all samples taken from the inlet of water filters total coliform bacteria is not found this mean that source water is clean. While for samples taken at outlet of water filter using three stages water filter total coliform bacteria is found in two locations with a concentration of 5 and 7 in 100 ml; that is above the limitation of PSI and WHO. While for water at the outlet of RO water filter total coliform is not found in two locations but it is found in the third within the range specified by PSI and WHO may be it is related to kitchen activities .

Escherichia Coliform and Thermotolerant Coliform Bacteria (E-coli**)**

Presence of E-coli indicate the presence of fecal contamination which unacceptable according to PSI and WHO regulations. This mean investigation must be done to find source of pollution and further treatment procedure needed (WHO, 2008). All sample taken at the inlet and outlet are free from fecal contamination.

4.1.2 Fouling

For one user of Three-Stage water filter, it is noted that this filter require replacement as its removal efficiency are reduced greatly due to fouling/ scaling. Fouling process is the accumulation of the particle, colloids and ions in the membrane surface or within the membrane due to its ability for the rejection of these contaminants that results in the deterioration of the membrane performance over the time. In order to avoid mechanical and chemical damage of the membrane due to fouling periodic cleaning is needed (Wange et al., 2011).

Table 8 shows effect of fouling that occurred in Three-Stage water filter in water quality. Also the presence of the total coliform at the outlet of water filter while at the inlet was not found may be due to biological fouling. Biological fouling is growth of bacteria in the presence of nutrient which lead to deterioration in water quality (Park & Hu, 2010).

Table 8 Water filter fouling

Location	***Type water filter***	***PH***	***TDS***	***E.C***	***Cl^-***	***HCO_3^{**}***	***NO_3^-***	***SO_4^{-2}***	***T.C***	***F.C***
Hebron	**S.C.C_2 in**	8.02	296	590	44.2	210	0	16.9	Nil	Nil
	S.C.C_2 out	7.99	267	534	32.1	190	0	13.2	Nil	Nil

4.1.3 Service Life and Maintenance Frequency

Service life is the life time of the filter until it is expired in liter (Hamouda et al., 2010). Service life depend on the type of this filter, quality of filter material, water quality at the inlet as clogging of the filter cause increase of the head loss thus result in reduction of life cycle of the cartridges (Evangelista et al., 2019).

From survey question as shown in figure 4;about 40% of the users install water filter before two to three years and 28% before one to two years this mean that water filter used widely and there is a sustained use of these systems.

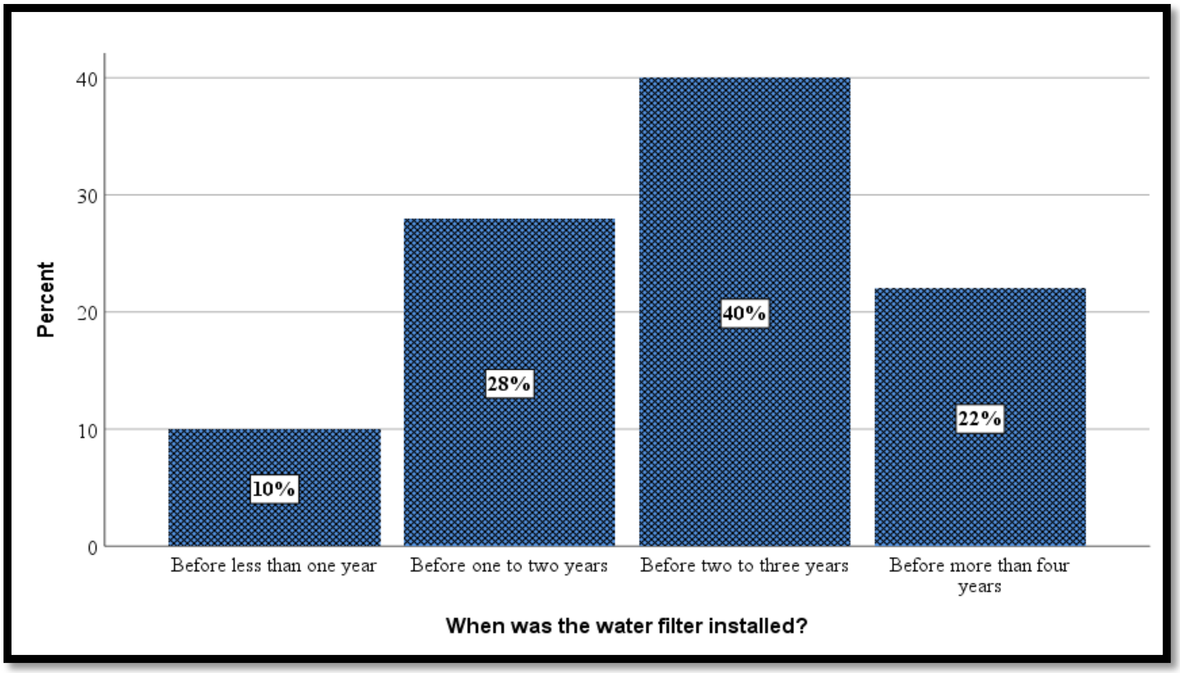

Figure 4 Installation time of water filter

Maintenance frequency of water filter depends on type of water filter and inlet water quality. Figure 5 shows the occurrence of periodic maintenance according to survey result.

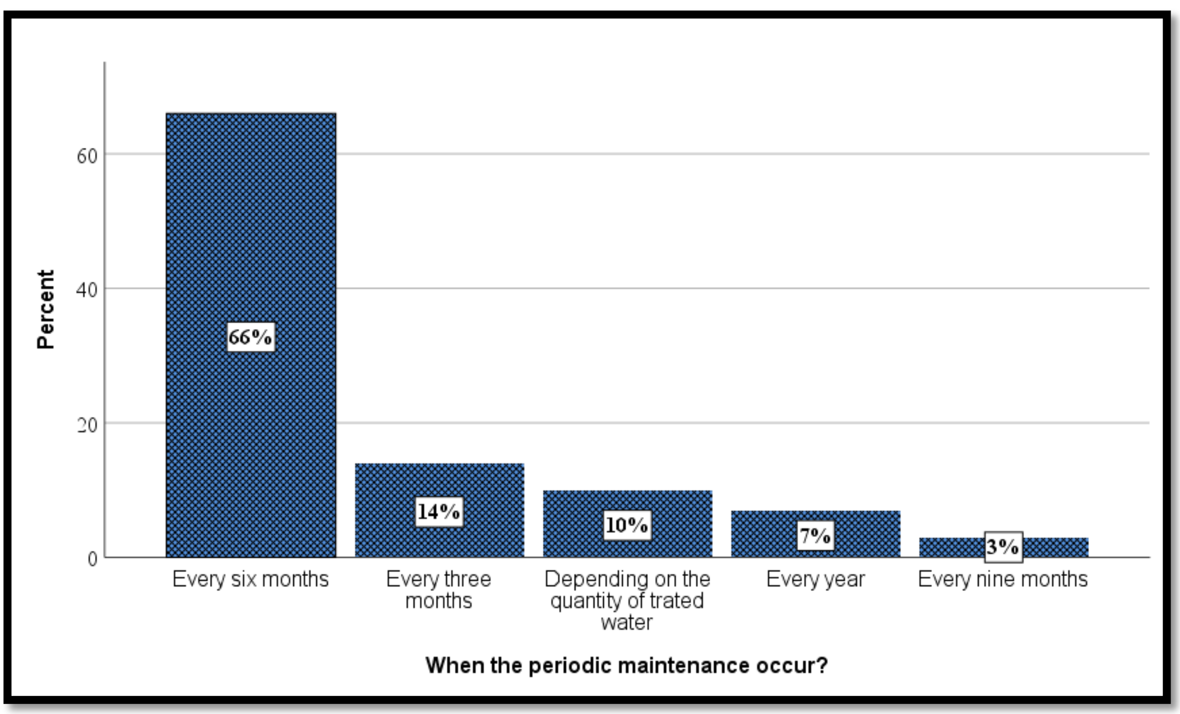

Figure 5 Occurrence of periodic maintenance

- Correlation between periodic maintenance of water filter and the satisfaction about quality of water produced.

Table 10 and figure 6 show the Correlation between periodic maintenance of water filter and the satisfaction about water quality produced.

Table 9 Correlation between periodic maintenance of water filter and the satisfaction about water quality produced

Correlations				
			How satisfied are the water quality produced by the filter?	When is the periodic maintenance of the filter?
Spearman's rho	How satisfied are the water quality produced by the filter?	Correlation Coefficient	1.000	.342**
		Sig. (2-tailed)	.	.000
		N	100	100
	When is the periodic maintenance of the filter?	Correlation Coefficient	.342**	1.000
		Sig. (2-tailed)	.000	.
		N	100	100
**. Correlation is significant at the 0.01 level (2-tailed).				

They show that there is a linear relationship between periodic maintenance of water filter and quality of water produced as problems like fouling occur reducing removal efficiency and changing water taste.

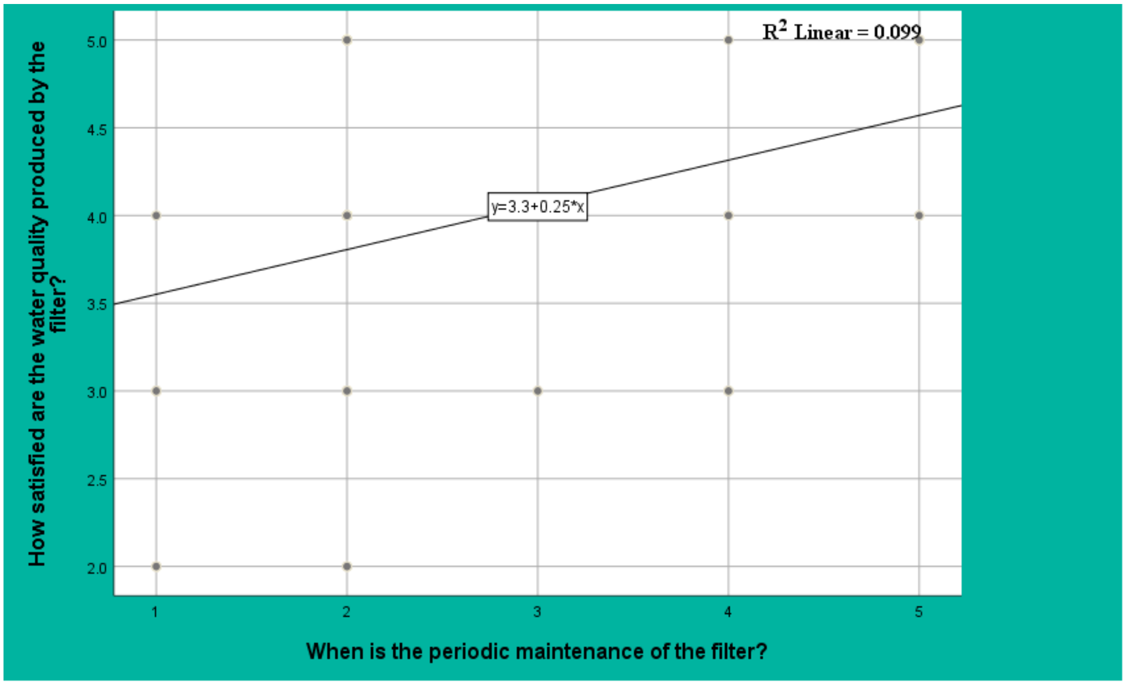

Figure 6 Relationship between satisfactions about water quality from filters with the occurrence of periodic maintenance

4.1.4 System Footprint

Environmental foot print includes solid residual and liquid residual (Hamouda et al., 2010). Recovery rate for RO system is the ratio between the volumes of the treated water at the outlet of water filter to the volume of untreated water at water filter inlet. Low recovery rate produce larger amount of rejected water cause wasting larger amount of water to produce clean water (Altaee & Hilal, 2015).

For liquid residues for RO system that is used in some systems for backwashing of the membrane. For RO systems used recovery rate is 1:2; which mean that for every 2 liter at the inlet produce 1 liter clean and 1 liter waste. Average household size for Palestinian family was found in 2016 about 5.2 (Wafa, 2017).National Academy of Medicine (NAM) recommend for adult male the average total daily water intake about 3.7 liters (15 cups) while for adult female the average total daily water intake is recommended of about 2.7 liters (11 cup) (One Medical, 2017). Taking the average total daily water intake 2.5 liter, for 5 persons total needed water for the family = 5* 2.5= 12.5 liter per day. By using RO water filter with the efficiency 1:2 this mean that to have 12.5 liter per day you enter 12.5*2= 25 per day. For a month 25* 30 = 750 liter per month while by using tap water you use about 12.5*30= 375 liter per month. Assuming that price of one liter of water = 4 NIS, this mean that you will pay for drinking water

- Without using RO water filter = 0.375*4= 1.5 Nis monthly
- With using RO water filter = 0.750*4= 3 Nis monthly.

4.1.5 Operational Skills

Most of systems used don't require operational skill from the user as the companies provide frequent maintenance of these systems. Membrane filtration contain external pump that increase operational cost than other systems. Development in water quality monitoring tool are needed to indicate if there is problems.

4.2. Economic Feasibility

Economic criteria for choosing specific type include capital cost for purchasing and installation such systems, operation and maintenance (Hamouda et al., 2010).According to EPA cost estimation of water filters include capital cost, operation and maintenance cost(EPA, 2007).

From the questionnaire, figure 7 shows that most of the users install two stages water filters of about 37% that cost less than 300 NIS. Then reverse Osmosis which costs between 1,000 to 2,000 NIS or more as it differ between distributers of about 32% and Three-stage water filter which cost from 300-500 NIS of 29% of the user. The cost of the existing water filter is highly related to the type of that filter as each filter has different cost from the other and this cost differ from one distributer to another. The type and cost of water filter depend on monthly income but not all time.

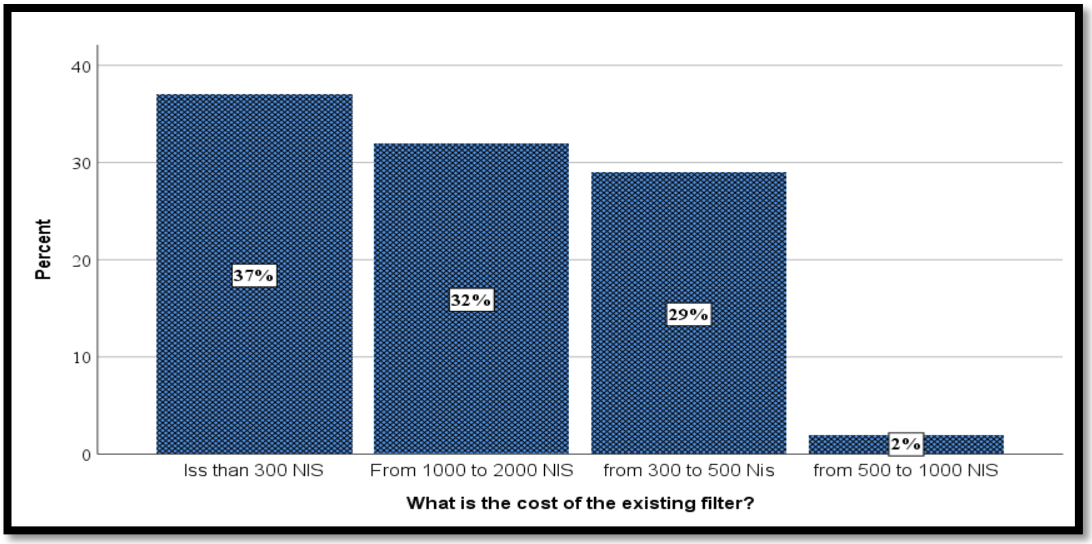

Figure 7 Cost of installed filters

- **Correlation between type of water filter and its cost**

  Table 10 and figure 8 shows the correlation between the type of water filter and its cost.

Table 10 Correlation between type of water filter and its cost.

Correlations			
		What type of filter do you have?	What is the cost of the existing filter?
What type of filter do you have?	Pearson Correlation	1	.709**
	Sig. (2-tailed)		.000
	N	100	100
What is the cost of the existing filter?	Pearson Correlation	.709**	1
	Sig. (2-tailed)	.000	
	N	100	100
**. Correlation is significant at the 0.01 level (2-tailed).			

It shows that there is a linear relationship between the type and cost of filter in spite of the difference between providers.

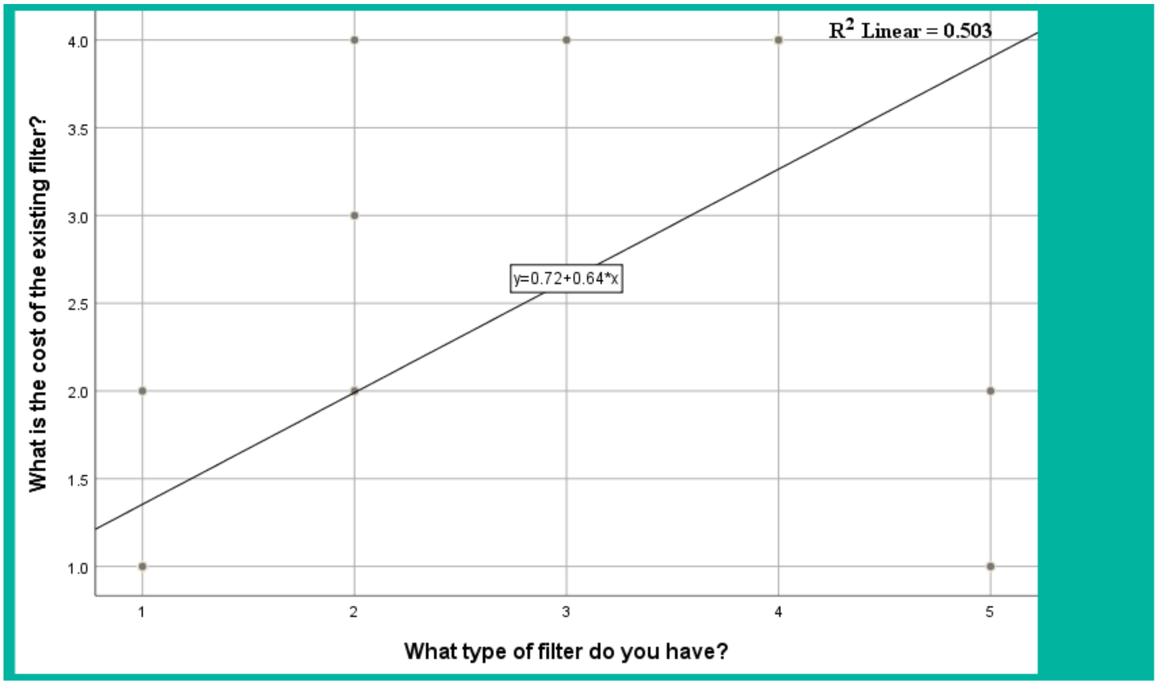

Figure 8Relationship between type of water filter and its cost

Maintenance that includes removal of cartridges varies according to the seller; type of the filter used and water quality at the inlet. It varies from less than 100 NIS of about 22%, 41% from 100 to 200 NIS and 37% more than 300 NIS as shown in figure 9. Maintenance cost highly related to the type of water filter higher cost of water filter need higher maintenance cost. Deteriorated water quality requires more frequent maintenance cost increasing maintenance cost annual.

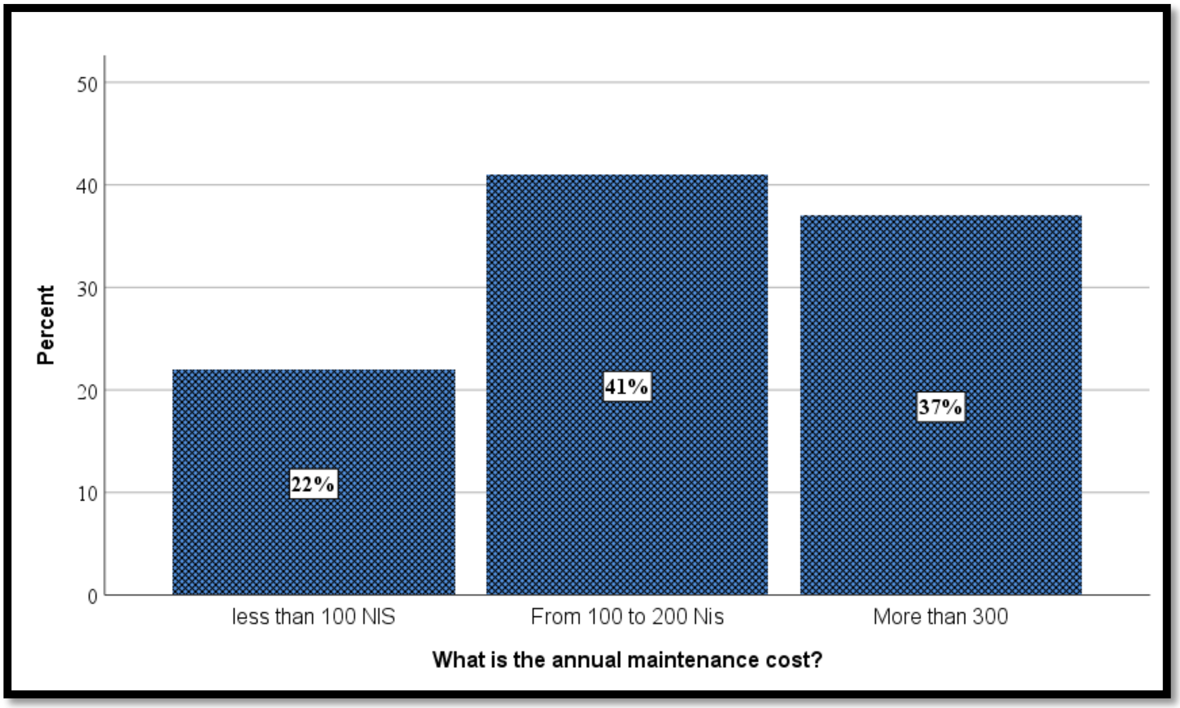

Figure 9 cost of annual maintenance

The availability of adequate technical and financial support limits the success of water filter usage (Johnston et al., 2010). Frequent maintenance usually is done twice a year for most of users. Maintenance usually done every 2000 liter production or it is estimated to be six months which varies depending on water quality at the inlet of the filter, type of water filter and other factors.

- **Correlation between annual capital and maintenance cost of water filters**

Table 11 shows the correlation between annual capital and maintenance cost of water filters. As shown in Table 11 and Figure 10, there is a strong linear relationship between capital cost of water filter which depend on the type of this filter and the annual maintenance cost.

Table 11 Correlation between annual capital and maintenance cost of water filters

Correlations			
		What is the cost of the existing filter?	What is the cost of maintaining the filter annually?
What is the cost of the existing filter?	Pearson Correlation	1	.787**
	Sig. (2-tailed)		.000
	N	100	100
What is the cost of maintaining the filter annually?	Pearson Correlation	.787**	1
	Sig. (2-tailed)	.000	
	N	100	100
**. Correlation is significant at the 0.01 level (2-tailed).			

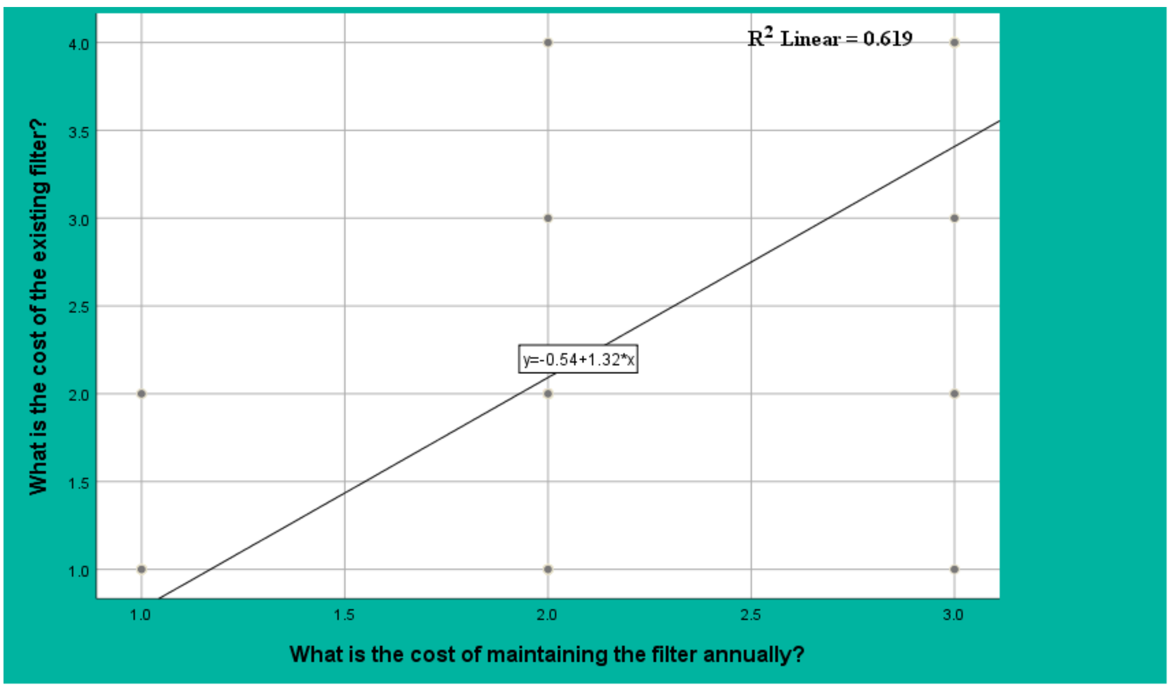

Figure 10Relationship between annual capital and maintenance cost

4.3. Health Impacts

In Figure 11 about 89% of the user of water filter use these systems due to health problems like hypertension and presence of the kidney stones.

For treated water it is found that for all filter types TDS concentration is less than 100 mg/l which mean that Ca and Mg, Na and K concentration also are below the recommendation of PSI of 100 mg/l for TDS which may cause health problem with long term use like heart problems. For the use these system re-mineralization stage is recommended to include increasing average daily intake of these essential minerals.

Many studies show that hard water with high magnesium content help to protect from cardiovascular diseases (CVD). Low concentration of Ca and Mg in drinking water lead to increase in triglyceride, total cholesterol, and LDL-cholesterol levels, diastolic blood pressure and systolic which increase the opportunity of Ischemic Heart Disease. The protective amount of Ca that must be taken daily from water is 75.7 mg while for Mg is about 6.87 mg to prevent heart diseases (Stevanovic et al., 2017).

Sodium-potassium is essential elements for renal health and for nervous system for the generation of electrical potential in nerve cell to conduct nerve impulses which generate heart beat and muscle contraction(Ling et al., 2019).Concentration above 2.5 g/l of Sodium chloride cause hypertension related to the concentration of sodium ions not chloride (WHO, 2003).

In a study in India it is found that there is no relationship between kidney stone occurrence and water quality (Mitra, Pal & Das, 2018). Another study shows that hard water increase urinary calcium concentration which increase formation of kidney stone (Bellizzi et al., 1998).

Sodium leads to high blood pressure or hypertension while calcium and magnesium and potassium have effects in lowering blood pressure and reduce cardiovascular problems. Human body adsorbs minerals from water better than that from food (Paddock, 2019; Naser et al., 2019).

Soft water with $CaCo_3$ concentration less than 90mg/l may not protect against cancer risk and affect skeletal and cardiovascular health also soft water cause leaching of metals like iron. Therefore, re-mineralization is essential for this type of systems to prevent corrosion and increase their daily intake of calcium and magnesium. AC provides water with components within the guidelines. Hard water with the concentration of $CaCo_3$ more than 300 mg/l produces undesirable taste and scaling of water heaters and pipes (Lothrop et al., 2015), So it essential to keep the concentration of these chemicals within the acceptable limits.

Most of water sample taken at the outlet of water filter produce soft water as mentioned before it is preferred to have water with $CaCO_3$ concentration more than 90 mg/l that will help to protect against cancer risk and affect skeletal and cardiovascular health. Also soft water cause leaching of some minerals like iron (Lothrop et al., 2015).

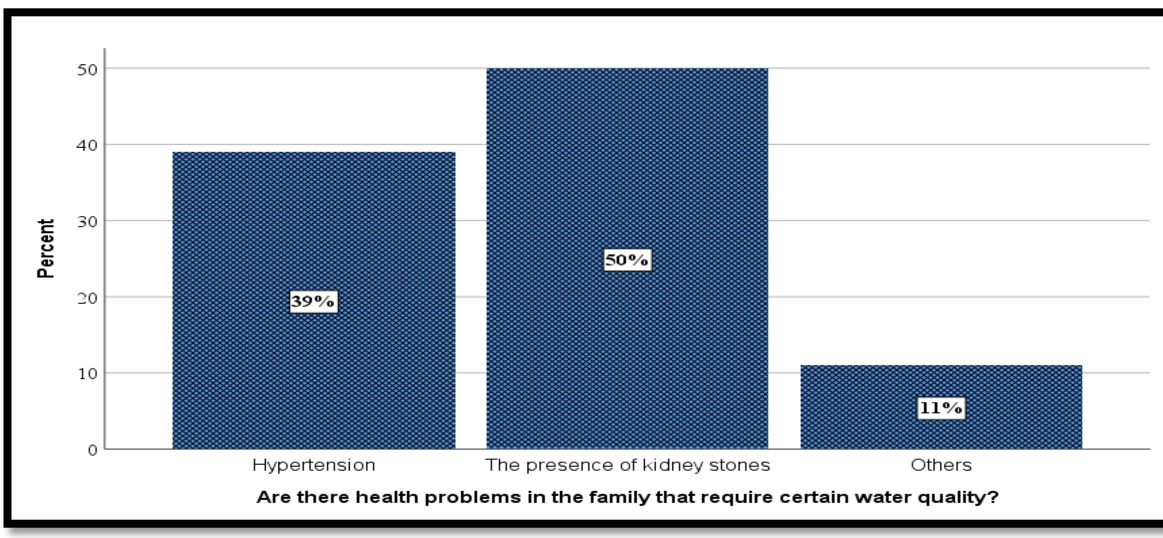

Figure 11 Relationship between health problems and use of water filters

4.4 Public Perceptions

It is noted that the adoption of household water treatment systems is affected by educational status as most of the user are educated people with relatively high monthly income. High monthly income and big family size encourage the adaption of water filters as shown in Figure 12.In a study of families with young children's using private wells; educate mothers usually treat their drinking water. Household income and education level widely affect positively the adoption of home water treatment systems and are not related to drinking water quality at the source (Lothrop et al., 2015).

Most of users of home water treatment systems think that water from municipal network is not clean due to aesthetical properties like taste, color and odor. And frequent intermittent that cause stagnation that deteriorate water quality as shown in Figure 13. As concluded here that the adaption of HWT systems or bottled water are due to lake of confidence in tap water quality from aesthetical properties like color taste and odor (Johnstone & Serret, 2011).

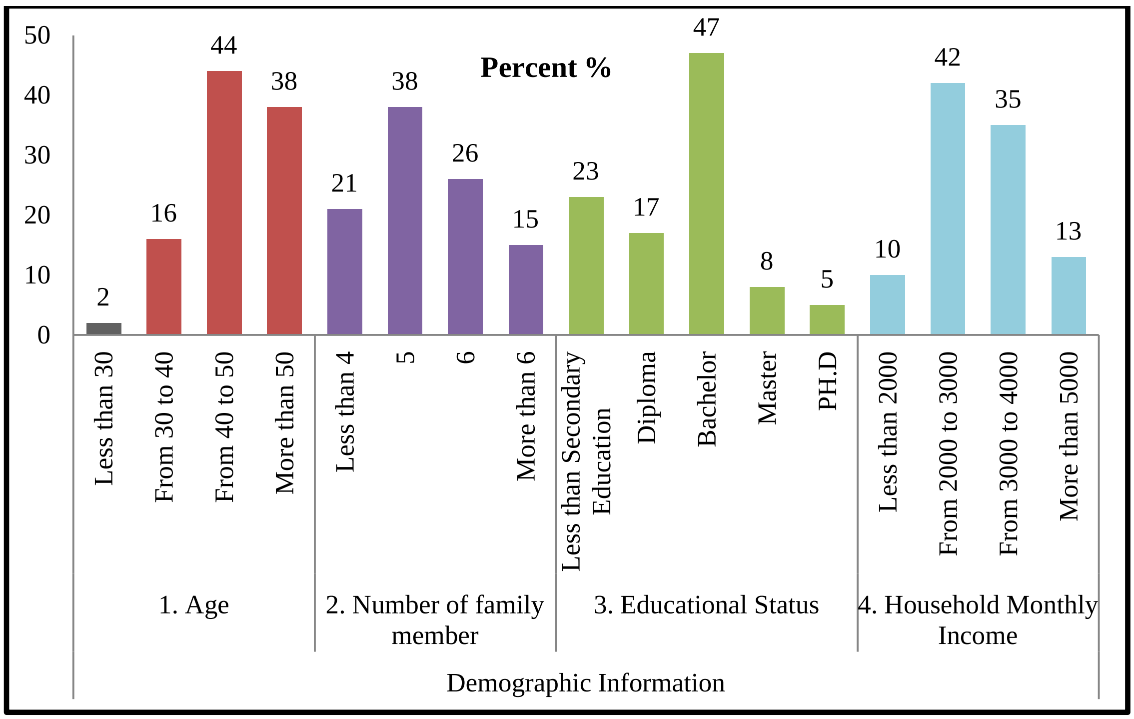

Figure 12 Demographic information

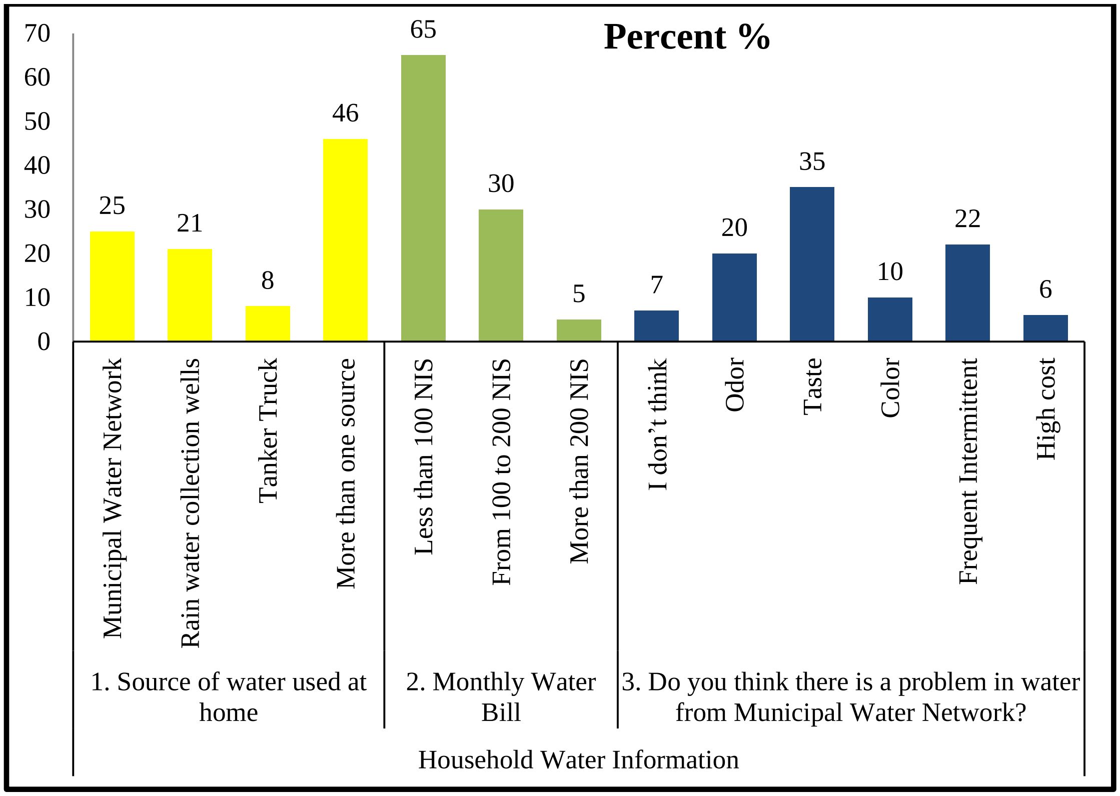

Figure 13 Household water information

From the questionnaire, figure14 shows that most of the users install water filter, because they think that water from municipal water network is unsafe of about 40% of the users, from previous question it is found that most of the users think that water from municipal network have a problem mostly of its taste. About 22% of the users install it due to the recommendations of relatives and friends, 17% due to the conviction of sales representatives and distributors of filters that municipal water is polluted, 12% install it due to doctor's recommendation due to health problem and 9% install it because Diarrhea is preceded by water in the family. The adoption of household water treatment systems related to socio economic conditions include household water treatment systems promotions, educational level, wealth level and access to technology (Daniel et al., 2018).

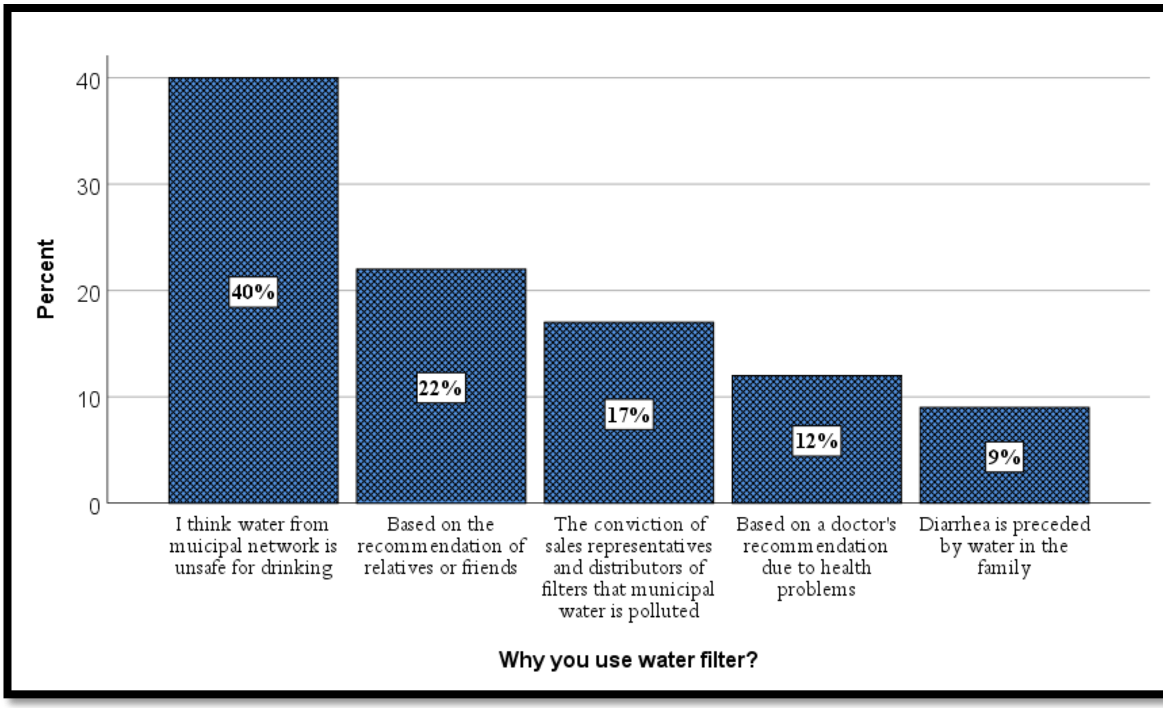

Figure 14The reason for the installation of water filter

No single feature can be alone the reason for the adoption of HWT systems as many factors affect the adaption such as negative perception about tap water quality and unavailability of prior experience in using HWT systems encourage the adoption of these system in households connected to piped network. The negative perceptions about tap water quality with the availability of the willingness to pay have a high influence in the adoption of HWT systems (Daniel et al., 2018).

As shown in Figure 15, most of users are satisfied about water quality produced by filters.

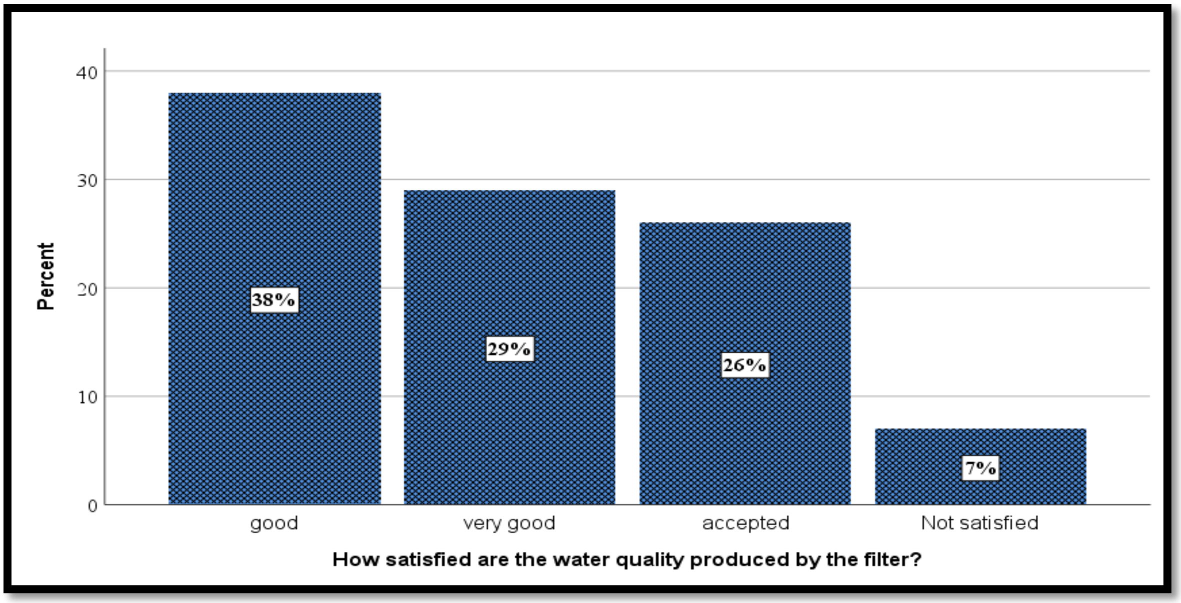

Figure 15 How satisfied about water quality produced

Figure 16 show that most of the users say that the cost of installing filter is medium with a percent of 62

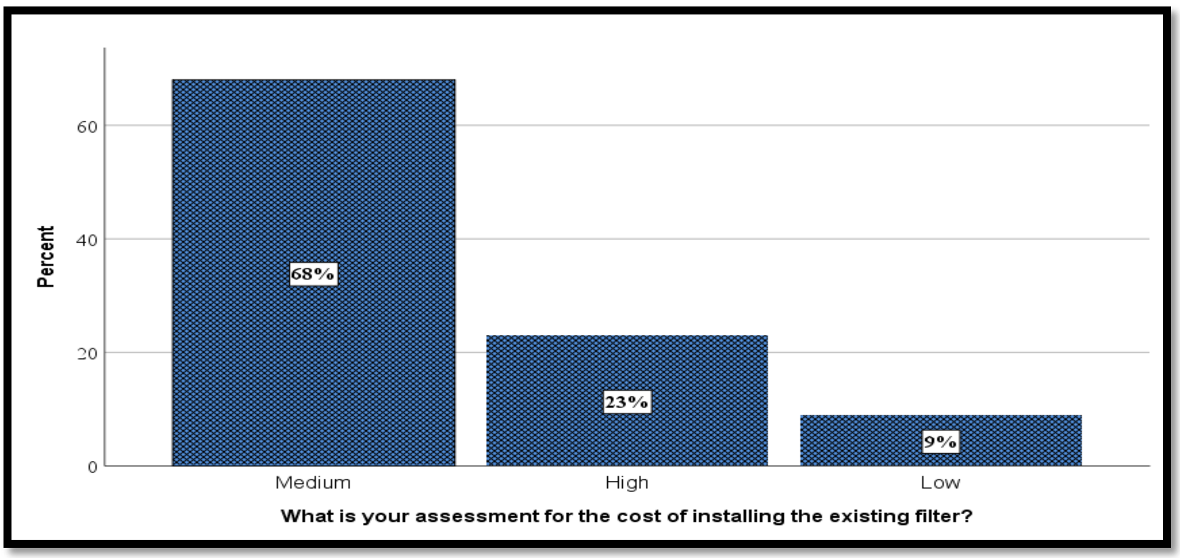

Figure 16 what is your assessment for the cost of installing the existing filter

Most of the user thinks that filter maintenance cost is medium with a percentage of 73% as shown in Figure 17.

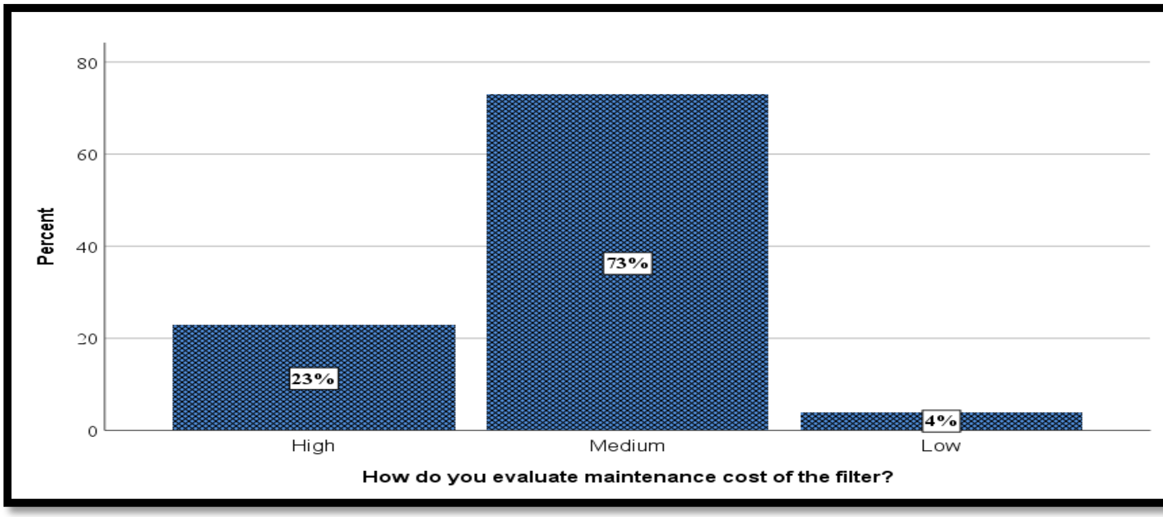

Figure 17How do you evaluate maintenance cost of water filter

- **Satisfaction about provider's performance with respect to filter maintenance.**

As shown in Figure 18 most of the users of these systems are satisfied about provider performance with respect to filter maintenance.

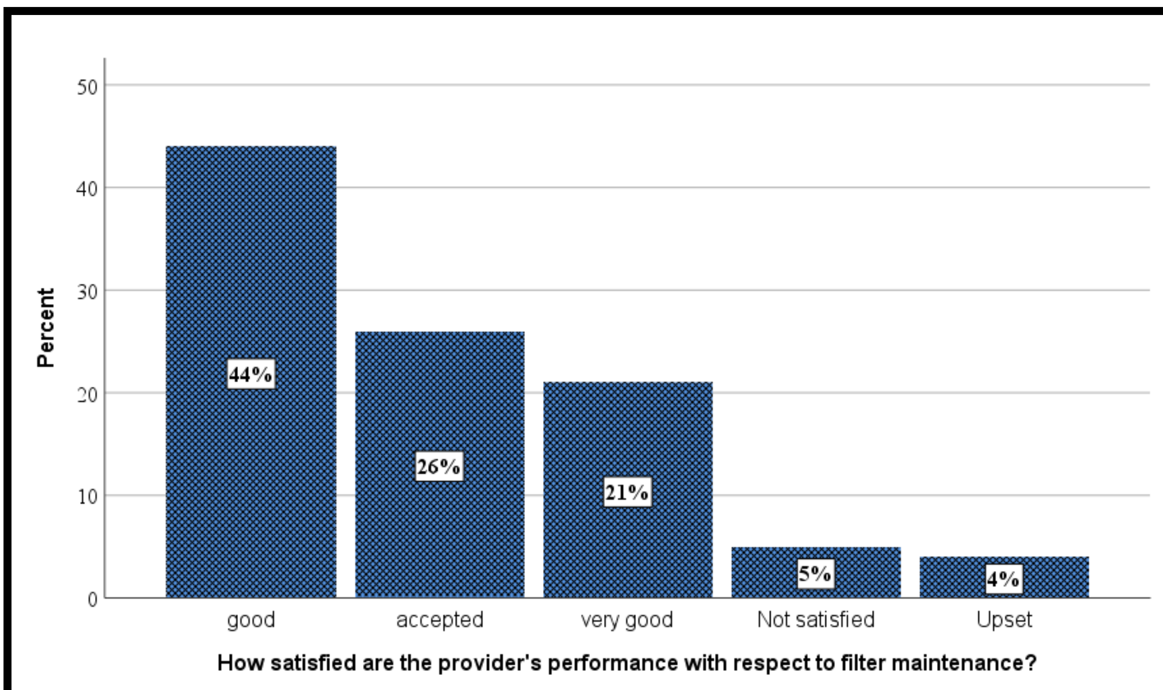

Figure 18 Satisfaction about provider's performance with respect to filter maintenance

It is found that there is a linear relationship between the satisfaction of the user from water filter provider performance like provides continuous maintenance with the quality of the water produced by filters as shown in figure 19. According to previous studies home water treatment systems reduce exposure to diarrheal diseases but with high adherence especially when water quality of the source is deteriorated which is more important than microbial removal efficiency to optimize health gain (Brown & Clasen, 2012).

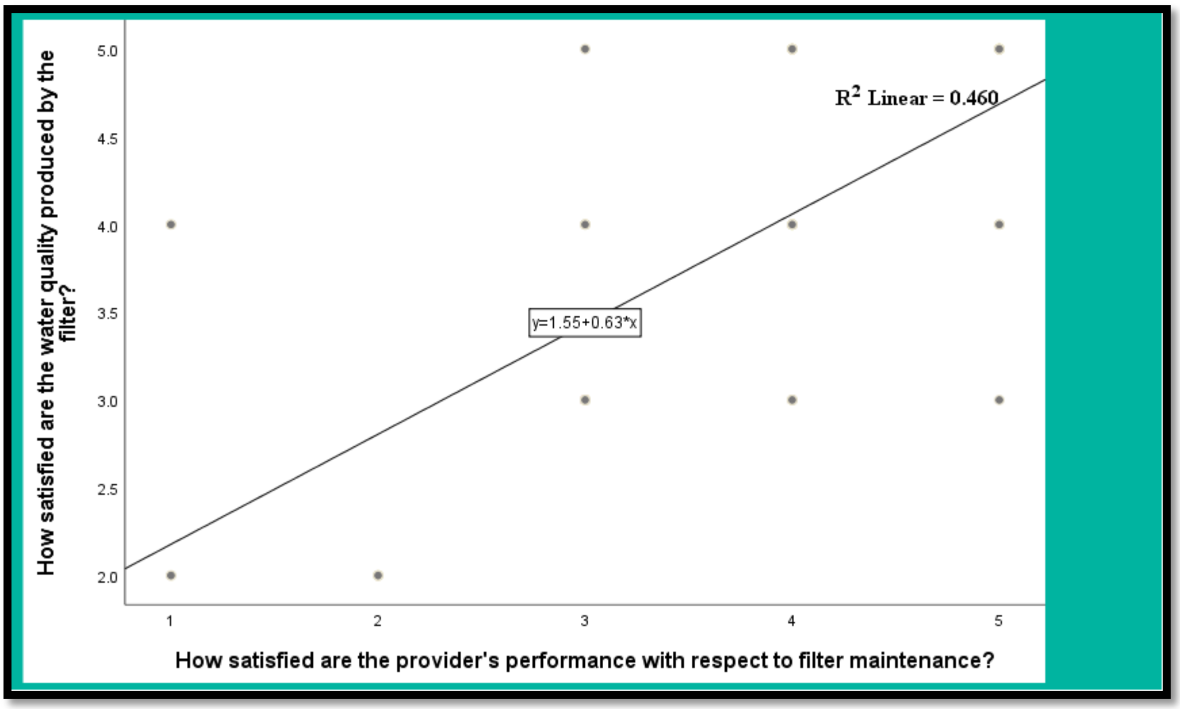

Figure 19 Relationship between water quality produced satisfaction with provider performance satisfaction

Chapter Five - Conclusions and Recommendations

5.1 Conclusions

- From lab tests that are conducted for Three-Stages and RO water filters, it is found that tap water quality from municipal network is clean and safe and within PSI and WHO standards.
- It is essential to choose RO water filter with high recovery rate to minimize wasted water.
- Capital and maintenance costs of water filters are highly related to the type of water filters and inlet water quality.
- The concentration of TDS is less than 100 mg/l which produces flat taste and is not acceptable according to PSI limits. TDS consists of beneficial constituents including calcium, sodium, potassium, magnesium cations, hydrogen carbonate, carbonate, sulfate, chloride and nitrate anions. This means that Ca concentration may be less than 30 mg/l and Mg concentration may be less than 10 mg/l which may lead to health problems as these elements are essential for bone, nervous system health and for preventing Ischemic heart disease. Re-mineralizatin is essential to increase average daily intake of that essential minerals.
- The adaption of HWTs is related to the lake of confidence of tap water quality due to aesthetical properties like color, taste and odor.
- No single feature can be alone the reason for the adaption of HWTs, many reason affect the adaption of these systems include family size, monthly income, educational level, lake of confidence of tap water quality and previous occurrence of diarrheal disease.
- The satisfaction of the users about water quality from filter is highly related to their satisfaction from seller performance for periodic maintenance.
- Consumers are responsible for water quality from the tap after water meters; procedures like checking water storage tank regularly. Regular maintenance and inspection for roof tank must be every six to nine months include inlet and outlet of

the tank, cover, Also frequent disinfectant every 18-24 months for storage tank and pipeline, keeping water storage tank tightly closed and changing old pipes periodically will reduce water pollution. This will help to reduce water pollution after water meter and reduction the need of these systems.

5.2 Recommendations

- Public awareness should be improved to increase their knowledge about their tap water quality and ministry of health should provide clear and accurate annual water quality report. And about claims of water filter distributers.
- Consumers must make water quality test before determining the most suitable type of water filter at a certified laboratory. Or regularity authority must enforce the consumer to make water quality test at their labs before the adaption of these system and the distributer must provide the consumer a report about the system performance.
- Ministry of health must raise the public awareness about the negative health impact of using that system the produce water lacks of many beneficial constituent with the long term consumption.
- Frequent maintenance is essential for filters to obtain the same water quality along life time of water filter.
- It is essential to use that system must have performance standard and certification (ANSI/NSF Certified devices).
- Consumer must make frequent maintenance of the internal fixture and change of old pipes to prevent pollution of water when it enters the house.

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Appendices:

Appendix 1: The Questionnaire

BIRZEIT UNIVERSITY

كلية الدراسات العليا

برنامج ماجستير هندسه المياه والبيئة

السلام عليكم ورحمة الله وبركاته ،

تحية طيبة وبعد ....

اخي المواطن/ اختي المواطنه:

مرفق استبيان لرساله ماجستير بعنوان"تقييم خبرة فلسطين في استخدام وحدات معالجة مياه الشرب المنزلية" تقوم باعدادها الطالبة الاء حجازي عثمان في معهد الدراسات البيئية والمائية بجامعة بيرزيت وتحت اشراف الدكتور ماهر ابو ماضي.

نرجو من حضرتكم التكرم بالاجابة على بنود الاستبانة، مع العلم بأن جميع البيانات ستعامل بسريه تامة، وسوف تستعمل لغايات البحث العلمي فقط.

شاكرين لكم حسن تعاونكم،،،

اعداد: الاء حجازي عثمان

العمر

اقل من 30 من 30 الى 40 من 40 الى 50 اكثر من 50

عدد افراد الاسره

اقل من 4 5 6 اكثر من ذلك، حدد---------

الحاله التعليميه

توجيهي او اقل دبلوم بكالوريوس ماجستير دكتوراه

الدخل الشهري للاسره

اقل من 2000 شيكل من 2000 الى 3000 من 3000 -4000 اكثر من 5000

مصدر المياه المستخدمه في المنزل

مياه الشبكه مياه ابار جمع المطر مياه الصهريج اكثر من مصدر

قيمة فاتورة المياه الشهرية

هل تعتقد بوجود مشكله في المياه المزوده من البلديه؟

لا يوجد مشكله الرائحه الطعم اللون انقطاع متكرر ارنفاع تكلفه المياه المعبأه في عبوات

متى تم تركيب فلتر المياه؟

اقل من سنه من سنه الى سنتين من سنتين الى ثلاثه اكثر من 4 سنوات ، حدد ....

نوع الفلتر المستخدم لديكم؟

مرحلتين ثلاث مراحل اشعه فوق بنفسجيه التناضح العكسي ، حدد كم مرحله ------ لا اعلم

لمادا تم تركيب الفلتر؟

للاعتقاد بان مياه الشبكه غير امنه للشرب بناء على توصيه الطبيب بسبب وجود مشاكل صحيه

بناء على توصيه الاقارب والاصدقاء الاقتناع من مندوب المبيعات لموزعين الفلاتر ان مياه الحنفيه ملوثه وغير صالحه للشرب الاصابه بحالات اسهالات سابقه في العائله كانت مرتبطه بالمياه

هل يوجد مشاكل صحيه في العائله تتطلب نوعيه معينه من المياه؟

ارتفاع ضغط الدم   وجود حصى في الكلى   غير ذلك، حدد------

ما هي تكلفه تركيب الفلتر الموجود؟

اقل من 300 شيكل   من 300 الى 500 شيكل   من 500 الى 1000 شيكل   من 1000 الى 2000 شيكل   حدد--

ما تقييمك لتكلفه تركيب الفلتر الموجود؟

مرتفعه   مقبولة   منخفضة

ما هي تكلفه صيانةالفلتر الموجود سنويا؟

حدد ....

ما تقييمك لتكلفه صيانةالفلتر الموجود؟

مرتفعه   مقبولة   منخفضة

متى تتم الصيانه الدوريه للفلتر؟

كل 3 شهور   كل 6 شهور   كل 9 شهور   كل سنه   حسب كميه المياه المعالجه   لا توجد صيانه دوريه

مدى الرضا عن اداء الشركة المزودة بخصوص صيانة الفلتر؟

5. راض جدا
4. راض
3. مقبول
2. غير راض
1. مستاء.

مدى الرضا عن جوده المياه الناتجة عن الفلتر؟

5. راض جدا
4. راض
3. مقبول
2. غير راض
1. مستاء.

شكرا لجهودكم،،،

Appendix 2: Water Quality analysis for North Eastern Basin in Jenin Area

Table 12 Water Quality Analysis for North Eastern Basin in Jenin Area (Source PWA, 2017)

Parameter	Results (mg/l)	Palestinian Guideline (mg/l)
NO_3^-	**2-110**	70
Na^+	43-105	200
Cl^-	**80-500**	200
Mg^{+2}	15-75	100
Ca^{+2}	75-200	200
So_4^{-2}	4-147	200
K^+	0.1-15(10)	10
TDS	**400-3200**	1500
Fecal Coliform CFU/100ml	0-TMTC	(0) CFU/100ml
Total Coliform CFU/100ml	0-TMTC	(0-3) CFU/100ml

Appendix 3: Water Quality analysis in Western Basin in Qalqilia and Tulkarem

Table 13 Water Quality analysis in Western Basin in Qalqilia and Tulkarem (Source: PWA, 2017)

Parameter	**Results (mg/l)**	**Palestinian Guideline (mg/l)**
NO_3^-	**12-130**	70
Na^+	20-75	200
Cl^-	**40-300**	200
Mg^{+2}	22-85	100
Ca^{+2}	30-125	200
So_4^{-2}	**1-231(2)**	200
K^+	**0.1-25(6)**	10
TDS	**200-1800**	1500
Fecal coliform CFU/100ml	0-TMTC	(0) CFU/100ml
Total coliform CFU/100ml	0-TMTC	(0-3) CFU/100ml

Appendix 4: Water quality analysis for Eastern Basin in Jericho and Jordan Valley area

Table 14 Water Quality Analysis for Eastern Basin in Jericho and Jordan Valley area (Source: PWA, 2017)

Parameter	Results (mg/l)	Palestinian Guideline (mg/l)
NO_3^-	**12-130**	70
Na^+	**20-475**	200
Cl^-	**40-2300**	200
Mg^{+2}	**22-285**	100
Ca^{+2}	**30- 425**	200
So_4^{-2}	**1-231(2)**	200
K^+	**0.1-25(6)**	10
TDS	**290-3800**	1500
Fecal coliform CFU/100ml	0-TMTC	(0) CFU/100ml
Total coliform CFU/100ml	0-TMTC	(0-3) CFU/100ml

Appendix 5: Water quality indicator by Water Sector Regulatory Council for Hebron Governorate(1)

Table 15 Water Quality Indicator by Water Sector Regulatory for Hebron Governate (1) (Source: WSRC, 2017)

District	Hebron City	BaniNa'im	Beit Ummar	Tarqumiyah
No of serviced citizen	238,985	27,000	21,000	19,000
Quantity of water available (MCM)	7.35	0.6	1.02	0.49
Per capita consumption L/cap/day	59	49	78	50
Water quality indicators				
1- samples from source				
Percent of samples free from Total Coliform	100%	0	100%	-
Percent of samples free from Fecal Coliform	100%	50%	98%	-
Percent of samples free from Nitrate	99%	-	100%	-
1- samples from Network and Distribution main				

Percent of samples free from Total Coliform	95%	72%	98%	96%
Percent of samples free from Fecal Coliform	99%	83%	98%	100%
Percent of samples contain residual Chlorine in network	93%	-	2%	-

Appendix 6: Water Quality Indicator by WSRC for Hebron Governorate (2)

Table 16 Water Quality Indicator by WSRC for Hebron Governorate (Source: WSRC, 2017)

District	Halhul	Dura	Sier	Yatta
No of serviced citizen	30,000	40,000	26,000	87,000
Quantity of water available (MCM)	0.91	0.48	0.68	1
Per capita consumption (l/cap/day)	65	28	38	23
Water quality indicators				
1- samples from source				
Percent of samples free from Total Coliform	-	100%	100%	-
Percent of samples free from Fecal Coliform	-	100%	100%	-
Percent of samples free from Nitrate	-	-	-	-
1- samples from Network and Distribution main				
Percent of samples free from Total	92%	100	98%	86%

Coliform				
Percent of samples free from Fecal Coliform	96%	100	100%	86%
Percent of samples contain residual Chlorine in network	-	-	-	-

Appendix 7: Chemical Analysis Report for Source of Water in North Hebron from MOH

Ministry of Health
Primary Health Care & Public Health
General Directorate
Central Public Health Laboratory

دولة فلسطين
وزارة الصحة
الإدارة العامة للرعاية الصحية الأولية والصحة العامة
مختبر الصحة العامة المركزي

Date : 28/06/2018 13:10

Chemical Analysis report

تقرير نتائج عينة مياه كيماوية

Report Date : 20/06/2018
Report No : 11229
Client : صحة البيئة

Sample No : 1817908
Payment : غير مدفوع
Country of Origin :

Sample Name : مياه
District : شمال الخليل
Manufacturer :

Sample code : HNKW23438A
Sample Type : (مصدر (نبع أو بئر جوفي
Trade Name :

Receiving Date 29/05/2018
Expiry Date
Product Date :

Source : نقطة التوزيع الرئيسي
Sample Condition: جيدة

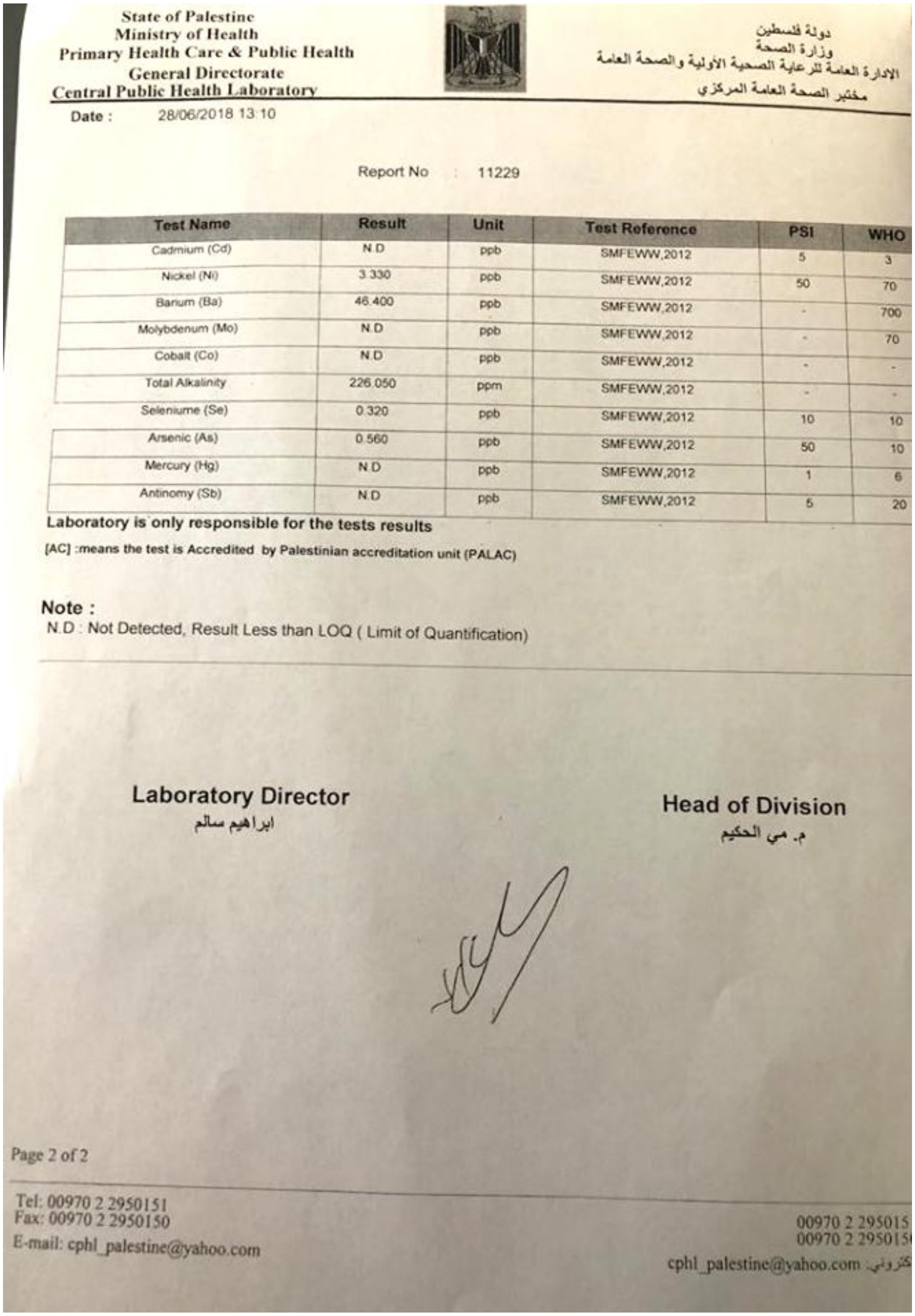
محطة التوزيع الرئيسي

Results :

Test Name	Result	Unit	Test Reference	PSI	WHO
[AC] Conductivity of Water	580.000	Micro S/cm	SMFEWW,2012	-	-
[AC] Fluoride in Water	0.170	ppm	SMFEWW,2012	1.5	1.5
[AC] Nitrate in Water	7.210	ppm	SMFEWW,2012	70	50
Nitrite in Water	0.000	ppm	SMFEWW,2012		3
[AC] PH of Water	7.500		SMFEWW,2012	6.5-8.5	6.5-8.5
[AC] Salinity of Water	0.030	%	SMFEWW,2012	-	-
Sulfate (SO4)	21.560	ppm	SMFEWW,2012	200	250
[AC] Total Dissolved Solids (TDS) in Water	335.000	ppm	SMFEWW,2012	1000	1000
[AC] Total Hardness in Water	318.410	ppm	SMFEWW,2012	500	500
Turbidity in Water	0.380	NTU	SMFEWW,2012	5	5
[AC] Ammonia in Water	0.000	ppm	SMFEWW,2012	-	1.5
[AC] Chloride CL in water	57.480	ppm	SMFEWW,2012	250	-
Calcium (Ca)	90.150	ppm	SMFEWW,2012	100	-
Magnesium (Mg)	22.670	ppm	SMFEWW,2012	100	-
Sodium (Na)	35.210	ppm	SMFEWW,2012	200	-
Potassium (K)	1.907	ppm	SMFEWW,2012	10	-
Aluminum (Al)	46.220	ppb	SMFEWW,2012	200	-
Iron (Fe)	82.340	ppb	SMFEWW,2012	300	-
Manganese (Mn)	N.D	ppb	SMFEWW,2012	100	-
Copper (Cu)	N.D	ppb	SMFEWW,2012	1000	2000
Zinc (Zn)	128.100	ppb	SMFEWW,2012	5000	-
Silver (Ag)	N.D	ppb	SMFEWW,2012	10	
Lead (Pb)	1.820	ppb	SMFEWW,2012	10	10
Total Chromium (Cr)	N.D	ppb	SMFEWW,2012	50	50

Tel: 00970 2 2950151
Fax: 00970 2 2950150
Email: cphl_palestine@yahoo.com

هاتف: 00970 2 2950151
فاكس: 00970 2 2950150
البريد الالكتروني: cphl_palestine@yahoo.com


State of Palestine
Ministry of Health
Primary Health Care & Public Health
General Directorate
Central Public Health Laboratory

دولة فلسطين
وزارة الصحة
الادارة العامة للرعاية الصحية الأولية والصحة العامة
مختبر الصحة العامة المركزي

Date : 28/06/2018 13:10

Report No : 11229

Test Name	Result	Unit	Test Reference	PSI	WHO
Cadmium (Cd)	N.D	ppb	SMFEWW,2012	5	3
Nickel (Ni)	3.330	ppb	SMFEWW,2012	50	70
Barium (Ba)	46.400	ppb	SMFEWW,2012	-	700
Molybdenum (Mo)	N.D	ppb	SMFEWW,2012	-	70
Cobalt (Co)	N.D	ppb	SMFEWW,2012	-	-
Total Alkalinity	226.050	ppm	SMFEWW,2012	-	-
Seleniume (Se)	0.320	ppb	SMFEWW,2012	10	10
Arsenic (As)	0.560	ppb	SMFEWW,2012	50	10
Mercury (Hg)	N.D	ppb	SMFEWW,2012	1	6
Antinomy (Sb)	N.D	ppb	SMFEWW,2012	5	20

Laboratory is only responsible for the tests results

[AC] :means the test is Accredited by Palestinian accreditation unit (PALAC)

Note :
N.D : Not Detected, Result Less than LOQ (Limit of Quantification)

Laboratory Director
ابراهيم سالم

Head of Division
م. مي الحكيم

Page 2 of 2

Tel: 00970 2 2950151
Fax: 00970 2 2950150
E-mail: cphl_palestine@yahoo.com

00970 2 295015
00970 2 295015
cphl_palestine@yahoo.com :كتروني

Figure 20 Chemical Analysis Report for Source of Water in North Hebron from MOH